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Our File/*Notre dossier:* 10238566
Your file/*Votre dossier:* 80101

September 21, 2020

VIA ELECTRONIC MAIL: IAAC.GrassyMountain.AEIC@canada.ca

Joint Review Panel for the Grassy Mountain Coal Project
c/o Impact Assessment Agency
160 Elgin Street, 22nd Floor, Place Bell Canada
Ottawa, Ontario K1A 0H3

Attention: Alex Bolton, Chair

Dear Sir:

Re: Grassy Mountain Coal Project - Reference Number: 80101

Please find attached the written submissions of the federal authorities Environment and Climate Change Canada, Fisheries and Oceans Canada, Health Canada, Natural Resources Canada and the Impact Assessment Agency of Canada, which submissions are presented in a combined Government of Canada package.

We ask that the Panel please note the following:

> The Panel previously asked Natural Resources Canada to provide submissions in respect of White Bark Pine. Environment and Climate Change Canada has led the technical review on this issue and covers it in its submission.
>
> The *curricula vitae* of some Government of Canada witnesses are outstanding and will be provided in advance of the hearing and as soon as possible.

Please contact us if you require anything further.

Yours truly,

<Original signed by>

Robert Drummond
Senior Counsel
Prairie Region
Department of Justice Canada
RD/kr

cc: Sydney McHugh

Canada

CEAA NO. 80101

IN THE MATTER OF A JOINT PANEL REVIEW OF THE
GRASSY MOUNTAIN COAL PROJECT PROPOSED BY BENGA MINING LIMITED

WRITTEN SUBMISSIONS OF THE GOVERNMENT OF CANADA

Robert Drummond / Sydney McHugh

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TAB 1

Environment and Climate Change Canada
Environnement et Changement climatique Canada

ENVIRONMENT AND CLIMATE CHANGE CANADA'S FINAL SUBMISSION TO THE JOINT REVIEW PANEL REGARDING THE GRASSY MOUNTAIN COAL MINE PROPOSED BY BENGA MINING LIMITED

SEPTEMBER 21, 2020



Canada

Address for Communications:

Communications may be sent to Environment and Climate Change Canada at the address below.

Attention: Margaret Fairbairn
A/Regional Director, Prairie and Northern Region
Environmental Protection Operations Directorate
Environmental Protection Branch
Environment and Climate Change Canada
9250 – 49th Street NW
Edmonton, Alberta
T6B 1K5

Signed on behalf of Environment and Climate Change Canada:

<original signed by>

September 18, 2020

Mary Taylor — Date

Director General, Environmental Protection Operations Directorate

Environmental Protection Branch

Environment and Climate Change Canada

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EXECUTIVE SUMMARY

In its letter of June 29, 2020 the Joint Review Panel overseeing the Grassy Mountain Coal Project requested that ECCC:

> *…participate in the public hearing in accordance with section 6.1 of the Joint Review Panel Agreement and section 20 of the Canadian Environmental Assessment Act, 2012. The Panel expects that ECCC will provide a technical written submission, make an oral presentation and participate actively in the public hearing.*
>
> *The Panel requests that ECCC provide a technical written submission on the potential environmental effects of the Project including recommendations as they relate to ECCC's expertise. In particular, the Panel requests that the following topics be discussed in their submission: air quality, water quality including selenium criteria, speciation and treatment, hydrology, species at risk, migratory birds, climate change, greenhouse gas emissions, and effects from accidents and malfunctions. The submission should also include an update on the background and status of the proposed Coal Mining Effluent Regulations. The submission should also include information regarding: the likelihood that the Project would cause significant adverse environmental effects, the predicted effectiveness of proposed mitigation measures, and the appropriateness of proposed monitoring and follow-up programs. The Panel requests that ECCC provide their submission by September 14, 2020, as per the schedule set out in the Notice of Hearing.*[1]

Environment and Climate Change Canada's (ECCC) review of Benga Mining Ltd.'s ('Benga') proposed Grassy Mountain Coal Project (the Project) is based on the Department's mandate and the federal legislation it administers.

ECCC's legislative framework for protecting and managing the environment is founded on various statutes, including the *Migratory Birds Convention Act*, the *Species at Risk Act*, the pollution prevention provisions of the *Fisheries Act,* and the *Canadian Environmental Protection Act*.

ECCC is participating in the environmental assessment process to provide the Joint Review Panel (the Panel) with:

- A review of Benga's characterization of effects to determine the potential environmental effects of the Project;
- A review of the predicted effectiveness of the proposed mitigation measures and considerations for additional mitigation measures;
- A review of the appropriateness of the proposed follow-up programs;
- Advice on monitoring needs (either site specific or regional) in order to enable adaptive management of impacts experienced during the development, operation and closure of metallurgical coal mine projects and

[1] [1] From the Joint Review Panel to Environment and Climate Change Canada re: Participation at the Public Hearing for the Grassy Mountain Coal Project https://iaac-aeic.gc.ca/050/documents/p80101/135240E.pdf

- An update on the background and status of the proposed *Coal Mining Effluent Regulations*.

During ECCC's technical review, departmental officials identified various issues with respect to Benga's assessment of the potential environmental effects of the Project and proposed mitigation measures. Some of these were resolved in whole or in part by Benga in their responses to Information Requests, Conformity and Sufficiency reviews and multiple addenda. The topics which have been addressed throughout the review process and for which ECCC has no further comment include hydrology, mine fleet emissions, marine vessel emission estimates, and Little Brown Bat. ECCC has identified elements of Benga's assessment which may pose a risk to the environment if not appropriately characterized, including predicted effects to water quality and associated impacts to wildlife from selenium exposure, effects on air quality, and the effects of climate change on the Project's design.

The submission provides advice and recommendations based on a review of the information provided by Benga within its application pursuant to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012). This submission also accounts for Benga's application to the Alberta Energy Regulator (AER), information posted on the Canadian Impact Assessment Registry (CIAR), and ECCC's supporting science. ECCC's recommendations to the Panel are summarized in Chapter 8. ECCC will be pleased to discuss these matters during the public hearings including the topics raised in the June 29, 2020 (CIAR #379) letter from the Panel to ECCC.

ECCC's submission provides information and recommendations pertaining to:

- The proposed *Coal Mining Effluent Regulations;*
- The effects of the Project to wildlife, including migratory birds and species at risk;
- The effects of the Project on the aquatic environment including a discussion on selenium speciation and criteria;
- The effects of the Project on air quality and greenhouse gas emissions;
- The effects of climate change on the Project's design; and
- Spill response measures and systems.

ABBREVIATIONS

µg/L	Micrograms per Liter
µg/m^3	Micrograms per cubic meter
AAAQO	Alberta Ambient Air Quality Objectives
AER	Alberta Energy Regulator
BAT	Best Available Technologies
BEP	Best Environmental Practices
Benga	Benga Mining Limited
CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria Air Contaminants
CEAA	*Canadian Environmental Assessment Act*
CE	Control Efficiency
CEPA	*Canadian Environmental Protection Act*
CIAR	Canadian Impact Assessment Registry
CO_2e	Carbon Dioxide Equivalent
COPCs	Chemicals of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPP	Coal Processing Plant
CSA	Canadian Standards Association
DFO	Fisheries and Oceans Canada
dw	Dry Weight
ECCC	Environment and Climate Change Canada
EI	Emissions Intensities
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EC_{10}	10 percent Effect Concentration
GCM	Global Climate Model
GHG	Greenhouse Gases

GIC	Governor in Council
IMO	International Maritime Organization
IR	Information Request
IPCC	Intergovernmental Panel on Climate Change
JRP	Joint Review Panel
Km	Kilometer
LSA	Local Study Area
MBCA	*Migratory Bird Convention Act*
MBR	*Migratory Birds Regulations*
mg/L	Milligram per liter
Mt	Million tonnes
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
OBPS	Output-Based Pricing System
OEA	Surface Transportation Board Office of Environmental Analysis
PAH	Polycyclic Aromatic Hydrocarbons
PM_{10} **$PM_{2.5}$**	Particulate Matter Less Than 10 microns in diameter Particulate Matter Less Than 2.5 microns in diameter
PMF **PMP**	Probable Maximum Flood Probable Maximum Precipitation
PNECs	Predicted No-effect Concentrations
RSA	Regional Study Area
SARA	*Species at Risk Act*
SIR	Supplementary Information Request
SO_2	Sulfur Dioxide
SSWQO	Site-specific water quality objectives
TRV	Toxic Reference Value
TSP	Total Suspended Particles
VOC	Volatile organic compounds

CHAPTER 1 – Introduction

This submission summarizes ECCC's review of the environmental assessment material and supporting information provided by Benga throughout the review process. It focuses on elements that are within ECCC's mandate and expertise. The submission includes outstanding concerns with the characterization of effects related to topics that ECCC has identified and provides recommendations for consideration by the Panel.

ECCC was established under the *Department of the Environment Act*. ECCC's mandate is determined by the statutes and regulations under the responsibility of the Minister of Environment and Climate Change. In delivering this mandate, ECCC is responsible for the development and implementation of policies, guidelines, codes of practice, inter-jurisdictional and international agreements, as well as related programs. ECCC's specialist advice is provided in the context of the *Canadian Environmental Protection Act* (CEPA), the pollution prevention provisions of the *Fisheries Act,* the *Migratory Birds Convention Act* (MBCA), and the *Species at Risk Act* (SARA).

ECCC administers the pollution prevention provisions of the *Fisheries Act*, which prohibits the deposit of a deleterious substance into fish-bearing waters. ECCC also regulates toxic substances and develops environmental quality guidelines under CEPA, 1999. ECCC is responsible for protecting and conserving migratory bird populations and individuals under the MBCA. ECCC also administers SARA, in cooperation with Fisheries and Oceans Canada (DFO) and Parks Canada, to prevent wildlife species from becoming extirpated or extinct; to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity; and to manage species of special concern to prevent them from becoming threatened, endangered or extirpated.

ECCC's review of Benga's assessment of the environmental effects and mitigation measures related to the Project is informed by the precautionary principle, which recognizes that the absence of full scientific certainty, shall not be used as a reason to postpone decisions in the face of the threat of serious or irreversible harm.

A summary of ECCC's mandate and legislation is provided in Chapter 2. Chapters 3-7 provide information on topics where the effects of the project on the environment have not been fully characterized or mitigated. Chapter 8 summarizes ECCC's recommendations. Appendix A provides the ECCC-contracted report by Advisian on Best Available Technologies / Best Environmental Practices to Reduce GHG Emissions from New Coal Mining and Processing Facilities.

CHAPTER 2 – Environment and Climate Change Canada: Mandate, Roles and Responsibilities

The scope of specialist or expert information or knowledge provided by ECCC in this submission to the Panel is within the Department's mandate as defined by the *Department of the Environment Act* and through other legislation assigned to the Minister of Environment and Climate Change.

The Department provided additional detail to the Panel on December 4, 2018 (CIAR #104[2]) regarding the legislation, policy or other directives under the responsibility of ECCC that may be relevant to the Project review.

ECCC's comments and recommendations in relation to the Project are intended to provide specialist or expert information or knowledge to the Panel in accordance with ECCC's program related responsibilities and associated guidelines and policies. These comments are not to be interpreted as any type of acknowledgement, permission, approval, authorization, or release of liability related to any requirements to comply with federal statutes and regulations. Responsibility for achieving regulatory compliance lies solely with Benga.

The following information provides an overview of the legislative, policy or other directives under the responsibility of ECCC that may relate to the Project, or the environmental assessment. The summaries have been prepared for ease of reference and convenience, but for purposes of accuracy, interpretation and application of the legislation, regulation or policy, the Review Panel is invited to refer to the original documents including any subsequent amendments.

2.1 Environmental Protection

2.1.1 *Department of the Environment Act*

https://laws-lois.justice.gc.ca/eng/acts/E-10/

The *Department of the Environment Act* established ECCC as a department within the portfolio of the Minister of Environment and Climate Change responsible for preserving and enhancing the quality of the natural environment, providing meteorological services, and coordinating policies and programs to achieve environmental objectives.

[2] From Environment and Climate Change Canada to the Joint Review Panel re: Federal Expertise regarding the Grassy Mountain Coal Joint Review Panel Process

https://iaac-aeic.gc.ca/050/evaluations/proj/80101/contributions/id/25569

2.2 Pollution Prevention

2.2.1 *Canadian Environmental Protection Act, 1999 (CEPA 1999)*

https://laws-lois.justice.gc.ca/eng/acts/c-15.31/

The *Canadian Environmental Protection Act, 1999* (CEPA) provides the Government of Canada with tools to protect the environment and human health and establishes strict deadlines for controlling certain toxic substances. A key aspect of CEPA is the prevention and management of risks posed by toxic and other harmful substances. Substances that are declared "toxic" under CEPA are added to the List of Toxic Substances in Schedule 1 of the Act. CEPA regulates many of the substances that have a deleterious effect on the environment; therefore, the Project may be subject to several regulations under CEPA, including but not limited to those outlined in ECCC's submission.

2.2.2 *Fisheries Act* – Certain Provisions

http://laws.justice.gc.ca/eng/acts/F-14/

Under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), water quality is assessed under sections 5(1) (a) for its potential to impact fish, aquatic species and migratory birds; under 5(1) (b) (ii) for its potential to cause an environmental change outside the province of the Project; and under 5(1) (c) for its potential to affect Aboriginal uses and interests. Efforts taken under CEPA are complemented by actions taken under other federal Acts administered by the Minister of Environment and Climate Change. ECCC's mandate for water quality stems from the pollution prevention provisions of the *Fisheries Act* (including section 26), which are administered and enforced by ECCC. The Compliance and Enforcement Policy for the Habitat Protection and Pollution Prevention Provisions of the *Fisheries Act* states that compliance with the federal *Fisheries Act* is mandatory. Subsection 36(3) of the *Fisheries Act* specifies that, unless authorized by federal regulation, no person shall deposit or permit the deposit of deleterious substances of any type in water frequented by fish, or in any place under any conditions where the deleterious substance, or any other deleterious substance that results from the deposit of the deleterious substance, may enter any such water. Proponents should note that only a federal regulation under the *Fisheries Act* or another Act of Parliament can authorize a discharge of a deleterious substance; no federal permit, provincial, territorial or municipal regulatory permit or approval allows for exemption from the *Fisheries Act*.

In the application of the *Fisheries Act*, court cases have accepted that a discharge or effluent that is acutely lethal to fish is deleterious. In other words, results of tests designed to determine whether fish will die in an effluent or discharge within a specified time period will determine one aspect of deleteriousness. However, any substance with a potentially harmful chemical, physical or biological effect on fish or fish habitat is also deleterious. For example, substances (such as sediment) that smother nesting areas or spawning grounds, or interfere with reproduction, feeding or respiration of fish at any point in their life cycle are also considered deleterious. In general, any substance with a potentially harmful chemical, physical or biological effect on fish or fish habitat may be considered deleterious. Heated discharges are also considered deleterious since the definition of deleterious (*Fisheries Act* section 34) also

includes water that has been so changed by heat that it can be deleterious to fish and fish habitat.

The act of depositing a deleterious substance should be considered a violation of the *Fisheries Act*, regardless of whether the water itself is made deleterious by the deposit. Subsection 36(3) of the *Fisheries Act* makes no allowance for a mixing or dilution zone. Any measurements or tests to determine whether something is deleterious should be done where the substance is at its highest concentration, typically at the point of discharge to the receiving water.

Compliance with the terms and conditions of provincial regulatory or permitting system does not absolve Benga from responsibility to comply with the requirements of the *Fisheries Act* or other federal legislation. Further, this submission does not constitute an authorization pursuant to subsection 36(4) of the *Fisheries Act.*

2.3 Biodiversity and Conservation

ECCC's advice and recommendations related to migratory birds, species at risk and wildlife are based on departmental responsibilities under the *Migratory Birds Convention Act* (MBCA) and the *Species at Risk Act* (SARA).

2.3.1 *Migratory Birds Convention Act, 1994* (MBCA) and *Migratory Birds Regulations* (MBR)

https://laws-lois.justice.gc.ca/eng/acts/m-7.01/

Migratory birds are also specifically referenced under Section 5(1) (a) (iii) of CEAA 2012:

> *'5. (1) For the purposes of this Act, the environmental effects that are to be taken into account in relation to an act or thing, a physical activity, a designated project or a project are*
>
> > *a) a change that may be caused to the following components of the environment that are within the legislative authority of Parliament:*
> >
> > > *(iii) migratory birds as defined in subsection 2(1) of the Migratory Birds Convention Act, 1994 ...'*

The purpose of the MBCA is to implement the Migratory Birds Convention between Canada and the United States by protecting and conserving migratory birds, as populations and individuals. Within this context, it is the responsibility of the Government of Canada to protect and conserve the roughly 500 species of migratory birds regularly occurring in Canada. ECCC provides the list of bird species protected under the MBCA, which derives from Article I of the Migratory Birds Convention.

Section 5.1 of the MBCA 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. This Act also prohibits the possession of a migratory bird, nest or egg without lawful excuse. The *Migratory Birds Regulations* (MBR) provide for the conservation of migratory birds and for the protection of individuals, their nests and eggs. A prohibition against hunting is set out in section 5 of the MBR. The term 'hunt' is given a specific

definition in section 2 of the MBR and includes attempting in any manner to kill, injure or harass migratory birds. A prohibition against the disturbance, destruction, or taking of a nest, egg or nest shelter of a migratory bird is set out in subsection 6(a) of the MBR.

Migratory birds, the nests of migratory birds and/or their eggs can be inadvertently harmed or disturbed as a result of many activities-including but not limited to clearing trees and other vegetation, draining or flooding land, or using fishing gear; this is known as incidental take. This inadvertent harming, killing, disturbance or destruction of migratory birds, nests and eggs is prohibited under the MBCA. Incidental take, in addition to harming individual birds, nests or eggs, can have long-term consequences for migratory bird populations in Canada, especially through the cumulative effects of many different incidents. For further details, please refer to the Avoiding Harm to Migratory Birds website at: https://www.canada.ca/en/environment-climate-change/services/avoiding-harm-migratory-birds.html.

2.3.2 *Species at Risk Act* (SARA)

https://laws-lois.justice.gc.ca/eng/acts/s-15.3

Provisions of SARA refer specifically to environmental assessment of projects. Section 79 of SARA requires that the federal authorities responsible for the environmental assessment notify the competent minister(s) in writing if the project is likely to affect a listed wildlife species or its critical habitat and to identify the adverse effects of the Project. If the Project is carried out, that authority must also "ensure that measures are taken to avoid or lessen those effects and to monitor them". The measures taken must be consistent with any applicable recovery strategy or action plan under SARA. Accordingly, the results of this environmental assessment inform the Canadian Environmental Assessment Agency (CEA Agency) as the Responsible Authority in the context of fulfilling the obligations of section 79 of SARA.

Endangered and threatened migratory bird species at risk (species, subspecies, and distinct populations) have federal legislative protection under the SARA.

The purpose of SARA is to prevent wildlife species from being extirpated or becoming extinct, to provide for the recovery of wildlife species that are Extirpated, Endangered or Threatened as a result of human activity, and to manage species of Special Concern to prevent them from becoming Endangered or Threatened. SARA supports the federal commitments under the 1996 Accord for the Protection of Species at Risk, which outlines commitments by federal, provincial and territorial ministers to designate species at risk, protect their habitats and develop recovery plans as well as complementary legislation, regulations, policies and programs, including stewardship.

ECCC has responsibilities for overall administration of SARA (subsection 8(1)). As well, SARA defines "competent ministers" as the Minister responsible for the Parks Canada Agency (PCA) (with respect to individuals[3] of a wildlife species in or on federal lands administered by that Agency); the Minister of Fisheries and Oceans (DFO) (with respect to aquatic species other

[3] As defined in SARA, "individual" means an individual of a wildlife species, whether living or dead, at any developmental stage and includes larvae, embryos, eggs, sperm, seeds, pollen, spores and asexual propagules.

than individuals on lands administered by the PCA); and, the Minister of Environment and Climate Change (with respect to all other individuals of a wildlife species). Competent ministers have responsibilities regarding recovery planning, protection, permitting, and other activities identified within the legislation.

SARA sets out a process for an independent assessment of species potentially at risk and for the consideration of Governor in Council for their listing on Schedule 1 of SARA as Extirpated, Endangered, Threatened, or of Special Concern. These assessments fall within the purview of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; http://www.cosewic.ca/index.php/en-ca/). SARA requires that recovery strategies and action plans be developed by the competent minister for species listed as Extirpated, Endangered or Threatened. Management plans must be developed for species of special concern

SARA also provides measures for the protection of listed threatened, endangered or extirpated species and their residences. Under section 32 and 33 of SARA, individuals and residences of aquatic species and birds protected by the MBCA are automatically protected anywhere they are found in Canada. These general prohibitions apply to all other Extirpated, Endangered or Threatened species listed on Schedule 1 of SARA when they are on federal lands in the provinces and on land under the authority of the Minister of Environment and Climate Change or the PCA in the territories. These prohibitions can also apply on non-federal (provincial, territorial and private) lands if the Governor in Council makes an order to that effect, based on a recommendation from the federal Minister of Environment and Climate Change (SARA s. 34 and s. 35). In the case of the species at risk that may be affected by the Project, no such order has been made.

Based on the best available information, SARA requires an identification of critical habitat for Threatened, Endangered, and Extirpated species to the extent possible in a recovery strategy or action plan. SARA defines the critical habitat of a species as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or an action plan for the species." Once critical habitat is identified in a final recovery strategy or action plan, SARA sets out a process to evaluate existing protection mechanisms, and if necessary, to put in place additional protection under SARA. The timelines and instruments which can be used to achieve critical habitat protection vary depending on land ownership and the species involved. SARA is designed to turn first to existing laws and initiatives before contemplating using SARA prohibitions directly, looking to federal laws when critical habitat occurs on federal land and to laws of the province or territory or Acts of Parliament including SARA when critical habitat occurs on non-federal lands.

As this Project is on provincial lands, and as there has been no Governor in Council Order that the SARA prohibitions are to apply to Alberta's lands, the SARA prohibitions only apply to aquatic species and migratory birds.

Listed species in the Local Study Area (LSA) for the Project assessment include two endangered species, four threatened species, and four species of special concern. Several species are discussed further in our submission. Recommendations are provided to assist in their protection.

Subsection 32 (1) of SARA states that no person shall kill, harm, or harass an individual of a species listed as endangered or threatened. Section 33 states that no person shall damage or

destroy the residence of one or more individuals of a wildlife species listed as an endangered or threatened. A "residence" is defined as a dwelling-place such as a den, nest or other similar area or place that is occupied during all or part of the species life-cycle.

Under Section 61, there is an additional prohibition for critical habitat of listed species under SARA. The Act defines the critical habitat of a species as

> "*the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or an action plan for the species*."

Finally, another consideration related to the environmental assessment of the Project is found in Section 79. This section requires that the federal authority responsible for the environmental assessment notify the competent minister(s) in writing if the Project is likely to affect a listed wildlife species or its critical habitat, and identify the adverse effects that the Project will have. If the Project is carried out, the federal authority must "ensure that measures are taken to avoid or lessen those effects and to monitor them". The measures taken must be consistent with any applicable recovery strategy or action plan under SARA.

2.4 Air Quality and Greenhouse Gases

ECCC has a broad mandate and policy framework with respect to air quality and climate change, including both national initiatives and international agreements. ECCC is also responsible for producing national emissions inventories of air pollution and climate change related emissions, for distribution both domestically and internationally, including under the United Nations Framework Convention on Climate Change.

2.4.1 Air Quality Management System

Air quality management is a shared responsibility among federal, provincial and territorial governments. The federal government in collaboration with provinces and territories is implementing an Air Quality Management System to improve air quality across the country and protect the health of Canadians and the environment. The system includes more stringent ambient air quality standards (which provide the drivers for air quality improvements), a framework for managing air quality through local air zones and regional airsheds, and the establishment of emission requirements for major industrial sectors and equipment types using regulatory and non-regulatory measures.

In 2013, the federal government established more stringent health-based ambient air quality standards for fine particulate matter and ground-level ozone (the main components of smog) using the authority of CEPA. New Canadian Ambient Air Quality Standards (CAAQS) were also established for sulphur dioxide and nitrogen dioxide in 2016 and 2017, respectively. In June 2014, the federal government proposed the *Multi-Sector Air Pollutants Regulations* to reduce air pollution from boilers and heaters, cement manufacturing, and stationary engines.

In May 2016, the federal government published final codes of practice for the aluminum sector and the iron, steel & ilmenite sector. It also published proposed Base-level Industrial Emissions Requirements (BLIERs) instruments for seven sectors for a 60-day comment period including: two codes of practice (for the potash sector and the pulp and paper sector); one pollution

prevention planning notice for the iron, steel and ilmenite sector; one guideline for new stationary combustion turbines; and three performance agreements (for the aluminum sector, the iron ore pellets sector and five company-specific performance agreements for the base metals smelting sector). Once finalized, these instruments will contribute to the reduction of air pollutant emissions and the improvement of the air quality across the country.

2.4.2 Transboundary Air

Based on Article V of the 1991 Canada-United States Air Quality Agreement, Canada and the United States committed to notify each other of any new air pollution source located within 100 km of the Canada/U.S. border that is expected to emit greater than 90 tonnes per year of any one of the common air pollutants.

2.4.3 Marine

Marine vessels are a potentially important source of Criteria Air Contaminants (CACs) from fuel combustion in their main engines, auxiliary engines, and boilers. These emissions consist of oxides of nitrogen (NOx), oxides of sulphur (SOx), particulate matter (PM), and volatile organic compounds (VOCs). VOCs can result in the formation of tropospheric ozone. Fuel combustion in engines and boilers of marine vessels also results in emissions of greenhouse gases (GHGs).

International marine transportation is a highly integrated and competitive global industry that operates within a framework of rules and standards set by the International Maritime Organization (IMO). Transport Canada leads Canada's participation at IMO and is supported by ECCC, which provides technical and scientific advice on environmental matters including air pollutant and greenhouse gas emission reduction approaches. ECCC also has regulatory authorities which are exercised in order to enact rules and standards domestically in Canada, including regulations on environmental fuel quality used by large and small vessels.

ECCC produces the national marine emissions inventory, which is a spatially and temporally resolved inventory and forecast of marine vessel air pollutant and greenhouse gas emissions in Canadian territorial waters and Exclusive Economic Zone (EEZ). The inventory accounts for ongoing and updated research on emission factors as well as regulatory changes.

2.4.4 Rail

ECCC has participated in past and current voluntary agreements with the rail industry to address air pollutant and greenhouse gas emissions from locomotives. ECCC's current role is to provide analysis and advice on emission reduction approaches through participation in the Management Committee and the Technical Review Committee for the Memorandum of Understanding between Transport Canada and the Railway Association of Canada for Reducing Locomotive Emissions. ECCC also has the legislative authority and has implemented regulations on the environmental fuel quality used by locomotives.

2.4.5 Off-road Vehicles and Engines

Mobile machinery such as construction equipment & industrial equipment and their fuels are subject to ECCC's legislative authority. Air pollutant emissions from these products are covered

by a variety of regulations such as the *Off-Road Compression Ignition Engine Emission Regulations* and the *Off-Road Small-Spark Ignition Engine Emission Regulations*. The fuels used in these engines are subject to a variety of environmental fuel quality regulations. These off-road engine emission regulations impose requirements on companies which manufacture or import vehicles & engines into Canada, and not the individual equipment users.

As part of ECCC's normal regulatory development and amendment process, the department regularly evaluates the technical feasibility, cost effectiveness and market acceptance of technological advances within the off-road market. ECCC consults widely with stakeholders before, during and after the regulator development process to solicit stakeholder feedback and address concerns. This broad list of stakeholders includes, but is not limited to, other government departments, the U.S. government (because Canadian and U.S. regulations are often aligned), manufacturers and equipment users.

2.5 Meteorological and Climate Conditions

2.5.1 Meteorology

Under the *Department of the Environment Act* powers, duties and functions of the Minister of Environment and Climate Change extend to a number of matters including meteorology. ECCC provides weather warnings, forecasts and information to help Canadians and a variety of economic sectors anticipate dangerous meteorological events and afford enough time to protect themselves, their livelihood and their property. ECCC operates and maintains monitoring infrastructure including surface weather and marine meteorology networks.

2.5.2 Climate Change

Climate change considerations are relevant to the Project because climate over the lifetime of the Project has been projected to be different from the current and past climate for the area. Implications of this change in climate on the Project should be considered.

2.6 Accidents and Malfunctions

CEAA 2012 requires that all designated projects consider: "the environmental effects of the designated project, including the environmental effects of malfunctions or accidents that may occur in connection with the designated project and any cumulative environmental effects that are likely to result from the designated project in combination with other physical activities that have been or will be carried out."

Proponents of all such designated projects must therefore take into account the projects' potential for unintentional spills and releases of hazardous substances and consequential harm to the environment and to human health and life.

ECCC's reviews of accidents and malfunctions are based on the Department's mandated interests as they relate to CEPA, the pollution prevention provisions of the *Fisheries Act*, and the MBCA. ECCC's comments and recommendations to project proponents are provided with a direct view to preventing and mitigating environmental effects that may occur as a result of an accident or malfunction.

2.6.1 Environmental Emergency Regulations

https://laws-lois.justice.gc.ca/eng/regulations/SOR-2019-51/

Authority to require emergency plans for toxic or other hazardous substances set out in Schedule 1 to the *Environmental Emergency Regulations*, 2019 is provided in Part 8 of CEPA. These Regulations are aimed at enhancing the protection of the environment and human life and health by promoting the preparedness for response to and recovery from environmental emergencies at fixed facilities of a release of a substance on Schedule 1 to the *Environmental Emergency Regulations*. The Regulations require those who own, have charge, management or control of toxic and hazardous substances set out in Schedule 1 to the *Environmental Emergency Regulations* at or above the specified thresholds to provide required information on the substance(s), their quantities and to prepare and implement environmental emergency plans. The primary goal of preparing and implementing an environmental emergency plan is to prevent emergencies from occurring and provide appropriate response activities in the event that an emergency does occur. For additional details, see http://www.ec.gc.ca/CEPARegistry/regulations/detaiiReg.cfm?intReg=70.

CHAPTER 3 – Proposed Legislation

3.1 Proposed *Coal Mining Effluent Regulations*

Introduction and Importance of the Topic to Impact Assessment

There are 28 identified existing coal mines in Canada, located in British Columbia, Alberta, Saskatchewan, and Nova Scotia. Coal mines are currently releasing effluent containing harmful substances into fish-frequented waters. Coal mining effluent is already subject to some provincial requirements, and coal mines must obtain a permit to operate that includes effluent quality standards. In the absence of a federal regulation authorizing effluent discharges under the *Fisheries Act*, there is a lack of regulatory clarity as these mines are subject to the general prohibition described under subsection 36(3) of the *Fisheries Act*, which prohibits the deposit of deleterious substances into fish-frequented waters.

The deposit of a deleterious substance to water frequented by fish constitutes a violation of the *Fisheries Act* except where federal regulations under subsection 36(5) of the Act, or other Governor in Council regulations, authorize the deposit of the deleterious substance to levels set out in the regulations. There are currently no such federal regulations for coal mines, but ECCC is developing a proposed regulatory approach for coal mines under the *Fisheries Act*. The Panel is therefore advised that any permitted Project Conditions concerning end-of-pipe discharge limits may be regulated under future *Fisheries Act* regulations, including the *Coal Mining Effluent Regulations.* Until such time as the regulations become law, the deposit of a deleterious substance to water frequented by fish constitutes a violation of the *Fisheries Act* except where federal regulations under subsection 36(5) of the Act apply.

The proposed regulation would include a "general approach" for most coal mines (which would include the Project) which are able to collect their mine wastewater and site runoff.

All mines will be required to conduct environmental effects monitoring, and would be subject to monitoring, reporting and record-keeping requirements. Monitoring requirements may include analysis of selenium in fish tissue, sediment and benthic invertebrate tissues, as well as in water samples taken from area(s) exposed to mine effluent and related reference area(s).

When developing limits for effluent in the proposed regulation, ECCC considers the limits in other domestic and international coal producing jurisdictions, performance of existing coal mines, performance achieved by treatment technology that has been commercially proven at the industrial scale, and potential aquatic effects of harmful substances.

ECCC has held four sets of consultation on the proposed regulatory framework since 2017. Written feedback has been received from industry, environmental non-governmental organizations, provinces, other government departments, and Indigenous groups. ECCC is considering the feedback received from consultation as it prepares a final regulatory package for ministerial and Governor in Council (GIC) decision.

Status

ECCC is targeting a pre-publication of the regulations in the Canada Gazette, Part 1, in Spring 2021. Final publication in Canada Gazette, Part 2, is targeted one year later.

For more information, please see: https://www.canada.ca/en/environment-climate-change/corporate/transparency/acts-regulations/forward-regulatory-plan/2019-2021/fisheries-act.html

CHAPTER 4 – Terrestrial Environment

4.1 Wildlife and Selenium

Introduction and Importance of the Topic to Impact Assessment

Selenium is a naturally occurring element present in sedimentary rocks and soils, known to be mobilized and introduced into aquatic systems through a variety of anthropogenic activities, including coal mining. Specifically, selenium is mobilized when rock overburden and waste materials are crushed and exposed to natural weathering processes (US EPA, 2018).

Selenium is documented to be toxic to wildlife, particularly to oviparous (egg-laying) vertebrates such as fish and birds. It is an essential micronutrient that is required for normal cellular function in animals, however it has an extremely narrow therapeutic range, and incremental exposures above nutritional levels can lead to adverse toxicological effects (Janz et al., 2010). In addition, there is limited information on the toxicity of selenium to amphibians (Janz et al., 2010).

ECCC is of the opinion that Benga has not adequately described the risks to wildlife related to the transport of selenium from waste rock leachate and exposure to receptors via dietary intake. The exclusion of a selenium source in the wildlife risk assessment, namely leaching selenium from waste rock and subsequent loading to surface waters, and the failure to incorporate selenium exposure to receptors via dietary intake, likely underestimates the risk posed to wildlife from the Project.

It is important to ensure that surface water selenium concentrations are accurately predicted and assessed because selenium readily bioaccumulates in aquatic-dependent wildlife, primarily through ingestion, and can move through the food web in aquatic ecosystems (e.g. accumulation in aquatic plants, invertebrates, fish, and birds) (Ohlendorf et al., 2011; Palmer et al., 2010). Selenium in the diet of female birds during the period prior to egg-laying can result in the transfer of selenium to the eggs, representing a critical selenium exposure route (Ohlendorf & Heinz, 2011). A well-known example of selenium toxicity in migratory birds occurred in the early and mid-1980s at Kesterson Reservoir inside the Kesterson National Wildlife Refuge in central California, where levels of selenium in the aquatic food web resulted in reproductive failure and mortality of adult birds (Ohlendorf, 2002). While the selenium that accumulated in the reservoir was not generated as a result of coal mining activities, this example demonstrates the risks that elevated selenium concentrations in the aquatic environment can pose to aquatic-dependent wildlife, including birds. Given that bioaccumulation of selenium in the egg causes developmental abnormalities and mortality of avian embryos, selenium levels in the egg provide the most sensitive measure for evaluating hazards to birds; egg tissue burdens are viewed by experts as a valuable indicator of selenium contamination in the local environment (Ohlendorf & Heinz, 2011).

Furthermore, selenium bioaccumulation in aquatic-dependent wildlife has been shown to adversely impact wildlife health, resulting in reproductive impairments and abnormal fetal development (Ohlendorf & Heinz, 2011).

Accurately characterizing the risks to receptors from selenium is critical to predicting the Project's effects on wildlife. All toxicologically relevant exposure routes must be captured in order to have confidence in any conclusions regarding wildlife health.

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
  - Section B – Geology and Geotechnical
- Consultant Report #6 – Aquatic Resources (CR #6)
- Consultant Report #12 – Human Health and Wildlife Risk Assessment (CR #12)
  - Appendix H: Screening Wildlife Risk Assessment
    - Section 2.1 Chemicals of Potential Concern
      - Table H-1 Chemicals of Potential Concern Emitted to Air, Page H-3 to H-4
      - Table H-2 Chemicals of Potential Concern Included in the Soil and Surface Water, Page H-4 to H-5
    - Section 4.3 Soil Quality Guidelines
      - Table H-8 Soil quality Guidelines Protective of Wildlife, Page H-22 to H-25
    - Section 4.4 Surface Water Quality Guidelines
      - Table H-9 Comparison of Maximum Predicted Surface Water Concentrations (mg/L) to Surface Water Quality Guidelines Protective of both Aquatic and Wildlife, Page H-26 to H-27
- Sixth Addendum to the Environmental Impact Assessment (April 30, 2018), (CIAR #70)
  - ECCC SIR 21 – Exposure of Aquatic and Terrestrial Biota to Contaminants of Concern, Page 63

Benga's Conclusions

Benga concludes that no impacts on local surface water (e.g. Blairmore Creek, Gold Creek, Crowsnest River) are predicted (CR #6, CIAR #42). However, the conclusion did not account for leaching of selenium from waste rock material and subsequent loading to surface waters as a relevant source of selenium, based on the presumption that all impacted water on the site would be captured and treated prior to release. Benga's comparison of predicted deposition of selenium into surface water therefore estimated that surface water concentrations will be below guidelines protective of freshwater aquatic life (CR #12, Appendix H, pg. H-7, CIAR #42).

The screening-level wildlife risk assessment for the Project evaluated the potential release of various Contaminants of Potential Concern (COPC) to the environment resulting from coal mining activities. Impacts to wildlife were predominantly assessed through inhalation of COPCs (e.g. CACs, metals, PAHs, VOCs) (CR #12, Table H-1, CIAR #42). Benga also evaluated potential impacts associated with wildlife exposure to chemicals in soil and surface water, including selenium (CR #12, Table H-2, CIAR #42). Predicted COPC concentrations in soil and surface waters (from air deposition) were compared to the corresponding soil (CR #12, Table H-8, CIAR #42) and water quality guidelines (CR #12, Table H-9, CIAR #42) for the protection of wildlife.

Benga predicted that COPC concentrations would be less than toxic reference values (TRVs) associated with inhalation, and concluded that Project air emissions will not cause population-level adverse effects on the health of wildlife in the study areas (CR #12, Appendix H, pg. H-2, CIAR #42). For other exposure pathways, Benga determined that the "project would not be expected to directly impact water quality" (CR #12, Table H-3, CIAR #42) based on modelled estimates of COPC concentrations in soil and water contaminated via aerial deposition, which were determined to be less than Alberta and US EPA soil and water quality guidelines

protective of wildlife health. Benga stated that surface water ingestion is considered to be the primary route of exposure for wildlife (CR #12, Table H-3, CIAR #42) and indicated that they "will also consider" using wildlife fencing, amphibian pit fall traps and mannequins (scare-crows) to reduce wildlife interactions with untreated COPC-laden water which accumulates in surge ponds, other water management ponds and drainage ditches (Sixth Addendum, ECCC SIR 21, CIAR #70).

ECCC's Conclusions

During mining activities, large quantities of rock are removed in order to gain access to coal seams. The mined rock, referred to as waste rock, is placed into piles adjacent to mine pits where it is exposed to natural weathering processes. Runoff and precipitation flow through these rock piles, mobilizing contaminants such as selenium, cadmium, sulphate and nitrate (Teck, 2014). Unless captured and treated, this "contact water" enters local watersheds. The potential for selenium to be released through the weathering of waste rock material is a documented pathway through which selenium is released during mountain-top coal mining activities (Lemly, 2019; Palmer et al., 2010; Teck, 2014; US EPA, 2018; Young et al., 2010).

When evaluating the potential impact of COPC concentrations in air, Benga assessed worst-case scenarios (e.g. highest expected air COPC concentrations) in their screening-level wildlife risk assessment in order to be protective of wildlife health. ECCC's view is that the screening-level wildlife risk assessment is not sufficiently conservative, as aerial deposition was assumed to be the only source of contaminants entering surface water. While Benga correctly identified aerial deposition of selenium (and other COPCs) to the surface water of local waterbodies as one pathway by which selenium may be released to the local aquatic environment, they did not evaluate the potential for selenium to be released into surface water from the weathering of waste rock which could result in an underestimation of risk to wildlife exposed to selenium (and other COPCs) in surface water. ECCC has identified weathering of waste rock material and the subsequent release of selenium into surface water as a relevant exposure pathway that was not considered. Benga took steps to evaluate the potential impact of selenium exposure on aquatic-dependent wildlife, such as migratory birds, however there are gaps in their analysis and overall conclusions.

It is ECCC's view that the screening level wildlife risk assessment conclusions may not be conservative, and that Project effects may be underestimated. Therefore, biomonitoring of oviparous aquatic-dependent vertebrates (e.g. fish, birds, amphibians) is required in order to characterize site-specific baseline conditions, to validate assumptions in the Wildlife Risk Assessment, and to track potential changes to the environment as a result of the Project.

Lessons learned from the Elk Valley

ECCC has undertaken a significant amount of work with respect to the impacts and effects from coal mining activities in the Elk Valley, British Columbia. These impacts may be relevant to an understanding of the potential risks to the environment from the Project where there are common elements between the existing Elk Valley mines and the Project. For example, the observed effects of selenium exposure on bird species related to coal mining in the Elk Valley can be used to inform the Panel about the predicted effects of the Project.

Over the past four decades, open-pit mountaintop coal mining, such as that proposed for Grassy Mountain, has resulted in the increase of selenium and a reduction of water quality in the Fording and Elk Rivers located in the Elk Valley in southeastern British Columbia (Lemly, 2019).

A biomonitoring study was completed in the Elk Valley focused on the degree to which selenium was capable of bioaccumulating in the eggs of two migratory bird species, American dipper (*Cinclus mexicanus*) and spotted sandpiper (*Actitis macularia*). The study found that mean egg selenium levels were 7.4 µg/g dry weight (dw) and 8.4 µg/g dw in American dipper eggs collected from reference and exposed sites, respectively (not statistically different) (Harding et al., 2005). Mean egg selenium burdens in sandpiper eggs were found to differ between exposed (7.3 µg/g dw) and reference locations (3.8 µg/g dw) (Harding et al., 2005). Overall, selenium burdens in eggs were found to be less than reported thresholds for waterfowl and other shorebird species (Harding et al., 2005), and were less than a recently derived US EPA selenium egg tissue guideline (EC_{10} = 11.2 µg/g dw) (US EPA, 2018).

In addition to increased concentrations of selenium in migratory bird (Spotted Sandpiper) eggs, Harding et al. (2005) also observed a reduction in hatching success for sandpipers nesting at exposed locations. However, overall productivity at reference and exposed locations for both study species were found to be higher than provincial averages (i.e. impacts to sandpipers and dippers at the population-level were not evident in the Elk Valley at the time of sampling).

A follow-up study, led by ECCC, aimed at repeating the work completed by Harding et al., (2005) was recently undertaken in the Elk Valley. Preliminary data suggest that selenium concentrations in the eggs of American dippers are slightly elevated at exposed sites relative to reference sites, although the highest measured values in dipper eggs were consistent with what was previously reported (e.g. approximately 8 µg/g dw) (Harding et al., 2005). Spotted sandpiper eggs were also collected as part of this study, but the sample size is limited; 11 eggs were collected, 5 from reference areas, and 6 from 2 different exposed areas (Michel Creek and Fording River). The mean egg selenium concentration (n=5) for Michel Creek was 4.04 µg/g dw (range: 3.7 to 4.6 µg/g dw) which are below toxicity thresholds. At Fording River, only 1 egg was successfully collected, however this egg had a selenium concentration of 13.7 µg/g dw, which exceeds the egg selenium tissue guideline established for bird eggs by the US EPA (US EPA, 2018; ECCC, 2020 (Preliminary Data)).

In addition to the monitoring work completed using dippers and sandpipers, other studies have been undertaken in the Elk Valley to determine the degree to which selenium may be impacting the health of oviparous aquatic-dependent vertebrates. A summary by Chapman et al., (2007) outlines the results generated from studies aimed at evaluating selenium bioaccumulation and various health-related endpoints in fish (longnose sucker, *Catostomus catostomus*; cutthroat trout, *Oncorhyncus clarki lewisi*), amphibians (Columbia spotted frog, *Rana luteiventris*), and marsh birds (redwing blackbird, *Agelaius phoeniceus*). In general, large-scale adverse population-level effects were not obvious, however there were indications that some negative effects were occurring on a localized level (Chapman et al., 2007). For example, selenium concentrations in Columbia spotted frog eggs ranged from 10 to 38 µg/g dw from areas impacted by coal mining and there was a positive relationship between egg selenium burdens and developmental deformities (Elk Valley Selenium Task Force, 2008).

Given the breadth of biomonitoring that has been completed to date in the Elk Valley to address selenium issues associated with mountaintop coal mining, a summary of the work to date may inform the Panel's conclusions.

ECCC Recommendations 4.1

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Update the Wildlife Risk Assessment to include all potential exposure pathways of selenium including dietary uptake from surface water contaminated by leached selenium due to weathering of waste rock piles.
    a) If the revised risk assessment indicates that effects to wildlife receptors are likely, then ECCC recommends that Benga be required to develop and implement mitigation measures to prevent the predicted adverse effects.
2. Implement a Biomonitoring Program to adequately characterize concentrations of COPCs in media at baseline conditions and during operation. The biomonitoring program should:
    a) Include chemicals with the potential to bioaccumulate (including selenium) in the Project study area in both lentic and lotic systems, in water and in aquatic biota (periphyton, invertebrates and vertebrates) as well as in the eggs of different egg-laying aquatic-dependent vertebrates (e.g. fish, birds, amphibians).
    b) Establish site-specific thresholds of selenium in aquatic biota (periphyton, invertebrates and vertebrates) which, when exceeded, would trigger Benga to take actions to adaptively manage and mitigate impacts to aquatic-dependant wildlife.
    c) Be used to update Benga's predicted effects of the Project.

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4.2 Migratory Birds

Introduction and Importance of the Topic to Impact Assessment

Migratory birds, as defined under the *Migratory Birds Convention Act, 1994* (MBCA), represent a broad group of species, including several species listed under the *Species at Risk Act* (SARA). The Project will affect migratory birds and their habitat, primarily those that nest in coniferous and mixedwood forests would likely be the most affected by Project Development.

Habitat destruction resulting from mine construction activities displaces birds from impacted areas, potentially increasing bird densities in nearby undisturbed habitats in the year following disturbance (Schmiegelow et al., 1997). Over the short-term, higher nesting densities in adjacent habitats could result in reduced reproductive success because of increased competition for resources (Flockhart et al., 2016), resulting in a decline in recruitment to the local population. Over the longer-term, loss of forest cover could lead to local population declines, in particular for specialist species who have evolved to occupy a specific habitat (Schmiegelow et al., 1997; Van Wilgenburg et al., 2018). Habitat displacement will result from the Project and therefore, as effects are unavoidable, mitigation measures are required to address the impacts of the Project on migratory birds.

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
- Eleventh Addendum to the Environmental Impact Assessment. (March 19, 2020), (CIAR #313)
    - Response to JRP IR 6.9

Benga's Conclusions

Benga states that the greatest effect of the Project on migratory birds will be direct habitat loss, most of which is expected to be temporary, as disturbed habitats will be reclaimed progressively during Project operations and Project closure. Benga has identified that forest-dwelling migratory bird species, particularly those that nest in coniferous and mixedwood forests would likely be the most affected by the Project (Eleventh Addendum, CIAR #313). Benga states that by year 27 of the Application Case (end of mine life), there will be a 23% reduction in the area of coniferous forest (open pine, open mixed coniferous, moderate mixed coniferous, closed spruce, and closed mixed coniferous habitat types) from 2,832 hectares (ha) to 2,171 ha (661 ha) and a 27% reduction in the area of mixedwood forest (open mixedwood and closed mixedwood habitat types) from 1,282 ha to 937 ha (345 ha).

Based on the assessment of all wildlife Valued Components (VCs), it is expected that the longest lasting impacts will be experienced by bird species requiring old-growth forests for breeding and foraging habitats. The Wildlife Local Study Area contains 169 ha of old growth forest, of which 8.3 ha will be affected, and therefore Benga anticipates the effects of habitat loss to be minimal (Eleventh Addendum, CIAR #313).

Benga also identified that the Project may result in indirect habitat losses from sensory disturbances, such as noise, since some migratory birds may avoid otherwise suitable habitats located close to the Project footprint (Eleventh Addendum, CIAR #313).

Benga has proposed mitigation measures for birds relevant to the reclamation planning. These measures include but are not limited to:

- Vegetation site clearing activities will occur outside the April 15 to August 31 period to avoid disrupting nesting migratory and resident songbirds and raptors. In the event that vegetation clearing must occur within the restricted activity period, pre-disturbance nesting surveys will be conducted by experienced avian biologists according to established sensitive species inventory guidelines;
- Retain slash and large woody debris in the salvaged soil to provide microsites for native plants and hide cover and perches for wildlife; and
- Reclamation will begin as soon as practical after mining activities are completed in areas where no additional mining, dumping or stockpiling is required. Benga anticipates that progressive reclamation of the South Rock Disposal area will begin before year 10 of mining.
- Progressive reclamation, and reclamation of the area to a landscape that includes provisions for a variety of land uses, including forestry, wildlife habitat, grazing, recreational use, etc.
- Monitor changes in land use policies and initiatives and, through adaptive management, incorporate new requirements into the ongoing reclamation plans.
- Ensure reclaimed areas promote the re-establishment of woody species and are on a trajectory for reforestation.
- Preserve remnant forest patches in the development areas to provide essential habitat, habitat connectivity, and hide cover for wildlife species;
- Incorporate the existing legacy mining disturbances into the development and reclamation plans for the project, and other proposed land use activities to the best extent possible so that habitat loss, habitat fragmentation, linear disturbance features, and cumulative habitat loss are minimized.

ECCC's Conclusions

The Project will result in loss of habitat for migratory birds for many years; effects to specific species will vary depending on habitat preferences. While cleared areas may create suitable habitat for some species such as Common Nighthawk, other species will not return to the project area until mature forests are reestablished.

ECCC agrees with Benga's characterization of effects and is supportive of the progressive reclamation activities proposed by Benga, including the restoration of the legacy mine footprint. The mitigation measures proposed by Benga would need to be implemented to reduce Project related effects on birds related to habitat loss. Provided that Benga meets the commitments that they have stated, the effects of the project can be effectively mitigated.

ECCC Recommendations 4.2

Should the Project be approved, ECCC recommends that the Panel request that Benga implement their commitments to:

1. Undertake vegetation and habitat removal and clearing activities outside the nesting season for migratory birds.
2. Undertake progressive reclamation as soon as possible to restore migratory bird habitat, and to undertake monitoring and adaptive management to improve the efficacy of reclamation.

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4.3 Species at Risk

Introduction and Importance of the Topic to Impact Assessment

Provisions of SARA require the Panel, as the federal authority tasked with undertaking the environmental assessment, to ensure that measures are taken to avoid or lessen effects on identified species at risk, and to monitor them. The Panel notified ECCC, pursuant to s.79(1) of SARA, that the Project has the potential to affect nine SARA species. ECCC additionally identified Limber Pine (COSEWIC Endangered) as an affected species. Mining activities will result in the mortality of Whitebark and Limber Pine trees. ECCC has concluded that there are environmental risks to Whitebark Pine and to Limber Pine and is providing comments on the characterization of effects for these species. For the other identified species at risk, mortality risk is low with mitigation, ECCC did not identify any potential critical habitat, avian species have a wide distribution and mitigation measures are well understood. Furthermore, ECCC does not possess expertise on other species that are primarily the management responsibility of the Province of Alberta (e.g., Grizzly Bear); for these species, the Panel is advised to consult Alberta Environment and Parks, Fish and Wildlife Branch for species-specific technical information.

4.3.1 Whitebark Pine

Whitebark Pine (*Pinus albicaulis*) is a five-needled pine tree that is essential to ecosystem functioning in many subalpine and treeline forests. Whitebark Pine occurs in western Canada in high elevation habitat from the United States border northward to Mount Blanchet Park in British Columbia, and Willmore Wilderness Park in Alberta; and from the coastal mountain ranges in the west to the Rocky Mountains of southern Alberta in the east. Whitebark Pine is listed as Endangered on Schedule 1 of SARA. Approximately 56% of the species' global range is in Canada (ECCC, 2017).

Whitebark Pine populations are in decline from blister rust, mountain pine beetle, fire exclusion (the practice of trying to reduce wildfires using fire suppression techniques) and climate change. There are currently about 200 million mature individual Whitebark Pine trees present on the Canadian landscape (ECCC, 2017). However, a 78% population decline is predicted over next 100 years based on current infection and insect infestation rates (Alberta Whitebark and Limber Pine Recovery Team, 2014).

Whitebark Pine recovery is naturally limited by its reliance on the Clark's Nutcracker (*Nucifraga columbiana*), a bird native to mountain ranges in western North America, for seed dispersal to reproduce, and by its long generation time (ECCC, 2017). Once established, it takes between 30-50 years for trees to begin producing cones, and 60-80 years to produce cones in a sizeable quantity (ECCC, 2017). Individuals that are resistant to White Pine Blister Rust are required to sustain the population or improve its abundance in the foreseeable future. Rust resistant mechanisms may be relatively rare among current cone-producing individuals. White Pine Blister Rust alone is projected to lead to a decline in Whitebark Pine of more than 50% over a 100-year time period.

The impacts of Mountain Pine Beetle, altered fire management regimes, and climate change will also increase the rate of decline of this species.

4.3.2 Limber Pine

Limber Pine (*Pinus flexilis*) is a five-needled pine tree, typically 3-15 m tall, and has been assessed by COSEWIC as Endangered. It is not currently listed on Schedule 1 of the SARA, although it is under consideration for future listing. Limber Pine naturally occurs only in western North America, extending from southeastern British Columbia and southwestern Alberta south to northern Arizona and New Mexico, and southern California. In Canada, Limber Pine occurs typically on warm, dry and exposed sites in the lower portions of the mountains and foothills at elevations of 850 m to 1900 m. Some occurrences are as high as 2000 m and may form mixed stands with Whitebark Pine. Limber Pine is a long-lived species, frequently reaching several hundred years of age and trees over 1000 years old are known. Cones are typically produced at about 50 years of age and production is irregular with some years of very low seed production. Seeds are primarily dispersed by birds but also by small mammals. Clark's nutcracker is the primary seed disperser for Limber Pine.

The number of mature Limber Pine trees in Canada is estimated to be 44.4 million. The Canadian population of Limber Pine is declining at an average annual rate of 1% per year. Limber Pine is severely threatened throughout its Canadian range by White Pine Blister Rust, Mountain Pine Beetle, and climate change (Limber Pine COSEWIC Assessment, 2014). Studies in Alberta indicate that most populations of Limber Pine are rapidly declining as a result of mortality from Blister Rust. Blister Rust infection exceeds the rate of Limber Pine recruitment, especially in the southern portion of the Alberta range where the Project is located (Alberta Limber Pine Recovery Plan 2014-2019).

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
  - Section E – Environmental Assessment
    - E.8.2.2
  - Section F – Closure and Reclamation
- Eighth Addendum to the Environmental Impact Assessment (October 24, 2018), (CIAR #89)
  - Part A – CEAA – Appendix A – Conformity IRs
    - CEAA-R2-1 – Clark's Nutcracker CEAA-R2-1 – Clark's Nutcracker
- Tenth Addendum to the Environmental Impact Assessment (September 9, 2019), (CIAR #251)
  - Package 2 – Vegetation and Reclamation

Benga's Conclusions

Whitebark Pine

Benga predicts the project will affect 3.5 percent of Whitebark Pine habitat in the Regional Study Area (RSA) and that the Project will disturb approximately 208.4 ha of Whitebark Pine and open grassland areas containing a sparse Whitebark Pine canopy, for an estimated total of 21,000 Whitebark Pine trees. Benga states that their estimate is intentionally conservative and includes estimates of juvenile trees and seedlings. Benga concluded that, with mitigation, the Project will not result in significant direct effects nor significantly contribute to cumulative effects on this species. In support of this conclusion, Benga stated that, as part of the Closure and Reclamation Plan, it committed to planting three times the number of trees lost due to project

activities and to support the establishment of disease-resistant trees. Tree planting success would further be assured by the application of adaptive management, active participation and engagement with recovery groups, and use of best management practices as they evolve (Eighth Addendum, Part A, CIAR #89).

Benga has stated that it has incorporated the precautionary principal in its reclamation planning to accommodate uncertainty. For instance, Benga proposes to plant 63,000 Whitebark Pine seedlings, or roughly three times the conservative pre-disturbance number to account for planting and natural mortality, reclamation of historical mine areas, and future losses. Benga estimates that the reclaimed area dedicated to Whitebark and Limber Pine species will be 310 ha (approximately 102 ha more than the estimated loss) (Eighth Addendum, Part A, CIAR #89).

Although the loss of Whitebark Pine from development of the Project will incrementally contribute to loss of Whitebark Pine foraging habitat (for Clark's Nutcracker) in the Rocky Mountain Region for an extended period of time, these losses are predicted to be very low in relation to the amount of Whitebark Pine habitat in the RSA (3.5% of habitat in the RSA) and in the Rocky Mountain Region of Alberta (0.07% of the Alberta total of mature trees).

Limber Pine

In the Eighth Addendum (page 20, CIAR #89) Benga states that:

> *The status of Limber Pine in Alberta is even less well known than Whitebark Pine (Whitebark and Limber Pine Recovery Team 2014b). Estimates of the population of mature (DBH >10 cm) trees range from 1,940,000 (Achuff, personal communication cited in Alberta Whitebark and Limber Pine Recovery Team 2014b) to 44,400,000 (Alberta Sustainable Resource Development and Alberta Conservation Association 2007b). Based on the more conservative estimate of 1,940,000 trees, the estimated loss of 1,000 Limber Pines from development of the Grassy Mountain Project could represent 0.05% of the provincial total.*

Benga has estimated that the proposed Project would disturb approximately 1,000 Limber Pine trees. Benga concluded that, with mitigation, the Project will result in Project effects and cumulative effects on these species that are not significant. In support of this conclusion and to mitigate effects Benga stated that, as part of the closure and reclamation plan, three times the number of Whitebark Pine and Limber Pine trees removed from project operations will be planted to support establishment of disease resistant trees. Tree planting success would further be assured by application of adaptive management, active participation and engagement with recovery groups, and use of best management practices as they evolve (EIA, Section E, CIAR #42)

ECCC's Conclusions

The mine will affect Whitebark Pine and Limber Pine populations at the local level for 30 or more years. ECCC is in agreement with Benga's intent to undertake progressive reclamation of the mine site, and is supportive of its plan to replant with Blister Rust Resistant trees, as this may be beneficial to Whitebark Pine and Limber Pine populations in the long term at a local level.

ECCC Recommendation 4.3

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Replant three blister rust resistant seedlings for each Whitebark Pine tree and Limber Pine tree destroyed by the Project, and to monitor and apply adaptive management where required to ensure seedlings are established and on a trajectory to becoming mature trees.

Literature Cited

Alberta Whitebark and Limber Pine Recovery Team. (2014). Alberta Whitebark Pine Recovery Plan 2013-2018. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 34. Edmonton, AB. 63 pp

Alberta Whitebark and Limber Pine Recovery Team. (2014). Alberta Limber Pine Recovery Plan 2014-2019. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 35. Edmonton, AB. 61 pp.

COSEWIC. (2014). COSEWIC Assessment and Status Report on the Limber Pine *Pinus flexilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 49 pp. www.restrelep-sararegistry.gc.ca/default_e.cfm

[ECCC] Environment and Climate Change Canada. (2017). Recovery Strategy for the Whitebark Pine (*Pinus albicaulis*) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. viii + 54 pp.

CHAPTER 5 – Freshwater Environment

5.1 Impact of Selenium on Aquatic Organisms and the use of Environmental Quality Guidelines for the Protection of Aquatic Life

Introduction and Importance of the Topic to Impact Assessment

Selenium is an essential micronutrient taken up by aquatic, soil- and sediment-dwelling organisms, through diet or via direct contact with the environment. Selenium bioavailability varies widely with environmental conditions, especially in aquatic ecosystems. In fish, excess selenium may accumulate in fish eggs and affect developing embryos and larvae, while adults appear to be less affected. There is potential for adverse effects to the aquatic organisms exposed to selenium concentrations in excess of environmental quality guidelines; such effects are long-term, persistent, and observable at the population level. The most severe effect resulting from long-term exposure to elevated concentrations of selenium in the food web is reproductive failure in egg-laying vertebrates (fish, waterbirds and amphibians).

During coal mining operations, waste water is produced when precipitation comes in contact with waste rock and from other coal mining operations, such as the coal wash plant, loadout, and water collected from active mine faces ('contact water'). Contact water is naturally rich in selenium due to the coexistence of the element in coal mineral ores, and release of selenium when coal-bearing rocks are extracted and weathered. Contact water containing soluble selenium will be discharged into Blairmore Creek and may also leach into both Blairmore and Gold creeks. Both creeks are tributaries of the Crowsnest River, which joins the Oldman River and reservoir, eventually joining with the Bow River to become the South Saskatchewan River in southeastern Alberta.

The presence of sulphate in water reduces uptake of selenium by primary producers (typically periphytic algae in lotic systems) while the uptake of selenium at higher trophic levels (i.e. benthic invertebrates and fish) is dietary and is virtually unaffected by sulphate. Uptake of selenium into algae is the rate-limiting step affecting selenium accumulation throughout the aquatic ecosystem. As such, understanding how site-specific conditions, (such as local water quality, including sulphate concentrations), affect uptake of selenium into algae provides a foundation for determining safe selenium concentration thresholds to protect local aquatic biota.

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
  - Section A – Project Introduction
    - 10.5 Surface Water Quality
    - 11.5 Water Quality
  - Consultant Report #5 –Water Quality (CR #5)
- Fifth Addendum to the Environmental Impact Assessment. (February 28, 2018), (CIAR #69)
  - AER-R1-108 Site-specific selenium guidelines
- Eighth Addendum to the Environmental Impact Assessment. (October 24, 2018), (CIAR #89)
  - Part C – AER Round 2 – Technical IRS

        - AER-R2-29 Sulphate, selenium, metals risk-based evaluation
        - Appendix C-3: Risk-Based Evaluation of Predicted Selenium, Sulphate & Metals
- Tenth Addendum to the Environmental Impact Assessment (September 9, 2019), (CIAR #251)
    - Package 5: Surface Water Quality, Hydrology, Hydrogeology, Fish and Fish Habitat, Cumulative Effects, Geotechnical, Reclamation, Wildlife, Land Use and EA Methodology
        - JRP IR-5.7 Selenium bioaccumulation model
        - JRP IR-5.8 Selenium at discharge points
        - JRP IR-5.9 Sulphate, hardness, synergistic effects, selenium
        - JRP IR-5.10 Sulphate site specific guidelines, toxicity studies
- Eleventh Addendum to the Environmental Impact Assessment (March 19, 2020), (CIAR #313)
    - JRP IR-6.16 Site-specific selenium guideline, sulphate, seasonal variation
    - JRP IR-6.23; Appendix 6.23-1 Draft Aquatic Monitoring Plan, adaptive management
- Government of Canada, re: Comments on the Grassy Mountain Coal Project Environmental Impact Assessment and Addenda (January 21, 2019), (CIAR #167)
    - Environment and Climate Change Canada's Technical Review of Addendum Eight
        - Technical Supplementary Information Requests (SIRs) and Outstanding Conformity IRs
        - IR 7 Risk Assessment

Benga's Conclusions

Benga has proposed a 15 µg/L site-specific water quality objective (SSWQO) for selenium that reflects uptake of selenium in the aquatic receiving environment. The SSWQO was derived from a pre-operational site specific risk assessment. The risk assessment incorporates the use of sequential modelling and the application of adjustment factors to derive the water quality objectives. These include:

1) A food-web to model the accumulation of selenium;

2) Application of a mitigation factor to relate sulphate concentration to the bioavailability of selenate based on DeForest et al. (2017); and

3) A species-specific estimate of fish egg selenium concentration derived from the concentration of selenium in the whole fish body (using US EPA, 2016).

Food-web model

The food web model described in the Eighth Addendum (Appendix C-3, CIAR #89) is based on the methodology developed by Presser and Luoma (2010). This approach estimates bioavailability of selenium for primary producers (algae) and subsequent bioaccumulation of selenium at each step of the food chain. The model methodology referenced does not distinguish between selenate and selenite in surface water, but encompass it within the calculation of bioavailability to primary producers. At lower trophic levels, selenite is absorbed more easily by primary producers such as periphyton and algae, resulting in increased rates of biomagnification of selenium in the food chain to the upper trophic level organisms.

The receiving environment where the effluent will be discharged is a lotic environment, flowing water, as opposed to a lentic, a still water environment. Benga's conclusions are based on the assumption that selenate is the dominant form of soluble selenium in lotic watercourses, however they did not provide site-specific analytical data for selenium speciation to validate the assumption. Benga concludes that selenate will be the only form of soluble selenium present in well-oxygenated watercourses during and post operations.

Application of a mitigation factor for sulphate

DeForest et al. (2017) recently published a methodology for deriving sulphate-based waterborne selenium guidelines for lotic (selenate-dominated) streams. Benga's proposed SSWQO incorporates this method to adjust the guideline based on sulphate amelioration of selenium bioavailability in lotic environments. Gold Creek and Blairmore Creek are lotic, well-oxygenated watercourses throughout the year (at least 9 mg/L dissolved oxygen).

Benga asserts that sulphate impedes selenium uptake in primary producers, which would subsequently reduce total uptake of selenium at each step of the food chain.

ECCC requested that Benga conduct an alternative risk assessment for selenium in the absence of sulphate as a toxicity modifying factor (Government of Canada, ECCC, IR 7, CIAR #167). In their response (Tenth Addendum, Package 5, CIAR #251), Benga indicated that it was entirely appropriate to apply a mitigation factor based on sulphate in the risk assessment, stating that sulphate mitigation of selenate uptake by algae has been known for decades, and that exclusion of sulphate mitigation in selenium guidelines is overprotective, the result of inadequately paired data, or due to the lag time for regulations to catch up with science.

Benga measured selenium concentrations at all nodes in Blairmore Creek and found them below the British Columbia and Alberta guidelines of 2 µg/L. Benga predicts that, a few years following mine operations, selenium concentrations will exceed the provincial threshold in Blairmore Creek but will remain below Benga's proposed SSWQO for selenium. All nodes in Gold Creek (which will not receive effluent discharges, unless additional mitigation measures for selenium attenuation are necessary) are predicted to remain below a selenium concentration of 2 µg/L in all mine phases due to proposed mitigation measures.

ECCC's Conclusions

ECCC is of the opinion that the SSWQO developed by Benga, which has been derived using pre-mining (baseline) conditions, contains several assumptions which decrease confidence in the degree of protection to aquatic organisms that the Objective can achieve. While ECCC does not object to the derivation of site-specific environmental quality guidelines, in this instance the site-specific risk assessment and its derived SSWQO may not accurately characterize the risk to receptors from exposure to selenium during and following mine operations.

ECCC has maintained throughout the environmental assessment the importance of determining the selenium form (selenate or selenite) that will be available to receptors in holding ponds and in Blairmore Creek. Different selenium species have different behaviours in the environment, different toxicity, and different bioavailability and bioaccumulation effects. To propose an appropriate site-specific water quality criterion for selenium, it is therefore essential to know what soluble form of selenium will be released, selenate or selenite, and in what proportions.

ECCC's critique of the methods used to derive the selenium SSWQO are described below.

Food Web Model

The uptake of selenium through the food chain into reproductive tissues of aquatic species is highly variable. Several factors play a role in selenium uptake, including water chemistry and differences in bioavailability of selenium species, influenced by the exposure of selenium to fish in lotic (flowing fresh water) versus lentic (still fresh water) environments. The varying rate of selenium uptake into aquatic ecosystems must be considered when predicting effects, and must be treated with sophistication when models are relied upon to inform risk assessments and site specific environmental criteria.

Predicting the effects of selenium in an ecosystem can be achieved using Presser and Luoma's (2010) approach. This approach considers selenium uptake from water and through the food-web, but only if initial conditions, and in particular the selenium speciation, remain consistent between the time when the assessment is performed, during mine operations, and after closure. The food-web models used by Benga to predict the bioaccumulation of selenium are based on pre-mining (baseline) conditions in the watershed, which would likely favor the presence of selenate over more anoxic forms. The ratio of selenate: selenite affects the model's enrichment factor, which is a measure of the bioavailability to primary receptors (algae, periphyton). The enrichment factor describes a critical step in food web modelling.

Consequently, ECCC is of the opinion that the enrichment factor calculated in Blairmore Creek will not remain the same once operations begin compared to the enrichment factor that would apply for modeled pre-operation estimates. The selenate:selenite ratio has not been demonstrated, estimated or modelled for the Baseline or Application Case, and therefore all modeled estimates of selenium movement through the food web for the Project's operation and closure phases are based on the assumption, which has not been demonstrated, that selenate will be the sole soluble selenium species present in the impacted watercourses once the Project is operational.

It is ECCC's position that basing the food web models on pre-mining conditions, and assuming that selenium will be in the form of selenate underestimates the exposure and bioavailability assumptions applied in the model.

Application of a Mitigation Factor for Sulphate.

The assumption put forward by Benga is that the proposed sulphate adjustment is valid for the Project, since the selenium will be released into well-oxygenated lotic receiving waters, and would therefore be in the form of selenate. ECCC maintains that this is an erroneous mass flow analysis of selenium releases and of the behavior of selenium in the environment. It is expected that, following treatment in the backfill pond, anoxic conditions will favor the reduction of selenate to selenite. Selenite will not be transformed into selenate upon contact with water in the receiving environment. Therfore, the assumption that selenate will be the sole soluble selenium species present in the impacted watercourses once the Project is operational has not been demonstrated. If selenite is also found in the mine effluent and in receiving watercourses following the beginning of the mine operations, it would invalidate the premise of a sulphate-mitigated effect on selenium uptake.

Sulphate mitigates selenate because it competes with selenate for absorption into primary producers, however sulphate has no effect on the absorption of selenite. There is no relationship between the selenium speciation in watercourses for pre-mining conditions (e.g. baseline conditions) and selenium speciation in the same watercourse following releases from the mine. Upon release into the environment, selenite may be transformed into selenate under favorable conditions, but this process is very slow (months to years).

A sulphate-adjusted guideline for selenate is based on sound science, since sulphate and selenate compete for the same active (saturable, energy-requiring) transporter in algae (likely by a sulphate carrier, although the mechanism has not yet been fully described). In contrast, selenite uptake by primary producers is an unregulated, passive process. Because of this difference in sulphate-regulated uptake for selenate and selenite, Canada's "Screening Assessment of Selenium and its Compounds" (ECCC, 2017) did not recommend sulphate-based site-specific predicted no-effects concentrations (PNECs). To ECCC's knowledge, currently there is no known domestic or international guideline that employs sulphate-adjusted guidelines, criteria, or trigger values for adaptive management.

If selenite is present in the mine effluent and in receiving watercourses following the beginning of the mine operations, it would invalidate the premise of a sulphate-mitigated effect on selenium uptake, and is therefore not a strong rationale upon which to base the SSWQO.

Species-specific estimate of fish egg selenium concentration.

The third step described by Benga in their development of the SSWQO for selenium involves estimating fish-egg selenium concentrations from concentrations in the whole fish body, per US EPA 2016. This approach is not problematic in itself, but it should be noted that the application of a third model, using input data which was modelled itself, and based on assumptions that are problematic for the reasons described above, increases the inherent uncertainty in the SSWQO. All modelling methodologies have a certain degree of uncertainty associated with them even when using the best input data. As several models have been used for the risk assessment and to derive the SSWQO, and given the uncertainty introduced by the input variable to the models (due to assumptions about selenium speciation during and following mine operations), the overall model uncertainty is even greater and compounded at each step of the analysis.

The effect of the Project on surface water quality is a driving consideration for the environmental assessment, and therefore, a high degree of confidence in the proposed water quality objectives must be established. If the Panel determines that an existing provincial or federal guideline should be applied in order to have more confidence in the water quality objectives, ECCC notes that this should preclude the use of US EPA guidelines (US EPA 2016) which are based on a food web-based approach developed primarily in warmer waters and the DeForest et al. (2017) paper which utilizes a fish egg selenium guideline of 20 µg/g dw and which excluded the more sensitive white sturgeon data (15.6 µg/g). In 2018, Alberta Environment and Parks (AEP) adopted British Columbia's 2014 (Government of Alberta, 2018; BC MOE, 2014) surface water quality guidelines for selenium for the protection of aquatic life. These provincial water quality guidelines propose an "alert" selenium concentration of 1 µg/L, a water quality guideline of 2 µg/L, a whole-body fish tissue concentration of 4µg/g dw, and an egg/ovary guideline of 11 µg/g dw. "Alert" concentrations trigger monitoring activities.

Field studies conducted in Canada and other regions of North America have demonstrated the reproductive effects of selenium on birds and fish when present at sufficiently high concentrations in the food web, as well as possible impacts on fish populations and biodiversity. Based on long-term effects on egg-laying vertebrates, bioaccumulation potential and persistence of selenium in the environment, it is essential to use protective surface water quality guidelines and to establish a preventive monitoring plan that will alert the authorities at an early stage of contamination. Surface water monitoring programs should measure selenium concentrations in fish reproductive tissues in addition to surface water, and aquatic health monitoring should occur at the same locations as water quality stations for the purpose of making a direct comparison, and should include water, sediments, invertebrates, fish muscle tissue, fish whole-body, and fish egg/ovary sampling from distinct habitat units (e.g., lentic/lotic, overwintering habitat, deeper ponds, etc.) and locations that are consistent between the predictions and baseline modelling. These actions will assist Benga to prevent irreversible impacts on the ecosystem.

ECCC Recommendations 5.1

Should the Project be approved ECCC recommends that the Panel request that Benga:

1. Reconsider the risk assessment methodology to:
    a) Exclude the application of a mitigation factor for sulphate, consistent with ECCC's Screening Assessment of Selenium and its Compounds (2017).
    b) Reflect exposure scenarios that are based on operational (not baseline) selenate:selenite ratios, especially in the determination of enrichment factors to predict bioaccumulation in food-web models.
2. Implement a Biomonitoring Program to adequately characterize concentrations of selenium in Blairmore and Gold Creeks at baseline conditions and during operation. The biomonitoring program should:
    a) Measure all selenium species' concentrations in mine effluent discharged to the receiving environment in water and in aquatic biota (periphyton, invertebrates and vertebrates) as well as in fish eggs and fish ovaries.
    b) Specify what would trigger Benga to take actions to adaptively manage and mitigate impacts to water quality.
    c) Be used to update Benga's predicted effects of the Project.

Notwithstanding the recommendations in 5.1 above, the deposit of a deleterious substance to water frequented by fish constitutes a violation of the *Fisheries Act* except where federal regulations under subsection 36(5) of the Act apply.

Literature Cited

Government of Alberta. (2018). Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Alberta Environment and Parks. Edmonton, AB.

[BC MOE] British Columbia Ministry of Environment, Beatty, J.M, & Russo, G.A. (2014). Ambient Water Quality Guidelines for Selenium. Technical Report Update. Water Protection and Sustainability Branch. Environmental Sustainability and Strategic Policy Division, British Columbia Ministry of Environment. 270 pp.

DeForest, D.K., Brix, K.V., Elphick, J.R., Rickwood, C.J., deBruyn, A.M.H., Tear, L.M., Gilron, G., Hughes, S.A., & Adams, W.J. (2017). Lentic, lotic, and sulfate-dependent waterborne selenium screening guidelines for freshwater systems. *Environ Toxicol Chem* 36(9), 2503-2513.

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CHAPTER 6 – Air Emissions and Greenhouse Gases

6.1 Baseline Air Quality Assessment and Nitrogen Oxide Emissions

Introduction and Importance of the Topic to Impact Assessment

The proposed Project is expected to contribute to air pollutants in the Crowsnest Pass region. Several communities are in close proximity to the Project; the towns of Blairmore and Coleman are both within 4 km of the Project boundary. Annual emissions from the mine (based on Benga's estimates for year 19) include 929 tonnes of nitrogen oxides (NO_x) and 114 tonnes of particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). The primary sources of these pollutants will be diesel powered off-road vehicles and blasting.

To estimate the potential impact of air pollutants on nearby residents, dispersion modelling is typically conducted to predict airborne pollutant concentrations. A key component of dispersion modelling is the baseline assessment – an estimate of background pollutant concentrations in the region in the absence of the proposed Project. To properly assess the Project's contribution to air pollutants and predicted effects, it is critical that baseline concentrations be accurate and reflect pre-project ambient concentrations. Representative baseline data is important as it allows modelled concentrations of air pollutants to be compared with monitored concentrations, should the Project proceed.

Air pollutant emissions from the proposed Project have the potential to degrade air quality in the surrounding region. Any potential increases in the concentrations of key non-threshold air pollutants, such as NO_2 and $PM_{2.5}$, have the potential to adversely affect human health and the environment in the surrounding area. The Panel may refer to Health Canada's submission for information on health effects of NO_2 and $PM_{2.5}$.

Canadian Ambient Air Quality Standards

Federal, provincial and territorial governments are working collaboratively to improve air quality through the implementation of the Air Quality Management System (AQMS) (CCME, 2017). The Canadian Ambient Air Quality Standards (CAAQS) are a key element of the AQMS. For some criteria air contaminants (CACs), namely nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and $PM_{2.5}$, ECCC has considered Benga's predictions in comparison to the CAAQS. The CAAQS are based on the principles of "keeping clean areas clean" and "continuous improvement." CAAQS are reviewed every five years using the most recent scientific information about the effects of pollutants to ensure they are stringent enough to protect human health and the environment. The CAAQS are supported by air quality management levels, which call for progressively more rigorous actions by jurisdictions as air quality approaches or exceeds the CAAQS, ensuring that the CAAQS are not "pollute-up-to" levels. The CAAQS are not intended to be used as an enforceable standard at the Project perimeter. However, ECCC relies on the comparison of predicted Project concentrations to the CAAQS to determine the nature and magnitude of the Project's impact on air quality levels, and the resulting monitoring and mitigation measures that may be required to maintain good air quality levels.

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
  - Consultant Report #1 – Air Quality and Climate (CR #1)
- Eighth Addendum to the Environmental Impact Assessment (October 24, 2018), (CIAR #89)
  - Part A – CEAA – Appendix A – Conformity IRs
  - Part B – Technical IRs
    - ECCC-R2-5 – Particulate Matter
    - ECCC-R2-6 – Nitrogen Dioxide
    - ECCC-R2-7 – Canadian Ambient Air Quality Objectives
- Tenth Addendum to the Environmental Impact Assessment (September 9, 2019), (CIAR #251)
  - Package 1 – Air Quality and Noise
    - JRP IR-1.6
    - Appendix 1.3-1 Draft Air Quality Monitoring and Adaptive Management Plan
- Government of Canada, re: Comments on the Grassy Mountain Coal Project Environmental Impact Assessment and Addenda (January 21, 2019), (CIAR #167)
  - Environment and Climate Change Canada's Technical Review of Addendum Eight
    - Technical Supplementary Information Requests (SIRs) and Outstanding Conformity IRs
- Government of Canada, re: Comments on the Grassy Mountain Coal Project (October 24, 2019), (CIAR #283)
  - Environment and Climate Change Canada's Proposed Information Requests on the Sufficiency and Technical Merit of the Ninth and Tenth Addendum
    - IR 2 – Nitrogen Dioxide Concentrations
- Osler, Hoskin & Harcourt LLP (Benga) - Comments on Sufficiency (October 31, 2019), (CIAR #291)
  - Environment and Climate Change Canada's Proposed Information Requests on the Sufficiency and Technical Merit of the Ninth and Tenth Addendum

Benga's Conclusions

Benga conducted dispersion modelling to assess impacts to air quality as a result of the Project, providing predicted pollutant concentrations for both baseline and application scenarios. Baseline concentrations were estimated by modelling community emissions, emissions from Highway 3, and rail line emissions (Benga's assessment involved adding the above-noted modelled concentrations to background concentrations to determine final predicted concentrations). Benga's background concentrations were taken from a monitoring station within the City of Lethbridge (located 117 km away), and were not based on local monitoring.

Benga provided updated Baseline and Application Case predictions for particulate matter ($PM_{2.5}$ and total suspended particulate (TSP)) and NO_2 in the Eighth Addendum (CIAR #89), responses to ECCC-R2-5 and ECCC-R2-6, respectively. Modeled NO_2 predictions exceeded the 1 hr CAAQS in 9 of 14 discrete receptors. In response to Information Request (IR) 1.6 (Tenth Addendum, CIAR #251), Benga noted that high baseline values accounted for a large proportion of the resulting pollutant levels. Indeed, most of the exceedances of the CAAQS also

occurred at these receptors under baseline conditions. Benga provided several explanations for the high baseline values, including:

- The use of monitoring data from Lethbridge, a community with a much larger population (and corresponding pollutant emissions), as background concentrations
- Inaccuracies in modelling mobile sources as fixed area or volume sources, and modelling near roadways and rail lines, resulting in over predictions.
- Receptors placed inside area sources (representing community emission sources) contributing to prediction uncertainty.

Benga also acknowledged in their response that "model predictions may overstate guideline exceedances" and that baseline predictions "overestimate expected concentrations." In Benga's October 31, 2019 letter (CIAR #291) to the Impact Assessment Agency of Canada, (Grassy Mountain Coal Project Comments on Sufficiency), Benga responded to ECCC's request for new baseline modelling, stating:

> *"Benga agrees that remodeling of community and transport emissions, and a reassessment of predictions near these sources, may result in less conservative predictions and lead to an understanding of source contribution. To this end, Benga has installed an air monitoring station in Blairmore near Highway 3; however, the period of record is currently limited. However, it is important to note that Project predictions will not change as a result of this additional data, and it is not expected to change the results of the submitted Air Quality Assessment. The exercise would only result in a more refined assessment, which Benga has committed to doing once sufficient baseline data is available from Benga monitoring station."*

In Benga's draft Air Quality Monitoring and Adaptive Management Plan (Tenth Addendum, Appendix 1.3-1, CIAR #251), Benga committed to monitoring NO_x concentrations near the plant and loadout areas, with the target of meeting CAAQS and the Alberta Ambient Air Quality Objectives (AAAQO) (Government of Alberta, 2019). Benga also committed to mitigation measures to reduce nitrogen oxide emissions, including using Tier IV compliant haul trucks, regularly upgrading the fleet, and investigating alternative blasting agent formulations with lower NO_x production.

ECCC's Conclusions

Model predictions for the Baseline and Application Cases

ECCC agrees that the predicted concentrations of some air pollutants associated with the Project, particularly NO_2, are not underestimated, and can be considered conservative. However, ECCC is of the view that the degree to which pollutant concentrations in the baseline assessment are overestimated is so great that they restrict the ability for reviewers to adequately assess the impact of the Project on the region's air quality. As noted in ECCC's IR-2 (Government of Canada, ECCC, CIAR #283), Benga's baseline assessment showed 98th percentile daily maximum 1-hour concentrations of NO_2 to be as high as 118 $\mu g/m^3$ within the town of Blairmore, and 121 $\mu g/m^3$ under the Application Case scenario. These baseline NO_2 concentrations are greater than those of the densest and most polluted urban areas in Canada and are not representative of pollutant levels in a rural community – and therefore likely

represent an error considering that pollutant levels in the Crowsnest Pass Region are expected to be low.

Benga noted that the tendency for the predictions to be conservative is consistent with the precautionary principle. However, ECCC is of the view that the errors identified above in the modelling can undermine the credibility of Benga's modelling results. When predicted concentrations are excessively high, the true extent of guideline exceedances is obscured and becomes effectively unknown. Given the rural nature of the community, it is highly improbable that 9 of the 14 discrete receptors would have true baseline concentrations that are above the 1-hour CAAQS for NO_2. While Benga has stated that the Project's contribution to elevated NO_2 concentrations at key receptors is low, they have not provided adequate evidence to demonstrate this low additive contribution. In their response to IR 1.6 (Tenth Addendum, CIAR #251), Benga arithmetically subtracted "98th Percentile Daily Peak 1-hour Concentrations" as the Application Case minus the Baseline Case, to calculate the Project contribution. The "98th percentile" statistical metric is based on specific high-percentile hours throughout the year. When this metric is calculated for different modelling scenarios, they are based on different individual hours, and should not be subtracted arithmetically. Thus, the true Project contribution to pollutant levels as well as the extent of guideline exceedances at these receptors remain unknown.

Furthermore, without representative Baseline and Application Case modelled concentrations, monitored pollutant concentrations will not have valid predictions for comparison. To resolve this, ECCC recommends that Benga undertake additional modelling to obtain new predictions of NO_2 and $PM_{2.5}$. ECCC is aware that Benga has recently commenced regional air pollution monitoring (CIAR #291). ECCC recommends that such monitoring be carried out for a minimum of one year before incorporating these results into a re-run of the dispersion model; this will minimize sources of error previously identified (i.e. biases due to imprecise application of source types such as road and community emissions).

Mitigation and Adaptive Management of air emissions

In Benga's draft Air Quality Monitoring and Adaptive Management Plan (Tenth Addendum, Appendix 1.3-1, CIAR #251), Benga established targets for the management of $PM_{2.5}$ and NO_x emissions, applying the CAAQS and AAAQOs as triggers (i.e. monitoring results that trigger enhanced mitigation measures) for these respective pollutants. Benga further clarified that refinement and optimization of the adaptive management process would be undertaken. ECCC recommends that the results of a baseline monitoring study and new modelling study, as described in the previous section, be considered when selecting trigger values rather than using the CAAQS and the AAAQOs as triggers, which could result in these standards being used as "pollute-up-to" levels.

Given the uncertainty in model predictions, and the potential for pollutant emissions from the Project to raise concentrations within nearby communities, mitigation measures to reduce NO_X and $PM_{2.5}$ from sources including off-road vehicles and blasting are recommended. Benga has confirmed that all major mining equipment will be Tier 4 compliant for the commencement of mining operations (CIAR #291). In addition, ECCC recommends that Benga implement a retrofit and replacement schedule for the mine fleet to ensure that lower emitting off-road vehicles are adopted as they become available. Further, ECCC acknowledges Benga's commitment to investigate alternative blasting formulations to reduce NO_X emissions.

ECCC Recommendations 6.1

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Conduct monitoring of air pollutant concentrations within the towns of Blairmore or Coleman for a minimum of one year to establish a baseline assessment of NO_2 and $PM_{2.5}$ which is representative of the Crowsnest Pass communities. Baseline monitoring should be conducted prior to the Project's commencement.
2. Re-model regional air pollutants, incorporating the baseline monitoring results (using data generated from recommendation 6.1.1), to produce new predictions of NO_2 and $PM_{2.5}$, based on Year 19 of the Project. The revised model should be conducted in a way that minimizes the sources of error previously identified (i.e. biases due to imprecise application of source types such as road and community emissions).
3. Establish adaptive management of air pollution which incorporates the results of the baseline assessment and model predictions described in 6.1.1 and 6.1.2; trigger values for adaptive management should be selected based on the principles of "keeping clean areas clean" and "continuous improvement." Hence, trigger values should be lower than the Canadian Ambient Air Quality Standards (CAAQS) and selected to ensure low air pollutant concentrations in the region are maintained.
4. Implement measures to control emissions of nitrogen oxides from the mine. These include:
    a) Implement a retrofit and replacement schedule demonstrating off-road equipment conversion to best-in-class technology, starting with final Tier IV engines, with new engines meeting the Off-Road Compression Ignition Engine Emission Regulations (under the *Canadian Environmental Protection Act*, 1999);
    b) Not remove emission control technologies from off-road equipment;
    c) Implement an emission control technology maintenance program, which may include combined use of individual vehicle fuel usage indicators, vehicle emission testing, and electronic diagnosis techniques to trigger maintenance: and
    d) Provide employee training on minimizing off-road equipment idling and the importance of avoiding tampering with emissions control systems.
5. Investigate alternative blasting agent formulations with lower emissions of nitrogen oxides (NO_x).

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6.2 Fugitive Dust Emissions

Introduction and Importance of the Topic to Impact Assessment

Fugitive dust from coal mining has the potential to adversely affect human health and the environment through various pathways. Fugitive dust is generally described as particulate matter of varying sizes, measured as $PM_{2.5}$, particulate matter less than 10 microns in diameter (PM_{10}), and TSP. For the proposed Project, sources of this particulate matter include unpaved haul road activity, material disposal, waste removal, blasting, and dust emissions from open rail cars.

Dust emissions from coal mines have the potential to create nuisance and safety concerns, as well as possible impacts to human and ecological health (OEA 2015). Dust emissions from existing mines are a source of continuing concern to communities near the mines themselves, as well as those along rail corridors where the coal is transported (e.g. Teck, 2019).

Sources of Information

- Sixth Addendum to the Environmental Impact Assessment (April 30, 2018), (CIAR #70)
  - ECCC SIR 12 – Adequacy Modelling Inputs
  - ECCC SIR 13 – Accounting for Fugitive Dust
- Eighth Addendum to the Environmental Impact Assessment (October 24, 2018), (CIAR #89)
  - Part B – CEAA - Appendix B - Technical IRs
    - ECCC-R2-5 – Particulate Matter
    - ECCC-R2-6 – Nitrogen Dioxide
    - ECCC-R2-7 – Canadian Ambient Air Quality Objectives
- Tenth Addendum to the Environmental Impact Assessment (September 9, 2019), (CIAR #251)
  - Package 1 – Air Quality and Noise
    - IR 1.1
    - IR 1.4
    - IR 1.7

Benga's Conclusions

In their air quality assessment, Benga estimated emissions from numerous sources of fugitive dust, and provided the results of a dispersion modelling exercise which produced predicted concentrations of $PM_{2.5}$, PM_{10}, TSP, and deposition of particulate in the region surrounding the proposed mine. Benga also provided details of planned mitigation measures to control dust. This includes covered conveyors to transport coal, full cladding on the load-out structure, speed limits, watering of haul roads and a latex binder solution to be sprayed on top of coal prior to rail transport.

<u>Haul road emissions</u>

Benga's air quality assessment assumed a control efficiency (CE) of 80% for road watering of haul roads – meaning that the mitigation measure would reduce fugitive dust emissions by 80% in comparison to emissions from untreated roads. In response to ECCC's questions regarding

the efficacy of road watering, Benga cited studies summarized by the US EPA (1998) which showed median emission reductions of 79%, 91%, and 81% for $PM_{2.5}$, PM_{10}, and TSP, respectively. As a follow-up in their Eighth Addendum (ECCC-R2-5, CIAR #89), and Tenth Addendum (Package 1, IR 1.4, CIAR #251), Benga provided modelling results for an alternative 50% CE haul road dust mitigation scenario. Benga demonstrated that haul road activity was the dominant source of particulate matter from the project, accounting for 91% of maximum daily $PM_{2.5}$ emissions under this scenario. Model results (Eighth Addendum, ECCC-R2-5, CIAR #89) showed a minor (but not negligible) project contribution of particulate matter and no exceedances of applicable $PM_{2.5}$ and TSP deposition standards for receptors far from the mine permit boundary (within the towns of Blairmore, Coleman, etc.). For some receptors within, and close to, the mine permit boundary, TSP deposition rates and concentrations of $PM_{2.5}$ increased appreciably as a result of project activities. Under the worst case, predicted 98th percentile 24-hour $PM_{2.5}$ concentrations nearly doubling for residential receptor R10 (under a 50% CE scenario). Benga noted that the 50% CE was provided as an example only, and that it is "committed to its target of 80% reduction in dust emissions from treated surfaces."

Emissions of coal dust from open rail cars

Benga indicated that coal from the Project (14,000 tonnes annually) will be transported by rail cars, which will remain uncovered for the 1100 km from Blairmore to Westshore Terminals in Vancouver. To mitigate fugitive dust emissions from open rail cars, Benga indicated that it will spray the coal surface of each car with Envirobind DCT, a latex binder solution. In response to inquiries regarding the effectiveness of this approach (Tenth Addendum, Package 1, IR 1.1, CIAR #251), Benga provided the results of laboratory experiments of Envirobind designed to simulate field conditions, through vibration and wind tunnel tests. Benga estimated the total loss of coal (emitted as fugitive dust) to be 0.09% along the rail line to port with the use of the latex binder solution. In their response to IR 1.7 (Tenth Addendum, Package 1, CIAR #251), Benga calculated that 3420 tonnes of coal dust would be emitted from rail cars annually and ultimately released to air, water and soil along the corridor. Benga calculated a 30-day deposition rate of 26 mg/100 cm^2, assuming that all dust would be evenly distributed along the 1100 km corridor within 50 m of the rail line. This deposition rate was then (favourably) compared to the 30-day Alberta deposition guideline of 53 mg/100 cm^2 for residential and recreation areas.

To monitor dust emissions from rail transport, Benga proposed continuous particulate monitoring on select rail cars, cameras on rail cars and at port to monitor visible dust, correlation of dust measurements with geographic features and wind measurements to identify problem areas. Benga has proposed that application of the latex binder at the loadout will be sufficient to reduce fugitive dust emissions and have not proposed alternative mitigation measures.

ECCC's Conclusions

Haul road emissions

While Benga provided updated predictions at 50% CE, as described above, it stated that 80% CE would be achievable, based on studies cited by the US EPA (1998). ECCC notes that use of an 80% CE in the model requires the assumption that this level of mitigation is achieved, throughout the year as a minimum (not average) level of mitigation. The CAAQS for $PM_{2.5}$ (24 hour) is based on the 98th percentile of 24 hour averages of 1 hour concentrations. This metric is sensitive to short term high concentration events, which may occur when dust mitigation

effectiveness is low. ECCC is of the view that Benga has not provided adequate evidence to demonstrate that a minimum 80% CE will be achieved in practice. The literature provided by Benga (summarized in US EPA, 1998), show that road watering has a wide range of effectiveness over time and space, including control efficiencies that can fall well below 80%. It is therefore uncertain whether this minimum level of mitigation would be achieved continuously, throughout the life of the mine. Given the large proportion of fugitive dust emissions attributable to haul road activity, ECCC recommends that, as part of a comprehensive Air Quality Monitoring and Adaptive Management Plan, Benga implement active particulate matter and passive dustfall sampling along the haul road to ensure that the level of mitigation (80% CE) is achieved, based on model predictions.

Emissions from open rail cars

ECCC acknowledges the study provided by Benga which evaluates the efficacy of the proposed latex binder solution as well as other studies cited by Benga (Tenth Addendum, Package 1, IR 1.1, CIAR #251) which show relatively consistent rates of coal dust loss. However, ECCC notes that Benga's calculation of the resulting deposition rate (Tenth Addendum, Package 1, IR 1.7, CIAR #251) assumed that all dust losses would be uniformly distributed along the rail corridor. This assumption does not take into account the potential for coal dust to accumulate in certain geographical areas, due to potential declines in binder efficacy at later points in the journey as well as differences in wind patterns along the corridor. Furthermore, dust deposition due to rail transport of coal from the Project will add cumulatively to the transport of coal from other projects in the region. The contribution of coal dust emissions from other mines was not taken into account in Benga's calculation of dust deposition. It is therefore possible that, with planned mitigations, Benga's prediction of 26 mg/100 cm^2 represents an underestimation of deposition rate, and that the 30-day Alberta deposition guideline of 53 mg/100 cm^2 could be exceeded at various locations along the rail route. Elevated rates of coal dust deposition from this and other projects have the potential to result in nuisance and safety impacts. Coal dust can also settle on vegetation and be deposited to fresh water bodies along the corridor, resulting in potential adverse impacts to terrestrial and aquatic ecosystems.

Open rail cars carrying coal have been shown to cause measurable increases in $PM_{2.5}$ along rail corridors in Washington State (Jaffe, 2015) and through the Fraser River Delta area in British Columbia (Akaoka, 2017). Elevated concentrations of airborne particulate matter were observed in these studies despite the application of dust suppressants on coal loads. Coal from the Project will likely also be transported through B.C.'s Fraser River Delta region, including through densely populated communities. While increases in $PM_{2.5}$ concentrations near rail cars have been shown to be small (OEA, 2015), these increases will add cumulatively to the already high pollutant levels in some of these communities (e.g. Metro Vancouver). CEAA 2012 requires that any cumulative environmental effects attributable to the Project, in combination with other physical activities that have been or will be carried out, be takin into account in the environmental assessment.

Accounting for Benga's proposed mitigation measures, fugitive dust from this project is still predicted to be emitted from open-top rail cars, resulting in elevated levels of airborne and deposited dust along the rail corridor, and adding to dust impacts from existing coal transportation in the region. Therefore, additional measures to monitor and mitigate fugitive dust emissions from the project may be necessary to reduce the Project's contribution to the

cumulative effects of coal transport along the rail corridor. ECCC recommends that, in addition to their planned monitoring activities, Benga monitor dustfall along the rail corridor to assess cumulative impacts from coal transportation. In addition, ECCC recommends that alternative fugitive dust mitigation measures be presented in the Air Quality Monitoring and Adaptive Management Plan, including the potential for re-application of the binder at a later point along the route to port as well as the potential for covers to be applied to rail cars.

ECCC Recommendations 6.2

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Implement active particulate matter and passive dustfall sampling along the haul road and compare with model predictions, to ensure that the proposed level of mitigation (80% Control Efficiency) is reached, and in the event that a minimum 80% CE is not attained, identify an adaptive management response that would be implemented to reduce particulate matter.
2. Conduct monitoring to establish baseline particulate matter deposition rates along the rail corridor prior to Project construction. During operations, continue to monitor the deposition of particulate matter to assess cumulative impacts and the Project's contribution of fugitive coal dust emitted from open rail cars along the corridor.
3. Within the Air Quality Monitoring and Adaptive Management Plan, present alternative fugitive dust mitigation measures, including the potential for re-application of the binder at a later point along the train journey to port as well as the potential for covers to be applied to rail cars.

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6.3 Greenhouse Gas Emissions

Introduction and Importance of the Topic to Impact Assessment

Climate change is one of the most important environmental issues of our time. Climate change is caused by the increase in concentrations of greenhouse gases (GHGs) in the atmosphere which produces a warming effect. These increases are primarily due to human activities such as the use of fossil fuels or agriculture. A wide variety of impacts may result from climate change, which have been documented by the Intergovernmental Panel on Climate Change (IPCC).

In Fall 2019, the Government of Canada announced further commitments to strengthen existing, and introduce new, actions to exceed Canada's 2030 emission reduction target, and to develop a plan to set Canada on a path to achieve a prosperous net-zero emissions future by 2050.

The publication of the final strategic assessment of climate change (SACC) in July 2020 (ECCC, 2020), provides guidance on how to consider climate change throughout federal impact assessments under the *Impact Assessment Act*. While the SACC does not apply directly to projects under CEAA 2012 such as the Grassy Mountain project, it is desirable to apply some of the principles of the SACC to these project reviews to support consistent, predictable, efficient and transparent consideration of climate change. ECCC analysis and recommendations for CEAA 2012 project reviews considers these principles.

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
- Consultant Report #1 – Air Quality & Climate (CR #1)
    - Section 4.3 – Project Greenhouse Gas Emissions
    - Section 6.6 – Air Quality Mitigation & Management
- Tenth Addendum to the Environmental Impact Assessment (September 9, 2019), (CIAR #251)
    - Package 1 – Air Quality and Noise
        - IR 1.8
- Government of Canada, re: Comments on the Grassy Mountain Coal Project (October 24, 2019), (CIAR #283)
    - Environment and Climate Change Canada's Proposed Information Requests on the Sufficiency and Technical Merit of the Ninth and Tenth Addendum
        - IR 4 – Greenhouse Gas Management Plan

Benga's Conclusions

GHG Emissions

According to Benga, direct and acquired GHG emissions associated with the operation phase of the project are estimated to be 0.43 million tonnes (Mt) of CO_2 equivalent (CO_2e) per year at maximum capacity (year 19 of project), for an estimated total of 10.32 Mt CO_2e over the lifetime of the project. Table 1 below provides a breakdown of the direct and acquired emission over the lifetime of the project, based on information Benga provided (Tenth Addendum, Package 1, IR 1.8, CIAR #251).

The GHG emission sources quantified by Benga include mining operations, rail transport, marine shipping, fugitive methane, and acquired electricity. The Project's main GHG emission sources are the diesel mining equipment (40%), the acquired electricity (28%), fugitive methane (16%), and rail and marine transport (15%) (Tenth Addendum, Package 1, IR 1.8, CIAR #251). ECCC notes Benga did not quantify GHG emissions associated with land use change and impacts on carbon sinks were not required to be assessed.

The GHG emissions associated with the construction phase of the Project (1 year) are estimated to be approximately 0.022 Mt of CO_2e over the lifetime of the Project (0.2% of the total GHG emissions). The majority of the construction emissions come from earthworks (platforms, stockpiles), the mine access road, and the mine and overland conveyor access road. The table below provides an overview of the yearly (highest emission year) and lifetime GHG emissions from the Project.

Decommission and reclamation activities occur largely concurrently with the mining activities, and have therefore been accounted for in the operation emissions. Other closure activities – deconstruction of other plant facilities, environmental monitoring, water pumps – were not included in the estimates because Benga indicated that the GHG emissions of these sources are insignificant.

Table 1: ECCC's summary of direct and acquired GHG emissions over the lifetime of the Grassy Mountain Coal Project.

Source		Highest Annual Emissions (Mt CO_2e)	Lifetime GHG Emissions (Mt CO_2e)
Construction		0.022 (year 0)	0.022
Operation	Mine (diesel equipment)	0.172 (year 19)	4.139
	Fugitive Methane	0.070 (year 19)	1.692
	Rail Transport	0.064 (year 19)	1.530
	Marine Shipping	0.002 (year 19)	0.044
	Acquired Electricity	0.120 (year 19)	2.896
Decommission and Reclamation		Included in Operations	
Total		**0.428** (year 19)	**10.323**

Mitigation Measures

Benga provided a draft greenhouse gas (GHG) management plan and proposed the following mitigation measures, all related to mobile off-road diesel equipment:

- Minimizing diesel consumption through dispatch management
- Regularly upgrading the mine fleet
- Optimizing haul road lengths and grades to reduce fuel consumption
- Developing a program to minimize idling
- Conducting maintenance to manufacturer's specifications
- Providing appropriate operational and maintenance training
- Investigating the use of lower GHG-intensity power sources
- Investigating sources of low-carbon diesel
- Investigation using electric shovels

Regarding the proposed mitigation measures for fugitive methane emissions, Benga identified pre-mine drainage as the only feasible type of methane recovery technology for surface mines, and stated that pre-mine drainage is unlikely to be technically or economically feasible because the Grassy Mountain site is not considered "gassy" and therefore methane recovery is not practical. Consequently, Benga is no longer considering a methane recovery technology to mitigate its fugitive methane emissions.

Regarding rail and marine emissions related to the transportation of coal, Benga indicated that the lowest emitting units would be requested when developing coal transport contracts with third parties.

ECCC's Conclusions

The Government of Canada will consider the extent to which the Project will contribute to or hinder Canada's ability to meet its climate change commitments, including the 2030 targets and net-zero by 2050 goal. To do so, it will consider absolute GHG emissions, mitigation measures, the Project's emissions intensity, and how the Project may impact federal and international GHG reduction efforts.

Projects can be assessed in terms of their emissions intensities (EI). The EI refers to the GHG emissions generated per unit of production. Applying Best Available Technology / Best Environmental Practices (BAT/BEP) is a means of reducing a Project's EI. BAT/BEP is defined as the most effective technologies, techniques, or practices, including emerging technologies that can be technically and economically feasible for reducing GHG emissions during the lifetime of the project.

With the emission information provided by Benga, the mine would fall in the middle range of currently operating mines (not the worst, but not the best) with respect to EI. Considering only direct (mine and fugitive methane) emissions and an annual production of 3.8 million tonnes of coal, the estimated EI is 0.064 tonnes CO_2e per tonne of metallurgical coal produced. In 2017, other surface metallurgical coal mines in Canada, of various annual productions, performed at EI's ranging from 0.053-0.074. Under the federal Output-based Pricing System (OBPS) regulations, the national, production-weighted average of several metallurgical coal mines, is 0.0624 tonnes CO_2e per tonne of metallurgical coal produced. Given that the Project will not start operation until 2022 at the earliest and the OBPS average represents existing mines, and recognizing further analysis of the geological characteristics of the mine is needed before drawing any final conclusions, this disparity suggests that Grassy may not be designed to minimize GHG emissions. ECCC recommends Benga undertake a BAT/BEP determination to further reduce the project's GHG emissions.

In 2019, ECCC contracted Advisian to undertake an analysis of BAT/BEP in the coal mining sector and has attached the final report in Appendix A to inform potential BAT/BEP determination and provide insight into potential GHG mitigation measures to further reduce GHG emissions. This report is for information purposes and Benga should not limit themselves to the technologies and practices outlined in the report.

ECCC Recommendation 6.3

Should the Project be approved, ECCC recommends that the Panel recommend that Benga:

1. Develop and implement a GHG emissions reduction plan for the lifetime of the project, prior to project construction. This plan should include, but not be limited to, the following:

    a) A BAT/BEP determination for all equipment and activities that would cover all phases of the project based on the approach presented in section 5.1.4.1 of the Strategic Assessment of Climate Change (ECCC, 2020). This tool is used to identify the GHG mitigation measures for all project emission sources such as mining equipment, fugitive methane, rail and marine transport, and acquired electricity that should be implemented during the lifetime of the project.

    b) A description of how the BAT/BEP determination will be periodically reviewed, including equipment replacement or revamping throughout the lifetime of the project to continuously reduce GHG emissions.

    c) A description of how the implementation of the selected BAT/BEP will impact the project's GHG emissions, including updated annual GHG emissions over the project's lifetime.

ECCC provided below a list of potential GHG mitigation measures for the emission sources to inform the BAT/BEP determination.

Mining Equipment

While Benga has provided mitigation measures for the mobile off-road diesel mining equipment already (which represents the largest source of GHG emissions (40%) of the project), ECCC recommends that Benga consider additional mitigation measures for mining equipment.

One potential mitigation measure for mining equipment is the replacement of diesel equipment with lower emitting equipment. Low carbon technologies and zero-emission mining equipment, including various technologies such as battery-electric and hydrogen fuel cell, is one potential alternative that could greatly reduce the project's emissions from off-road diesel equipment. Different sources indicate zero-emission haul trucks will be available within five to ten years (Linder, 2020; Moore, 2020). ECCC recommends that Benga include in their GHG emissions reduction plan an analysis of the feasibility of implementing zero-emission and low carbon technologies in place of diesel combustion equipment, including a timeline to implement those technologies throughout the project lifetime.

Fugitive Methane

Benga estimates that fugitive methane will contribute 16% of the Project's net GHG emissions. Benga indicates that methane recovery is not feasible (Tenth Addendum, Package 1, IR 1.8, CIAR #251). The federal methane regulations only apply to upstream oil and gas facilities and cannot therefore mitigate the project's fugitive methane emissions. In ECCC IR 4 (Government of Canada, ECCC, CIAR #283), ECCC recommended that Benga:

- Describe one or more specific activities that Benga plans to undertake to achieve the objective of understanding the potential for reducing project-specific fugitive methane emissions from exposed coal. Include a general timeframe for each of the activities.
- Provide an explanation of how these mitigation activities may lead to reduction of fugitive methane emissions.

ECCC reiterates the above recommendation and further recommends that Benga provides, as per its GHG Management Plan, an assessment of mitigation measures for project-specific fugitive methane emissions from exposed coal, including an analysis of the applicability of available and emerging techniques such as those summarized in the Advisian BAT/BEP report, to the project.

Rail and Marine Transportation

Rail and marine transportation contribute 15% of the Project's predicted net GHG emissions. ECCC recognizes that mitigating these emissions could be challenging due to being operated by third parties. Aligned with Benga's proposed shipping plan, ECCC recommends Benga requires the lowest emitting units from third party shipping when developing shipping contracts and includes this information in the GHG emissions reduction plan.

Acquired Electricity

Acquired emissions from electricity consumption associated with the operation of Coal Processing Plant (CPP), and potentially operating electrically powered shovels and drilling equipment, are based on the emissions generated from the regional power supplier. Alberta currently produces 90% of its electricity with fossil fuels. ECCC acknowledges that over time these acquired GHG emissions will decrease, due to the phase out of coal in Alberta by 2030 under Alberta's Climate Change legislation. Benga shall however be responsible for implementing necessary mitigation measures for minimizing the impacts associated with laying the powerline for drawing the electricity from the grid for use at project site. ECCC recommends Benga include in the GHG emissions reduction plan mitigation measures for minimizing the impacts associated with laying the powerline for drawing the electricity from the grid for use at project site.

Net-zero Goal

ECCC anticipates the emissions intensity of surface metallurgical coal mining projects to decrease over time, due to the development of more efficient technologies and practices, and the implementation of federal and provincial policies and regulations to reduce GHG emissions, such as carbon pricing and the proposed Clean Fuel Standard. ECCC encourages Benga to consider the integration of multiple BAT/BEP to significantly reduce GHG emissions and support Canada in meeting its net-zero by 2050 goal.

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6.4 Effects of Climate Change on the Project

Introduction and Importance of the Topic to Impact Assessment

The Environmental Impact Statement Guidelines (EIS Guidelines) and the Joint Review Panel Terms of Reference both indicate that the effects of the environment on the Project shall be considered (EIS Guidelines; Section 6.6.2). In particular, the guidelines specify that the Environmental Impact Statement (EIS) will address how local conditions and natural hazards, such as severe and/or extreme weather conditions and external events (e.g. flooding, drought, ice jams, landslides, avalanches, erosion, subsidence, fire, outflow conditions, and seismic events) and the longer term effects of climate change, could adversely affect the Project, and how this in turn could result in impacts to the environment. The guidelines also specify that the EIS should "provide details of planning, design, and construction strategies intended to minimise the potential environmental effects of the environment on the Project" (p.35).

The climate (precipitation and temperature) of the Project area is projected to be different from current and past climate over the project lifetime, including the post-closure period, and therefore climate change considerations are relevant to the environmental assessment of the Project. The implications of climate change on the Project, as well as the Project's potential impacts on the environment, should be identified and considered.

Extreme precipitation events are expected to occur with more frequency and intensity in the future, due to climate change (IPCC, 2012; IPCC, 2013; Kharin et al., 2013; Bush & Lemmen, 2019). The identification and appropriate interpretation of climate change data and projections is therefore important for the assessment of possible climate related risks to the Project and, in turn, to the environment. This is particularly important with respect to the Project's design considerations. For example, Benga has identified design components, such as water management infrastructure, as being sensitive to heavy rainfall extremes (EIA, Section C.10, CIAR #42).

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
  - Section C – Project Description
    - C.10 – Effects of the Environment and Climate Change on the Project
  - Section E – Environmental Impact Assessment summary
    - 1.3.5 – Climate Change
- Consultant Report #1 – Air Quality and Climate
  - Section 5.14 - Climate Change
- Fourth Addendum to the Environmental Impact Assessment (November 27, 2017), (CIAR #55)
  - Attachment 2 (pg. 2-96 to 2-114)
  - CEAA IR 25 - Extreme Weather Events and Climate Change
  - Appendix 25A (pg. 25A-1 to 25A-12)
- Sixth Addendum to the Environmental Impact Assessment (April 30, 2018), (CIAR #70)
  - Attachment I – CEAA Outstanding Conformity SIR, SIR 4 (pg. 5)
  - Attachment II – ECCC SIR 5 (pg. 22)
  - Appendix A-4 – Project Schedule (Updated April 2018) (pg. A4-1)

- Eighth Addendum to the Environmental Impact Assessment (October 24, 2018), (CIAR #89)
  - Part B – Technical IRs
    - ECCC-R2-1 – Climate Change Predictions
- Tenth Addendum to the Environmental Impact Assessment (September 9, 2019), (CIAR #251)
  - Package 3 – Geotechnical and Dam Safety, Land Use and Land Management
    - JRP IR 3.2
- Eleventh Addendum to the Environmental Impact Assessment (March 19, 2020) (CIAR #313)
- Environment and Climate Change Canada to the Canadian Environmental Assessment Agency (October 3, 2016) (CIAR #48)
  - Attachment 1 – Federal Pre-Panel Review of the SIRs (Round 1)
    - IR 15 – Extreme Weather Events and Climate Change
- Government of Canada, re: Comments on the Grassy Mountain Coal Project Environmental Impact Assessment and Addenda (January 21, 2019), (CIAR #167)
  - Environment and Climate Change Canada's Technical Review of Addendum Eight
    - Technical Supplementary Information Requests (SIRs) and Outstanding Conformity IRs
- Government of Canada, re: Comments on the Grassy Mountain Coal Project (October 24, 2019), (CIAR #283)
  - Environment and Climate Change Canada's Proposed Information Requests on the Sufficiency and Technical Merit of the Ninth and Tenth Addendum
    - IR 5 – Design Values for Extreme Precipitation
- Osler, Hoskin & Harcourt LLP (Benga) - Comments on Sufficiency (October 31, 2019), (CIAR #291)
  - Environment and Climate Change Canada's Proposed Information Requests on the Sufficiency and Technical Merit of the Ninth and Tenth Addendum
- Environmental Impact Statement Guidelines (EIS Guidelines)
  - Section 6.6.2, pg. 35

Benga's Conclusions

Benga has provided information on climate change projections in the Project area including projected changes in precipitation (including extreme precipitation), temperatures, and return periods (the average time between extreme precipitation events, such as floods) for the Project area and, in some cases, Alberta. These projections were selected and interpreted based on approaches employed during the development of the EIA in 2016. Benga's climate change projections have been considered in the Project design, influencing the engineering concepts for the design of ponds, sediment and surge dams, spillways and the water management plan. Benga has acknowledged that the magnitude of a dam failure could be high, and that a worst case scenario could release large volumes of untreated selenium contaminated water from surge ponds, representing a risk to water quality and ecosystems (Tenth Addendum, Package 3, IR 3.2, CIAR #251).

Benga has stated that their water management plan allows for active management of future short duration extreme precipitation events and that they have based their pond designs on

worst-case scenarios. Their maximum inflow design and minimum storage capacity are based on historical records (e.g., 1 in 100 year flood, Probable Maximum Flood (PMF)) (Tenth Addendum, Package 3, IR 3.2(c), CIAR #251). Benga indicated that they have used PMF, which is estimated from probable maximum precipitation (PMP) and snowmelt, as one of the values for developing their dam designs, but did not present information on how PMP may be altered in a changing future climate.

Benga provided current precipitation-related design values used for the surge, sediment and raw water ponds. The updated Project Schedule in Appendix D (EIA, CIAR #42) indicated that the water management infrastructure related to the surge ponds would be active "from 2046-20XX", representing an indeterminate timeframe during which contaminant (i.e. selenium) attenuation would no longer require active management of the infrastructure (Sixth Addendum, ECCC SIR 5, CIAR #70). Benga committed to design and build each dam to meet Canadian Dam Association Guidelines and will develop their final design criteria to the AER as part of the Canadian Dam Safety application(s).

Benga concluded that the current design of Project ponds is appropriate for the short-term precipitation increases predicted for the future by the climate models and for the time periods they examined. Benga has acknowledged that their current designs are based on calculations and methodology from 2016, and that newer methodologies, such as those described in the 2019 Canadian Standards Association guidance on *Intensity Duration Frequency for Canadian Water Resources Practitioners* has been developed. They have also indicated their intent to refine the Project design, using more recent guidelines, if they are of the opinion that the application of the newer guideline will result in "material design changes" during the detailed engineering phase.

ECCC's Conclusions

ECCC has identified a number of areas where Benga's assessment of potential future changes in the severity and frequency of short duration extreme precipitation are not scientifically robust. Future changes in short-duration precipitation extremes may have implications for water management infrastructure, including potential impacts to water quality should the design values of the Project's water management infrastructure underestimate the severity and frequency of extreme weather events.

In their conformity response to CEAA IR 25 (Fourth Addendum, Attachment 2, CIAR #55), Benga indicated that the 20-Year return period for annual daily precipitation extremes is projected to decrease (i.e. events of such magnitude will occur more frequently) and that the magnitude of annual and extreme (high) precipitation events are also projected to decrease (Fourth Addendum, Attachment 2, pg. 2-102, CIAR #55). These findings are conflicting, as a decrease in return period for an event of a specific magnitude should translate to an increase in the magnitude of an event of a given return period (or probability/frequency).

Benga estimated a future change in the 1-in-20 year return period as a reduction of either 10% or 20% per each degree of warming based on findings of Kharin et al. (2013). This scaling, based on global climate model simulations, is robust, and provides general guidance as to sign and magnitude of anticipated change at smaller scales. However, the projections of precipitation extremes cited by Benga were obtained for one or two Global Climate Model (GCM) grid points. GCM grid points represent a larger area, typically 100-200 km, and in the case of precipitation

and extreme short duration heavy precipitation, cannot be interpreted as reflective of local scale conditions. Small scale precipitation processes are not resolved in the currently available global climate models nor many regional climate models and thus the contradiction in the projections based on scaling (Kharin et al. 2013) and Benga's model projections of extremes at individual grid points, is the result of using global or regional climate model outputs at grid point level at which robust projections are not possible to obtain. Benga could have improved the robustness of their projections by considering the use of projections from a larger region (e.g. increase the number of model grids from which climate change projections are used).

Benga indicated that they have used PMF, which is estimated from PMP and snowmelt, as one of the values for developing their dam designs, but have not presented information on how PMP may be altered in a changing future climate. Short-duration heavy precipitation (including PMP per Kunkel et al., 2013) is expected to increase with future warming due to increases in atmospheric moisture, though it is difficult to obtain precise projections for future changes in extreme precipitation at the regional and local scales (IPCC, 2012; IPCC, 2013; Kharin et al., 2013; Zhang et al., 2017; Kunkel et al, 2013). ECCC is of the opinion that possible future changes in PMP/PMF, including any uncertainty, should be considered for the Project's precipitation-related design values. Design values that are estimated based on historical records, such as those Benga has adopted do not account for ongoing climate change. Climate-sensitive aspects of longer-term projects that are based on fixed design values obtained from historical climate observation of a particular period are unlikely to have equal resilience to weather and climate extremes of a particular magnitude (e.g., a 50 year flood) over their entire lifetime if no adaptation measures are in place.

In addition, heavy precipitation events due to future climate change may result in effects to water quality from increased surface runoff or breaches of water management structures (Eighth Addendum, Part B, ECCC-R2-1, CIAR #89). Benga provided current precipitation-related design values used for the surge, sediment and raw water ponds which indicated that the water management infrastructure related to the surge ponds would be active "from 2046-20XX", representing an indeterminate timeframe during which contaminant (i.e. selenium) attenuation would no longer require active management of the infrastructure.

ECCC is satisfied with the range of extreme precipitation projections for the Project area for three future time periods (2020-2029, 2050-59 and 2090-2099) provided by Benga in the Eighth Addendum (Part B, ECCC-R2-1, CIAR #89) which also indicated that extreme precipitation is projected to increase by as much as ~20-40% in the future. However, ECCC disagrees with Benga's conclusion that it is "appropriate" to retain the current design for the Project based on current climate conditions based on the results of the analysis they presented.

Benga's initial pond designs are based on either the 'Very High Dam Classification' (over 1000-year peak flows) or the 'Significant Dam Classification' (500-year peak flows). However, Benga's conclusion that the current design values are appropriate for the future is based on their comparison of design values for the current climate, and projected maximum precipitation for three different 10-year periods in the future. This approach compares values for events with different probabilities of occurrence (or rareness). The Panel sought further clarification on this issue during the environmental assessment review (Tenth Addendum, Package 3, IR 3.2, CIAR #251). Benga's response provided design precipitation depths for three different rainfall durations for historical and future conditions (200-yr, 1000-yr and Probable Maximum for an

intermediate future emissions pathway) (Tenth Addendum, Package 3, Table 3.2-1, CIAR #251). However, ECCC notes that Benga applied the same fixed value (44.8mm for 24-hours) and added it to the 1000-yr return period and the PMP. This approach is not supported by science as the water holding capacity of the atmosphere increases with temperature at an exponential rate, and atmospheric moisture also increases proportionally to temperature increase. The approach taken by the Proponent would underestimate the increases in return values for higher return periods.

Furthermore, estimates of future short duration precipitation extremes that are based on statistical relationships fitted between local-scale observed extreme precipitation and modelled simulations are unlikely to be robust because the changes in local observed extreme precipitation are small compared with the natural variability of extreme precipitation (Li et al., 2019). This lack of information on observed extremes means that a statistical model like the one used by the Proponent is unlikely to be well constrained (Li et al., 2019).

ECCC recommends that Benga utilize an appropriate methodology to estimate return values for design and that they consult the 2019 Canadian Standards Association Guidance on Intensity Duration Frequency for Canadian Water Resources practitioners, which provides examples of such methods (e.g., the use of a simple scaling technique to adjust precipitation, as a percentage, based on projected temperatures) in order to provide a more robust and accurate analysis of predicted rates of change for PMP.

ECCC has identified approaches and interpretations applied by Benga in their assessment of potential future changes in the severity and frequency of short duration extreme precipitation which are not scientifically robust. Future changes in short-duration precipitation extremes may have implications for water management infrastructure, including potential impacts to water quality should the design values of the Project's water management infrastructure underestimate the severity and frequency of extreme weather events. Benga has indicated that they will use best-available science and methodologies during the detailed design phase if new guidance materially alters their conclusions; ECCC would advise that the best-available methods to characterize climate related effects on the Project be considered to ensure that water management infrastructure is designed to withstand the effects of a changing climate over the next century.

ECCC Recommendations 6.4

Should the Project be approved ECCC recommends that the Panel require Benga to:

1. Characterize climate changes relevant to the project design values, including potential changes in short-duration precipitation extremes, using scientifically appropriate best-available methodologies such as those outlined in the recent CSA guidance (CSA, 2019);
2. Where it is necessary or appropriate, utilize revised projected climate change conclusions to inform the design relevant elements of the Project, such as water management infrastructure and the Project's water management plan, in order to enhance the resilience of the Project to increasingly severe and extreme weather events.

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CHAPTER 7 – Accidents and Malfunctions

7.1 Spill Response Measures and Program

Introduction and Importance of the Topic to Impact Assessment

The following information is provided in response to the Panel's request that ECCC's submission address accidents and malfunctions (Joint Review Panel, CIAR #379).

ECCC provided information to the Panel on December 4, 2018 (CIAR #104) regarding the legislation, policy or other directives under the responsibility of ECCC including the *Environmental Emergency Regulations*. These regulations were repealed in 2019 and replaced with the *Environmental Emergency Regulations, 2019* which came into force on August 24, 2019. The new regulations added 33 substances to the list of regulated substances in Schedule 1, and introduced new definitions and periodic reporting requirements for facilities, substances and emergency plans.

The *Environmental Emergency Regulations, 2019* apply to any person or company that owns or has the charge, management or control of any of the 249 listed hazardous substances located at any fixed land-based facility in Canada. Facilities that have a regulated substance and meet the concentration, total quantity and/or container capacity thresholds may have to submit notices to ECCC, prepare, implement and test an Environmental Emergency Plan, keep records or report environmental emergencies. In the EIA Benga identifies diesel fuel and ammonium nitrate as two products that may pose risk to the general public and biota; both of these substances are listed in Schedule 1 of the *Environmental Emergency Regulations, 2019*.

Spills of process-affected water, tailings, process chemicals, hydrocarbons and other substances have the potential to affect water quality and harm fish and aquatic organisms, as well as migratory birds. These environmental effects may also directly impact human health via the consumption of contaminated water, fish or wildlife.

Sources of Information

- Environmental Impact Assessment (EIA) (CIAR #42)
  - Section C – Project Description, pages C133-C135, C163-164
- Joint Review Panel email to ECCC (June, 29, 2020), (CIAR #379)
  - Participation of Environment and Climate Change Canada in the Public Hearing for the Grassy Mountain Coal Project
- ECCC letter to Joint Review Panel Re: Federal Expertise regarding the Grassy Mountain Coal Joint Review Panel Process (December 4, 2018), (CIAR #104)

Benga's Conclusions

Benga identified diesel fuel and ammonium nitrate as two products that may pose risk to the general public and biota. They concluded that "The results of the evaluations concluded that the products used in the mining of the Project area would not impact the general public or biota. [The consultant's] assessment evaluated current operating practices." (EIA, Section C, CIAR #42).

Benga indicated that they will prevent spills by establishing programs to monitor product inventory, inspect containment and transfer facilities, and conduct leak detection monitoring. They will also develop a comprehensive spill response program to "prevent any adverse effects on the environment." Benga states that they will design Emergency Response Plans for various sites and emergency situations, including establishment of an Emergency Response Team which will be trained to assist during emergency situations including chemical spills (EIA, Section C, CIAR #42).

Benga provided information on the scenario description of an explosives accident (EIA, Section C, CIAR #42).

Accident and Malfunction Considerations

ECCC acknowledges that Benga's emergency response plans and spill response program are only "conceptual" at this stage of the Project. ECCC encourages Benga to prepare Emergency Response Plans and a spill response program that reflect a consideration of all plausible types of accidents and malfunctions and that take into account site-specific conditions and sensitivities associated with the Project. For emergency planning purposes, and to ensure preparedness for a "worst-case" accident scenario, plans should assume that a major incident is not only possible, but rather likely to occur during the lifespan of a project. Therefore, ECCC encourages Benga to commit to mitigation strategies, contingency plans and response capabilities that are commensurate with the environmental risks that this Project may pose, including, but not limited to, contingency plans based on "worst-case" and "alternative" accident scenarios. Final emergency response plans should demonstrate Benga's ability to prevent, prepare for, respond to and recover from accidents and malfunctions.

Benga has emergency preparedness and response responsibilities associated with the onsite use, handling or storage of chemicals and hazardous materials that have the potential, through accidents or malfunction, to adversely affect the natural environment. These substances include but are not limited to diesel fuel and ammonium nitrate. These responsibilities arise from CEPA 1999, the MBCA, and subsection 36(3) of the *Fisheries Act,* and include but are not limited to substances listed under Schedule 1 of the *Environmental Emergency Regulations, 2019*. In their plans, Benga should consider how third-party contractors who work on the project will meet Benga's due diligence standards in respect of oil and hazardous material spill prevention, preparedness, mitigation, response and restoration.

There is benefit to sharing Emergency Response Plans with interested stakeholders and Indigenous groups. Section 19(3) of CEAA 2012 states that the environmental assessment of a designated project may take into account community knowledge and Aboriginal traditional knowledge. Local communities may therefore provide vital information on evacuation procedures as they have knowledge of the land and local environment.

CHAPTER 8 – Summary of Recommendations

4.1 Wildlife and Selenium

ECCC Recommendations 4.1

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Update the Wildlife Risk Assessment to include all potential exposure pathways of selenium including dietary uptake from surface water contaminated by leached selenium due to weathering of waste rock piles.
    a) If the revised risk assessment indicates that effects to wildlife receptors are likely, then ECCC recommends that Benga be required to develop and implement mitigation measures to prevent the predicted adverse effects.
2. Implement a Biomonitoring Program to adequately characterize concentrations of COPCs in media at baseline conditions and during operation. The biomonitoring program should:
    a) Include chemicals with the potential to bioaccumulate (including selenium) in the Project study area in both lentic and lotic systems, in water and in aquatic biota (periphyton, invertebrates and vertebrates) as well as in the eggs of different egg-laying aquatic-dependent vertebrates (e.g. fish, birds, amphibians).
    b) Establish site-specific thresholds of selenium in aquatic biota (periphyton, invertebrates and vertebrates) which, when exceeded, would trigger Benga to take actions to adaptively manage and mitigate impacts to aquatic-dependant wildlife.
    c) Be used to update Benga's predicted effects of the Project.

4.2 Migratory Birds

ECCC Recommendations 4.2

Should the Project be approved, ECCC recommends that the Panel request that Benga implement their commitments to:

1. Undertake vegetation and habitat removal and clearing activities outside the nesting season for migratory birds.
2. Undertake progressive reclamation as soon as possible to restore migratory bird habitat, and to undertake monitoring and adaptive management to improve the efficacy of reclamation.

4.3 Species at Risk

ECCC Recommendation 4.3

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Replant three blister rust resistant seedlings for each Whitebark Pine tree and Limber Pine tree destroyed by the Project, and to monitor and apply adaptive management where required to ensure seedlings are established and on a trajectory to becoming mature trees.

5.1 Impact of Selenium on Aquatic Organisms and the use of Environmental Quality Guidelines for the Protection of Aquatic Life

ECCC Recommendations 5.1

Should the Project be approved ECCC recommends that the Panel request that Benga:

1. Reconsider the risk assessment methodology to:
    a) Exclude the application of a mitigation factor for sulphate, consistent with ECCC's Screening Assessment of Selenium and its Compounds (2017).
    b) Reflect exposure scenarios that are based on operational (not baseline) selenate:selenite ratios, especially in the determination of enrichment factors to predict bioaccumulation in food-web models.
2. Implement a Biomonitoring Program to adequately characterize concentrations of selenium in Blairmore and Gold Creeks at baseline conditions and during operation. The biomonitoring program should:
    a) Measure all selenium species' concentrations in mine effluent discharged to the receiving environment in water and in aquatic biota (periphyton, invertebrates and vertebrates) as well as in fish eggs and fish ovaries.
    b) Specify what would trigger Benga to take actions to adaptively manage and mitigate impacts to water quality.
    c) Be used to update Benga's predicted effects of the Project.

Notwithstanding the recommendations in 5.1 above, the deposit of a deleterious substance to water frequented by fish constitutes a violation of the *Fisheries Act* except where federal regulations under subsection 36(5) of the Act apply.

6.1 Baseline Air Quality Assessment and Nitrogen Oxide Emissions

ECCC Recommendations 6.1

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Conduct monitoring of air pollutant concentrations within the towns of Blairmore or Coleman for a minimum of one year to establish a baseline assessment of NO_2 and $PM_{2.5}$ which is representative of the Crowsnest Pass communities. Baseline monitoring should be conducted prior to the Project's commencement.
2. Re-model regional air pollutants, incorporating the baseline monitoring results (using data generated from recommendation 6.1.1), to produce new predictions of NO_2 and $PM_{2.5}$, based on Year 19 of the Project. The revised model should be conducted in a way that minimizes the sources of error previously identified (i.e. biases due to imprecise application of source types such as road and community emissions).
3. Establish adaptive management of air pollution which incorporates the results of the baseline assessment and model predictions described in 6.1.1 and 6.1.2; trigger values for adaptive management should be selected based on the principles of "keeping clean areas clean" and "continuous improvement." Hence, trigger values should be lower than the Canadian Ambient Air Quality Standards (CAAQS) and selected to ensure low air pollutant concentrations in the region are maintained.
4. Implement measures to control emissions of nitrogen oxides from the mine. These include:
    a) Implement a retrofit and replacement schedule demonstrating off-road equipment conversion to best-in-class technology, starting with final Tier IV engines, with new engines meeting the Off-Road Compression Ignition Engine Emission Regulations (under the *Canadian Environmental Protection Act*, 1999);
    b) Not remove emission control technologies from off-road equipment;
    c) Implement an emission control technology maintenance program, which may include combined use of individual vehicle fuel usage indicators, vehicle emission testing, and electronic diagnosis techniques to trigger maintenance: and
    d) Provide employee training on minimizing off-road equipment idling and the importance of avoiding tampering with emissions control systems.
5. Investigate alternative blasting agent formulations with lower emissions of nitrogen oxides (NO_x).

6.2 Fugitive Dust Emissions

ECCC Recommendations 6.2

Should the Project be approved, ECCC recommends that the Panel request that Benga:

1. Implement active particulate matter and passive dustfall sampling along the haul road and compare with model predictions, to ensure that the proposed level of mitigation (80% Control Efficiency) is reached, and in the event that a minimum 80% CE is not attained, identify an adaptive management response that would be implemented to reduce particulate matter.
2. Conduct monitoring to establish baseline particulate matter deposition rates along the rail corridor prior to Project construction. During operations, continue to monitor the deposition of particulate matter to assess cumulative impacts and the Project's contribution of fugitive coal dust emitted from open rail cars along the corridor.
3. Within the Air Quality Monitoring and Adaptive Management Plan, present alternative fugitive dust mitigation measures, including the potential for re-application of the binder at a later point along the train journey to port as well as the potential for covers to be applied to rail cars.

6.3 Greenhouse Gas Emissions

ECCC Recommendation 6.3

Should the Project be approved, ECCC recommends that the Panel recommend that Benga:

1. Develop and implement a GHG emissions reduction plan for the lifetime of the project, prior to project construction. This plan should include, but not be limited to, the following:

    a) A BAT/BEP determination for all equipment and activities that would cover all phases of the project based on the approach presented in section 5.1.4.1 of the Strategic Assessment of Climate Change (ECCC, 2020). This tool is used to identify the GHG mitigation measures for all project emission sources such as mining equipment, fugitive methane, rail and marine transport, and acquired electricity that should be implemented during the lifetime of the project.

    b) A description of how the BAT/BEP determination will be periodically reviewed, including equipment replacement or revamping throughout the lifetime of the project to continuously reduce GHG emissions.

    c) A description of how the implementation of the selected BAT/BEP will impact the project's GHG emissions, including updated annual GHG emissions over the project's lifetime.

6.4 Effects of Climate Change on the Project

ECCC Recommendations 6.4

Should the Project be approved ECCC recommends that the Panel require Benga to:

1. Characterize climate changes relevant to the project design values, including potential changes in short-duration precipitation extremes, using scientifically appropriate best-available methodologies such as those outlined in the recent CSA guidance (CSA, 2019);
2. Where it is necessary or appropriate, utilize revised projected climate change conclusions to inform the design relevant elements of the Project, such as water management infrastructure and the Project's water management plan, in order to enhance the resilience of the Project to increasingly severe and extreme weather events.

APPENDIX A – Best Available Technologies / Best Environmental Practices to Reduce GHG Emissions from New Coal Mining and Processing Facilities, Advisian

ECCC Disclaimer

This report has been prepared on behalf of and for the exclusive use of Environment and Climate Change Canada by an external Contractor.

This report has been prepared prior to the announcement of the Minister's goal to achieve net-zero emission by 2050. Hence, it does not explore the subject of BATBEP with the consideration of net-zero emission by 2050.

This report does not include an exhaustive nor a complete list of all BATBEP and emerging technologies, considering it was prepared by an external contractor, and the contract was limited in time and budget.



Best Available Technologies / Best Environmental Practices to Reduce GHG Emissions from New Coal Mining and Processing Facilities

Final Report - Rev 1

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307011-00106-EN-REP-0002 – Best Available Technologies / Best Environmental Practices to Reduce GHG Emissions from New Coal Mining and Processing Facilities: Final Report - Rev 1

Rev	Description	Author	Review	Advisian approval	Date
Task 1	Task 1 Draft Submission	N. Sorial	R. Hunt	R. Hunt	25 Oct 2019
Task 2	Task 2 Draft Submission	N. Sorial	R. Hunt	R. Hunt	13 Dec 2019
Task 3	Task 3 Draft Submission	N. Sorial, J. Burger	R. Hunt	R. Hunt	17 Jan 2020
Task 4	Task 4 Draft Submission	N. Sorial, J. Burger	R. Hunt	R. Hunt	14 Feb 2020
Rev 0	Final Report	N. Sorial, J. Burger	R. Hunt	R. Hunt	13 Mar 2020
Rev 1	Update (Table 4-3/4-4)	N. Sorial, J. Burger	R. Hunt	R. Hunt	1 Apr 2020

Advisian
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Abbreviations/Acronyms

Acronym	Expanded From
% wt	Percentage by weight
AB	Alberta
BAT	Best Available Technology
BC	British Columbia
BEP	Best Environmental Practice
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditure
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CMM	Coal Mine Methane
CMOP	Coalbed Methane Outreach Program
CPP	Coal Processing Plant / Coal Preparation Plant
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
GMG	Global Mining Guidelines Group
h	hour
kg	Kilogram
km	Kilometre
kt	Kilotonne (1,000 metric tons)

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Acronym	Expanded From
ICMM	International Council on Mining & Metals
IPCC	Intergovernmental Panel on Climate Change
L	Litre
LHD	Load-Haul-Dump
m	Metre
MACC	Marginal Abatement Cost Curve
MJ	Megajoule
Mt	Megatonne (1,000,000 metric tons)
MVA	Mega Volt Ampere
MW	Megawatt
MWe	Megawatt electric
MWh	Megawatt-Hour
NRCan	Natural Resources Canada
NS	Nova Scotia
Nm^3/s	Normal Cubic Meter per Second
NWCC	National Wind Coordinating Collaborative
O&M	Operation and Maintenance
OBPS	Output-Based Pricing System
OPEX	Operating Expenditure
ppm	Parts per million
PV	Photovoltaic
R&D	Research and Development
RCO	Regenerative Catalytic Oxidation/Oxidizer

Acronym	Expanded From
RE	Renewable Energy
RTO	Regenerative Thermal Oxidation/Oxidizer
RMI	Rocky Mountain Institute
ROM	Run of Mine
SK	Saskatchewan
SMNR	Small Modular Nuclear Reactor
t	Tonne (metric ton)
TIER	Technology Innovation and Emissions Reduction Regulation
TRL	Technical Readiness Level
UNECE	United Nations Economic Commission for Europe
USDoE	US Department of Energy
USEPA	United States Environmental Protection Agency
VAM	Ventilation Air Methane
yr	Year

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1 Executive summary

This report was written by Advisian for ECCC with the objective of identifying and evaluating best available and emerging technologies and practices for reducing GHG emissions from new coal mining projects in Canada. Both surface and underground mines were considered as well as coal processing facilities, with a focus on metallurgical coal.

GHG emissions in coal mines stem from two key sources: fugitive methane emissions from the coal seam, and emissions associated with energy use on site. For a surface mine, the most significant contributors are methane and mobile fleet operations, which assuming a methane emission factor and grid intensity characteristic of BC, account for an estimated 41% and 37% respectively of total mine emissions. In the case of an underground mine, methane is typically the highest single source of emissions at approximately 82% under the same BC conditions. Thermal drying at the processing plant is another large source of emissions for both types of mines.

After conducting a technology scan and engaging with various industry stakeholders, Advisian identified 17 GHG-reducing measures for surface mining operations and 15 for underground. These covered four main areas of abatement: methane, mobile fleet, coal drying, and renewable energy integration. Measures were classified as either commercially available with sufficient cost and performance data available to allow a quantitative assessment or emerging technologies and practices which were discussed qualitatively. Advisian performed a cost-benefit analysis involving lifecycle financial modelling and GHG quantification of each of the commercially available technologies and practices. This was compared against the benchmark performance of a surface mine base case and an underground mine base case.

For surface mines, electrically operated conveyors and trolley assist systems were found to offer the greatest GHG reductions with a financial return. Respectively, they have the potential to reduce the mining GHG intensity by 18% and 16% mitigating more than 1 million tCO_2e each over a 30 year mine life. While technically reliable, both technologies have lower flexibility compared to conventional truck haulage. They are best suited to mine plans with more centralized material transport. Producers are encouraged to consider these technologies during the mine design phase, given their demonstrated value both from an environmental and economic perspective. The GHG benefit of electrification technologies depends on access to electricity with a low emission intensity.

For underground mines, a number of methane capture and diversion/destruction/utilization technologies have favourable economics with a significant benefit of up to 51% GHG intensity reduction and 6 million tCO2e abatement over a 30 year mine life. Further development efforts and investments are required to support piloting of methane drainage projects in Canada. This is necessary for de-risking the technology and increasing understanding of the GHG abatement potential of improved methane management in coal mining.

The retirement of coal firing in dual-fuel coal dryers is a readily deployable GHG reduction strategy that requires zero upfront capital. The financial viability and GHG offset potential from solar and wind integration projects improves if they are displacing electricity in a local grid with higher carbon intensity.

The study suggests that material GHG reduction opportunities exist within coal mining and processing activities. Electrification of material movement and methane emission management are key recommended measures. As Canada strives for net-zero emissions by 2050, the coal mining sector must ramp up the implementation of GHG abatement projects. Future planned mines should abandon conventional mining practices that neglect GHG impacts and adopt a portfolio of emission reduction strategies that tackle the different emission sources within mining operations.

2 Introduction

This chapter provides background information regarding the objective and scope of the study at hand.

2.1 Project Objective

Advisian was engaged by Environment and Climate Change Canada (ECCC) to provide qualitative and quantitative data on best available technologies (BATs) and best environmental practices (BEPs) for reducing the direct greenhouse gas (GHG) emissions from new coal mining and processing facilities in Canada. A BAT/BEP is defined as "the most effective technology, technique or practice economically achievable for reducing GHG emissions" (Environment and Climate Change Canada, 2018).

The Government of Canada introduced the Impact Assessment Act in August 2019 repealing and replacing the Canadian Environmental Assessment Act, 2012. The new Act is reoriented to a holistic view of project impacts with a focus on sustainability. Included in the new process is an assessment of the extent to which a given project is expected to hinder or contribute to Canada's climate change commitments. Canada's current target under the Paris Agreement is to reduce GHG emissions by 30% below 2005 levels by the year 2030.

Consequently, the Government of Canada is developing a strategic assessment of climate change aimed at providing guidance to project proponents and stakeholders on how GHG emissions associated with a project are to be assessed. Among many other elements of assessment, the Government of Canada is considering the integration of GHG-related BAT/BEPs. The benefit of this approach is to urge project proponents to consider GHG emissions management and abatement early in the design phase and help achieve long term emission reductions on industrial projects.

Coal production, one of the main economic sectors in Canada, generated 2.1 Mt CO_2e in 2017 accounting for 0.3% of the country's total GHG emissions (Environment and Climate Change Canada, 2019). While still in development, the BAT/BEP approach has led ECCC to seek information on BAT/BEPs specific to reducing GHG emissions from the coal mining industry. This report provides Advisian's research, analysis and findings on the topic. Note that BAT/BEPs related to stationary combustion have been excluded, except where specific mining context was relevant. General stationary combustion BAT/BEPs are covered under a separate ECCC contract.

2.2 Project Scope

The BAT/BEP study was conducted in four stages or tasks as conceived by ECCC. The scope of activities that were carried out and delivered at the end of each task is outlined in Table 2-1.

This study combines qualitative and quantitative analysis to equip ECCC with the information they need to develop an understanding of the GHG emissions reduction landscape in coal mining and evaluate different abatement options. Various sources of information were used and cited throughout the study. This includes publicly reported regulatory data, industry reports, and academic literature. Performance and cost data associated with some BAT/BEPs were limited in the public domain. Accordingly, data collection by Advisian

included non-public sources shared by industry stakeholders, and data generated by the authors through previous projects. In all cases the source/method by which the data was generated is disclosed.

Table 2-1: Project Scope

Task	Due Date	Activity	Details
Task 1	25-Oct-2019	Overview of GHG Emissions	▪ Description of coal mining methods and process flow diagrams ▪ Overview of GHG emission levels and drivers
Task 2	13-Dec-2019	Best Available Technologies & Best Environmental Practices	▪ Assessment of GHG-reducing BAT/BEPs including technical, environmental and economic considerations ▪ Case Studies involving successful deployment of BAT/BEPs in industry
Task 3	17-Jan-2020	Emerging Technologies & Practices	▪ Review of emerging GHG-reducing technologies and practices including barriers and drivers to commercialization
Task 4a	14-Feb-2020	Draft Report	▪ Draft report incorporating all prior ECCC feedback plus executive summary and concluding chapter
Task 4b	13-Mar-2010	Final Report	▪ Final report incorporating final ECCC feedback plus summary slide deck

3 Coal Mining & Processing

This chapter provides background information regarding coal mining and an overview of the sector in Canada.

3.1 Types of Coal

Coal is a carbon rich sedimentary rock formed from the remains of decayed plant matter that has undergone chemical change under heat and pressure over hundreds of millions of years. Coal is the world's largest hydrocarbon resource and encompasses deposits of varying degrees of coalification, the progressive transformation of the original vegetation to carbon. The degree of coalification has a direct impact on coal's physical and chemical properties and is referred to as the 'rank' of the coal. Generally, the older the deposit, the higher its carbon concentration, and subsequently its energy content.

Coal is classified according to four primary ranks. In order of increasing carbon content / energy content, these are: lignite, sub-bituminous, bituminous, and anthracite. Figure 3-1 summarizes the differences between these coals and their typical uses.

Figure 3-1: Coal Ranks and Their Uses

	Lignite	Sub-Bituminous	Bituminous	Anthracite
Carbon Content [1] (% wt moist)	25-35%	35-45%	45-86%	86-97%
Energy Content [2] (MJ/kg moist)	15-19	19-30	>30	>31
% World Reserves [3]	17%	30%	52%	~1%
Characteristics	Lowest rank and economic value, also know as brown coal	Burns cleaner than lignite due to typically low sulfur content	Has binding properties and low sulfur and phosphorous content favourable for coking	Premium hard black coal with minimal volatile matter, burns with no soot/smoke
Uses	• Power generation	• Power generation • Industrial heat/power	• Power generation • Industrial heat/power • Steelmaking	• Domestic/Commercial space heating • Steelmaking

[1] (EIA, 2018), [2] (ASTM, 2019), [3] (World Coal Association, 2019a)

In addition to rank, coal is also commonly categorized based on its destined end use as either thermal/steam coal or metallurgical/coking coal:

- **Thermal/Steam Coal** is that sent to power stations for electricity generation or used as an energy source for industrial heat/power applications such as in cement production and paper mills. Lignite, sub-bituminous and bituminous coals are all utilized as thermal coal. The high cost of anthracite makes it less attractive for power generation; however, its clean burning properties make it a candidate for space heating applications.

- **Metallurgical/Coking Coal** is that used to produce coke for the steelmaking industry. Since iron occurs in nature in the form of iron oxides, the ore must be reduced using carbon, which can be derived from coal. This process involves baking the coal at high temperatures in the absence of oxygen driving off volatile compounds and impurities. The purified carbon left behind, called coke, is formed into pellets that are then used as an ingredient in smelting iron ore into iron to make steel. Some steelmaking operations also use pulverized coal displacing some of the coke required by the process. A portion of the carbon added in this process combusts to produce heat and is emitted as CO_2, while the majority is chemically retained in the slag and iron product (He, Guanb, Zhuc, & Lee, 2017). Only the higher rank coals including bituminous and anthracite with low sulfur and phosphorous content are suitable for coking.

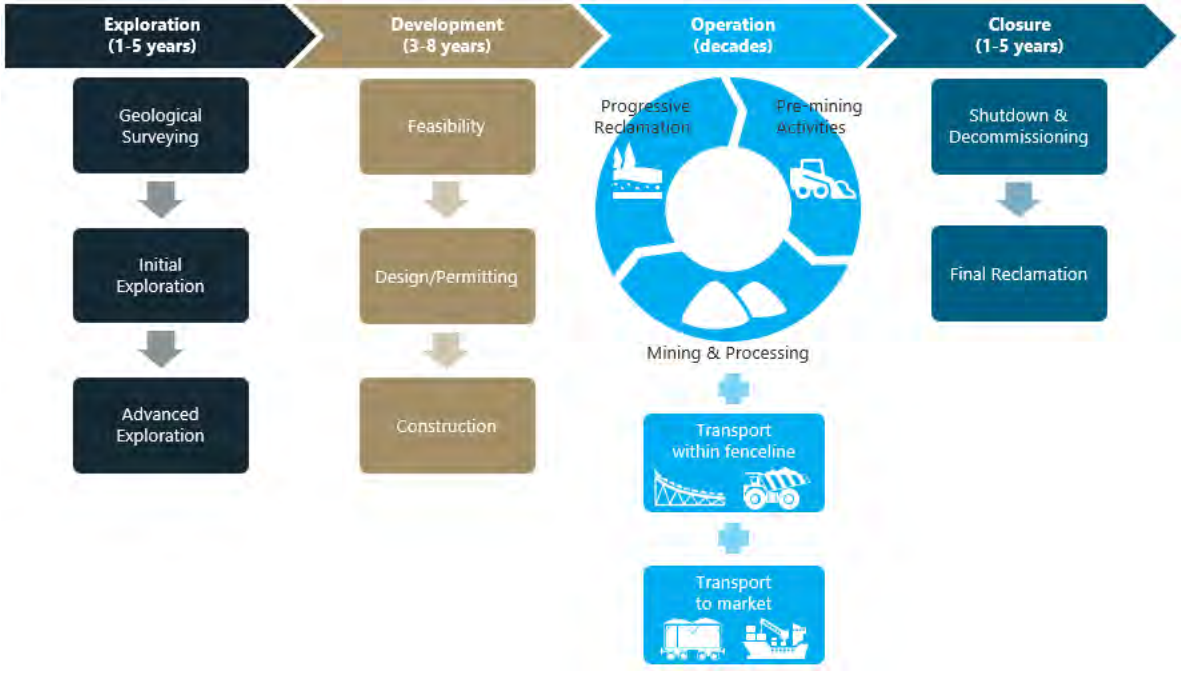
According to NRCan (2018), Canada produced 61 Mt of coal in 2017 split roughly equally between thermal and metallurgical coal. More than 90% of the thermal coal mined in Canada is used domestically, while nearly 85% of the country's metallurgical coal is exported overseas, primarily to Asian markets, making Canada the third largest global exporter of metallurgical coal after Australia and the United States (NRCan, 2018).

With the planned phase out of coal-fired electricity generation in Canada by 2030, the future of thermal coal mining in Canada is uncertain. Metallurgical coal mining however, is not under the same pressures and is anticipated to continue to support domestic and international demand.

3.2 Mining Lifecycle

Exploiting a coal deposit is an extensive process that lasts decades. The key stages in the mining lifecycle are depicted in Figure 3-2.

Figure 3-2: Mining Lifecycle



Based on information from (Government of British Columbia, 2019)

The first step in the mining process is to find and evaluate a deposit. Coal exploration starts with geological surveying followed by ore sampling and progressive data collection. Once an economical deposit is determined, the development process begins. This stage involves feasibility studies as well as mine design and environmental assessment. Construction of the mine takes place after regulatory approval is obtained and final investment decision is made. This includes site preparation and erection of mining facilities and supporting infrastructure.

The operation stage is the producing phase of the mine lifecycle which can last multiple decades depending on the size of the deposit and planned life of the mine. When a mine is in operation, ongoing activities involve continually exposing or accessing coal seams, mining the ore, and progressively reclaiming the associated disturbance where suitable to do so. When a mine is dedicated to a nearby power plant, referred to as mine mouth plant, little to no processing of the ore is required and coal is typically sent in its raw condition, referred to as run-of-mine (ROM). However, in the case of metallurgical or thermal coal for export, the mined coal undergoes some processing on-site, also known as beneficiation, to improve its quality.

Operation also involves coal handling and transport. The method of transport depends on the destination and how far it is. Coal is normally conveyed or hauled over short distances, such as to a mine mouth power plant or processing plant. This is considered within the mine fenceline. Outside the mine gate, rail is typically used for longer continental distances, and seaborne shipment is used for international trade.

The final stage of the mining lifecycle is mine closure once reserves are exhausted or if production is no longer economical. Closure involves the shutdown and decommissioning of mine operations including removal if equipment and dismantling of facilities. This is followed by final reclamation of the disturbed land per regulatory conditions.

For the purposes of this study, Advisian focuses on the operation stage including coal transport to mine gate. The BAT/BEPs examined in this study were selected based on their ability to have a material impact on emission sources within this boundary definition. Emissions associated with earlier stages of the mining lifecycle are considered marginal in comparison to operational emissions over the productive life of the mine. For example, construction GHG emissions from the proposed Grassy Mountain metallurgical surface coal mine in Alberta is estimated to be less than 0.5% of the total lifecycle emissions according to the environmental impact assessment application submitted by Riversdale Resources. Similarly, mine closure emissions contribute minimally to overall lifecycle emissions and are often omitted from environmental impact assessment estimates, especially since reclamation activities largely occur concurrently with mining activities and are accounted for over the operating life of the mine.

3.3 Mining Methods

Coal can be mined by either surface mining or underground mining. The choice of mining method is largely determined by the geology of the coal seam and surrounding topography. Surface mining is typically used to extract thick shallow coal beds, less than 60 m deep. Underground mining accounts for the larger share of global coal production, but in several important coal producing countries, Canada included, surface mining is the more common method (World Coal Association, 2019b).

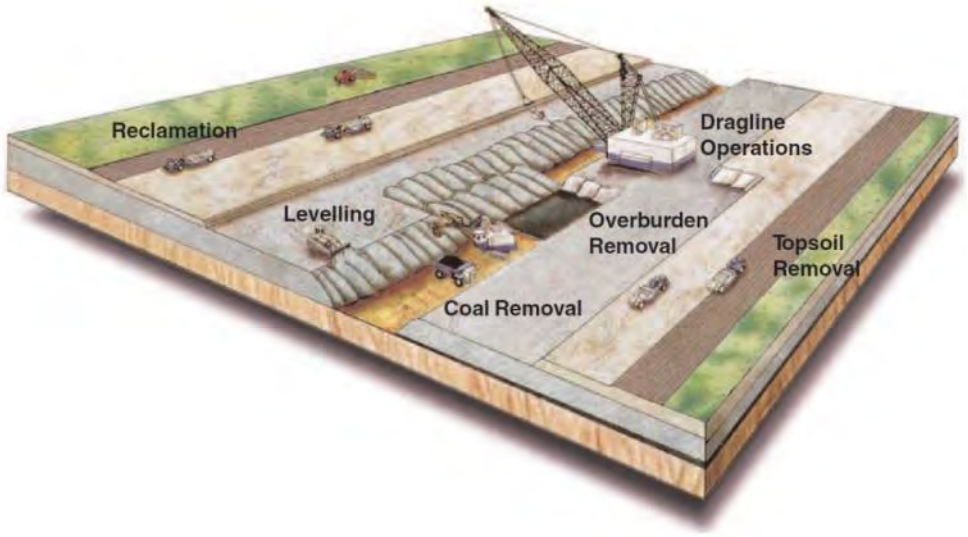
Surface mining has a number of advantages over underground mining. For example, coal recovery is higher – as much as 95% of the total deposit compared to 40-70% respectively. The productivity of surface mines, measured in tonnes per miner hour, can also be double or triple that of underground mines. These and other

factors result in a lower cost per tonne of coal mined using surface techniques (National Research Council, 2007). Surface mining also involves fewer health and safety risks to miners. On the downside, it has a larger footprint on the local surface environment.

3.3.1 Surface Mining

In surface mining, the layer of earth covering the coal deposit must first be removed to expose the coal seam for extraction. Surface mines in Canada are either strip mines, in which excavation occurs laterally in the form of an advancing trench; or open pit mines, in which excavation occurs in the form of a pit or burrow. Figure 3-3 shows a depiction of a surface strip mining operation.

Figure 3-3: Surface Mining Schematic



(National Research Council, 2007)

Strip mining is better suited for flat terrains, whereas open pit mining can be done in mountainous areas. The main difference between the two techniques is that in strip mining, the waste rock removed from one side of the trench can be concurrently used to backfill the mined area on the other side. In open pit mining however, waste material is typically transferred to external spoils until the pit is mined and then it is returned for reclamation. A mine may operate multiple active pits and/or advance from one pit to the next over its operating life to exploit the coal deposit.

Generally, surface coal mining involves the following sequence of unit operations:

1. Clearing the area of trees and vegetation and removing the upper layers of the unconsolidated soil, known as topsoil, which is salvaged and stored for later use. Diesel fuelled Bulldozers and scrapers play an important role in this stage of the mining process.

2. Drilling and blasting the hard strata on top of the coal seam referred to as the overburden. This is necessary in order to fragment the rock and allow for its excavation and removal. Blast holes are drilled using diesel fuelled rotary drills then charged with explosives from a bulk explosive truck.

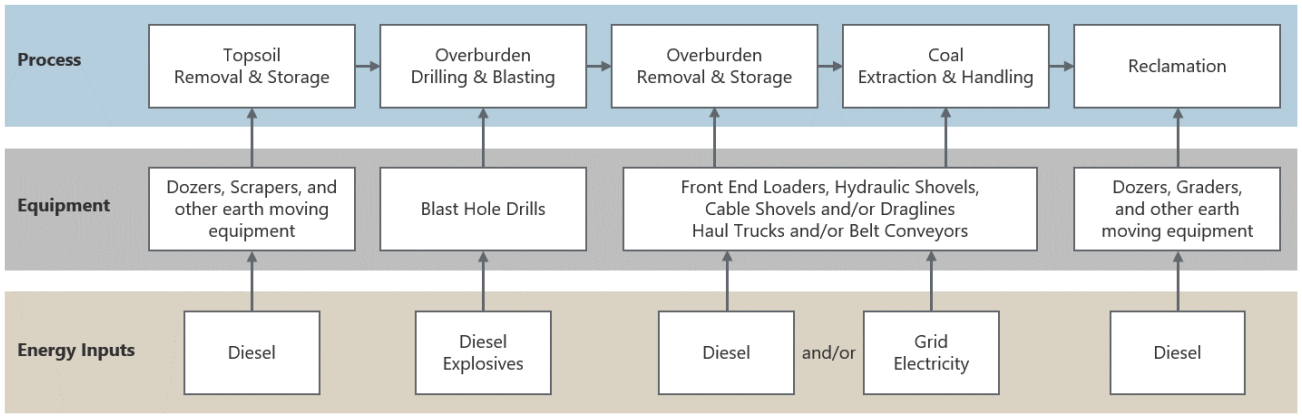
3. Removing the blasted overburden to expose the underlying coal and storing it for later use. This may be done using electrically driven draglines (typically used in strip mines) or by shovel and truck (typically used in open pit mines). Diesel fuelled end-dump off-highway mine trucks are commonly used. These may be loaded using any combination of: electric cable shovels, diesel operated hydraulic shovels, and/or diesel operated front end loaders.

4. Removing the exposed coal and sending it for processing or end use. The same equipment options used for overburden removal can be used for coal, although shovel and truck operations are by far more common than draglines. Raw coal is either trucked directly to the processing plant or to a stockpile area then conveyed to the plant. Where no processing is required, coal may be trucked all the way to a mine mouth power station or to rail load-out area for longer transport.

5. Reclaiming the mined area by backfilling with spoil and grading then spreading the topsoil and seeding. Equipment used during this stage include bulldozers and graders and other equipment used in agriculture.

Surface mining steps along with associated key equipment and energy inputs is illustrated in the block diagram of Figure 3-4.

Figure 3-4: Surface Mining Block Diagram



3.3.2 Underground Mining

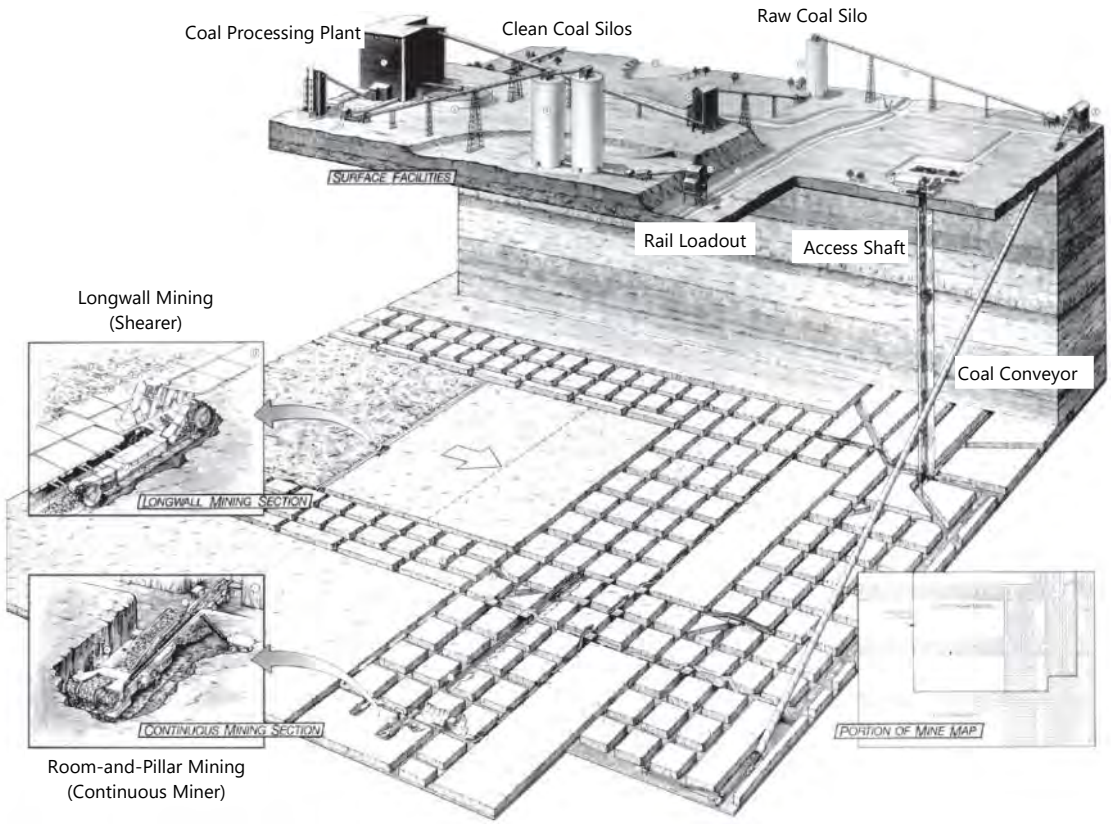
In underground mining, the mine workings take place several hundred feet below the surface surrounded by the overlying and underlying strata. Access to the coal seam is achieved through several openings from the surface that are bored through the ground to the coal bed level. These can either be in the form of sloping tunnels and/or vertical shafts.

Once the coal seam has been accessed, a network of underground roadways is established allowing for the installation of service facilities essential for underground mining including: worker and material transport, air ventilation, water drainage, and power. The extraction of coal during this phase of mine development is known as “first mining”. The extraction of the remaining coal once the mine becomes operational is termed “second mining”.

Various types of personnel carriers, typically diesel fuelled, are available for moving miners to and from the underground work area. Elevator systems are also used where shaft entrances are employed to carry miners and equipment between the coal seam and the surface. The coal is normally transported using a combination of conveyor belt systems and electric rubber-tired vehicles called shuttle cars.

Modern underground coal mining relies on two common mining systems: room-and-pillar using a continuous miner machine, and longwall using a shearer. Figure 3-5 is an illustration of underground coal mine workings using both techniques as well as surface facilities.

Figure 3-5: Underground Mining Schematic



(National Research Council, 2007)

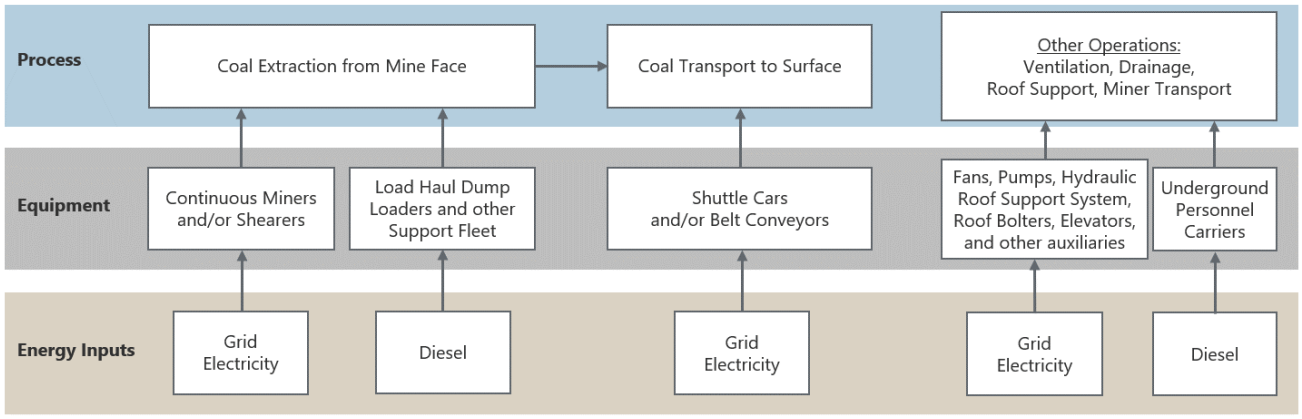
In room-and-pillar mining, coal is mined by cutting a network of parallel entries or rooms into the seam leaving behind pillars of coal to support the overhead strata. These pillars can be recovered at a later stage allowing the roof to collapse in a controlled fashion. Mechanized remote control mining machines known as continuous miners, tear the coal from the seam using rotating steel drums with tungsten carbide steel teeth. The excavated coal is typically loaded onto shuttle cars which are driven by miners to a conveyor leading to raw coal stockpiles or silos on the surface. From there coal is conveyed again to feed the processing plant. After cutting a section of coal roughly equal to its length, the continuous miner retreats to the next entry and a roof bolting machine installs bolts to secure the roof. Underground equipment also includes Load-Haul-Dump (LHD) machines that clean out headings as part of the operation.

In longwall mining, coal is mined in slices along the mine face. A rotating cutting machine called a shearer travels back and forth extracting all the coal between the floor and ceiling across a long wall and allowing the roof behind it to collapse at it advances. Self-advancing, hydraulically-powered supports hold up the roof above the shearer while coal is extracted. A conveyor system is used to transport the coal to the surface.

Longwall mining achieves higher recovery and production rates but is only suitable where coal seam thickness is consistent and in the absence of geographic faults. Longwall mines still use continuous miners to develop the mine and initial longwall panels. The choice of mining technique depends on geologic and economic considerations, longwall mining being a more capital-intensive operation.

The key underground mining operations along with required equipment and energy inputs is illustrated in the block diagram of Figure 3-6.

Figure 3-6: Underground Mining Block Diagram



3.4 Coal Processing

Raw coal in the as mined condition consists of a mixture of different sized fractions and often contains unwanted impurities such as rock, dirt, clay, sand, etc. Coal consumers, especially for use in steelmaking, require coal of a consistent quality. Coal processing – also known as coal preparation, coal beneficiation, coal cleaning, or coal washing – is the treatment of raw coal or ROM to bring it to a desired quality or end product.

Different mines apply different levels of coal processing and employ different process flow designs at the coal processing plant (CPP). Appendix A provides a sample of publicly available mine flowsheets to demonstrate varying processes. Generally, coal processing involves a combination of one or more of the following high-level unit operations:

1. Reducing the size of ROM coal to an acceptable maximum size for handling in the processing plant. This can be done using double roll crushers or rotary/feeder breakers that crush or break larger lumps of ore.

2. Classifying the coal by size and applying different cleaning processes on the different fractions. Screens are the primary means of sizing coal, acting as sieves that separate incoming coal into different streams by size. Multiple layers of sequential sizing and cleaning may be necessary. Coarse coal is typically cleaned using cyclones that utilize a dense medium, or water at the later stages of cleaning, to gravity separate coal from

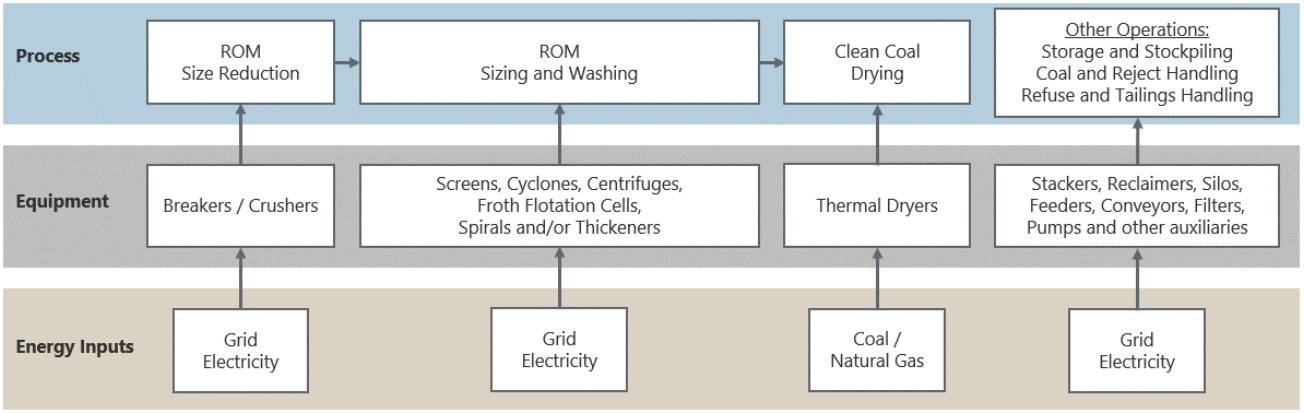
heavier impurities. Small coal fractions can be cleaned using centrifuges and/or froth flotation cells for a higher quality product. Equipment such as spirals and thickeners are used to dewater the cleaned coal.

3. Drying is required after froth flotation due to the excessive amount of moisture that results in the coal. This is typically done thermally using fossil fuel fired dryers.

Coal processing results in two main output streams: the clean coal product, which can be in the form of hard coking coal (HCC) and/or pulverized coal injection (PCI), and the waste reject. Multiple auxiliary systems support CPP operations including equipment required for handling and storing the various flow streams within the plant. With the exception of drying, coal processing operations are fully electrified.

Coal processing steps along with typical equipment and energy inputs is summarized in Figure 3-7.

Figure 3-7: Coal Processing Block Diagram



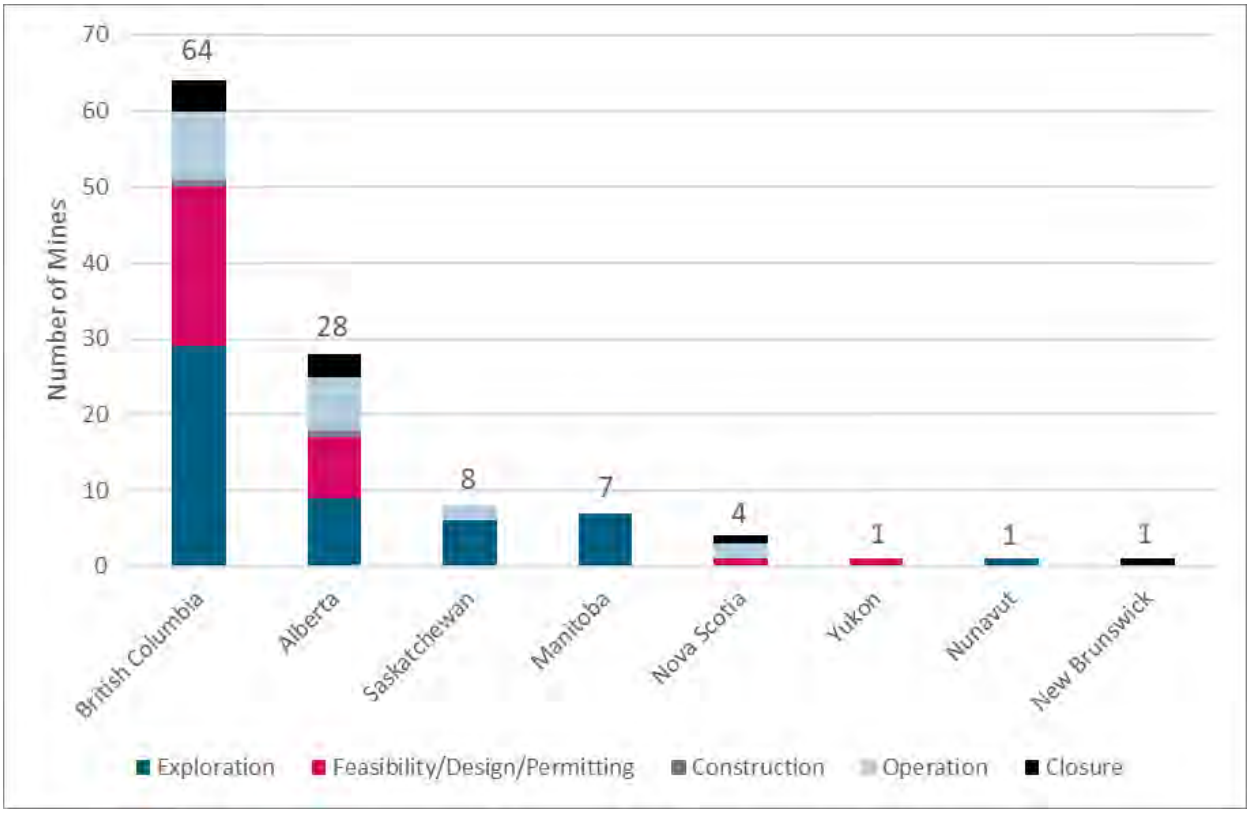
3.5 Canadian Coal Mines

Canada has the sixteenth largest proved coal reserves in the world, and in 2017, was the thirteenth largest coal producer, contributing 1% to total global production (NRCan, 2018). Continued demand for metallurgical coal from export markets in Asia Pacific is expected to drive production growth in the coming years (Canada Energy Regulator, 2018). Responsible environmental practices and reduction in the GHG emissions associated with resource extraction and processing over a mine's lifecycle will be an important factor in the longevity of the Canadian coal mining industry.

Canada has lignite, sub-bituminous, bituminous, and anthracite coal deposits. 95% of the country's reserves are concentrated in British Columbia, Alberta, and Saskatchewan. Lignite is primarily found in Saskatchewan, sub-bituminous coal in Alberta, and bituminous coal in British Columbia, Alberta, Nova Scotia, and New Brunswick. The only known considerable body of anthracite is situated in north western British Columbia (The Canadian Encyclopedia, 2019).

According to the online GlobalData database, there are currently 115 coal mines nationwide at various stages of the mining lifecycle. Figure 3-8 shows the distribution of mines by province and stage of development from exploration to closure.

Figure 3-8: Number of Coal Mines by Province and Stage of Development



Based on information from GlobalData database

As of the beginning of 2019, there were 20 operational mines in Canada as detailed in Table B-1 and Table B-2 of Appendix B. Of these mines, 17 are surface mines and two are underground mines plus the Grande Cache mine in Alberta which has both surface and underground operations. Current production from underground mines is estimated to be less than 5% of total Canadian coal production. All three operational underground mines in Canada are room-and-pillar.

The coal produced in British Columbia is predominantly metallurgical coal and is exported to international markets. By contrast, the majority of the coal produced in Alberta and Saskatchewan is thermal coal used domestically for power generation.

Looking at potential future coal mine developments as represented in Table B-3 of Appendix B, it is reasonable to discern that most new activity in the Canadian coal sector will be focused on surface coal mining of metallurgical coal, particularly in British Columbia.

4 GHG Emissions Overview

This chapter presents an overview of GHG emissions from coal production based on publicly available data sources followed by a discussion of emission drivers.

4.1 Emission Sources

GHG emissions in coal mines stem from two key elements: fugitive methane emissions from the coal seam, and energy use for mine operations as described below.

4.1.1 Methane Emissions

Coal Mine Methane (CMM), also referred to as seam gas, is formed during the coalification process and is released from the coal seam and surrounding strata during mining operations. Methane continues to be released from the coal during post-mining activities including processing, storage and transportation. The rate of release depends on the geology of the deposit and ore characteristics which determine how gassy a mine is. In general, older higher rank deposits have higher methane content due to the higher degree of coalification. Similarity, underground seams typically retain more methane than surface deposits due to their exposure to higher pressures increasing the adsorption capacity of the coal (Irving & Tailakov, 2001).

While site specific measurements and models provide the most accurate means of estimating methane emission rates for a given mine, national emission factors are commonly used as a tier two estimation method. Canada's National Inventory Report relies on studies that utilize measurement samples to develop weighted emission factors by province, ore type and mine type. The most recently published emission factors are shown in Table 4-1. These factors were adopted for the purposes of this study; however, it is important to note that there are variances within the literature and mine operators may resort to alternate factors when estimating their facility emissions.

Table 4-1: Methane Emission Factors for Coal Mining

Province	Ore Type	Mine Type	Emission Factor ($tCH_4/ktROM$)
Saskatchewan	Lignite	Surface	0.07
Alberta	Sub-bituminous	Surface	0.20
Alberta	Bituminous	Surface	0.55
Alberta	Bituminous	Underground	1.69
British Columbia	Bituminous	Surface	0.86
British Columbia	Bituminous	Underground	2.78
Nova Scotia	Bituminous	Surface	0.07
Nova Scotia	Bituminous	Underground	14.49

Adapted from (Environment and Climate Change Canada, 2019)

4.1.2 Energy Use

Coal mines utilize various sources of energy depending on method of mining, mine location, and associated mine design and planning.

1. *Explosives* are used in surface mining to fragment the overburden for ease of excavation and removal. A mixture of ammonium nitrate and fuel oil (ANFO) is commonly used for that purpose. Bulk explosives release CO_2 upon detonation.
2. *Diesel* is the primary fuel for mine mobile and earthmoving equipment. These form a vital component of surface mining operations. Underground mines require a smaller fleet of diesel fuelled utility vehicles as support equipment.
3. *Coal or Natural Gas* are used as fuel for operating coal dryers at mines that incorporate a processing plant. Thermal drying is necessary where coal cleaning by froth flotation is employed to reduce the moisture content of the coal product. Dryers can be coal fired, gas fired or dual fuel.
4. *Electricity* is used to power electrically driven equipment and is typically imported from the local grid as opposed to generated on site. Some surface mines utilize electric excavation equipment such as draglines and cable shovels displacing a portion of the diesel requirements. Underground mines are largely electrified including underground excavation equipment and surface support equipment. Coal processing plants are another significant consumer of electricity.

4.2 Emission Levels Based on GHGRP

The government of Canada's Greenhouse Gas Reporting Program (GHGRP) collects annual data on facility level GHG emissions through owner reporting. Industrial facilities including coal mining operations that emit 10,000 tCO_2e/yr or more are required to report their GHG emissions to the program. This includes direct emissions from mobile and stationary fuel combustion sources as well as methane emissions. Emissions associated with grid electricity trade are considered indirect emissions and are not included in the reporting scope. The most recent publicly available data is for 2017.

GHGRP data offer a valuable lens into the varying GHG emission levels of coal mines across Canada. A total of 17 coal mines participated in the program in 2017, of which 2 were lignite mines, 4 sub-bituminous, and 11 bituminous. With the exception of the Grande Cache mine which was in temporary care and maintenance in 2017, all other mines are surface mines. The underground Quinsam mine in British Columbia and Donkin mine in Nova Scotia were below the reporting threshold in 2017.

GHGRP data represents absolute annual operational direct emissions which has been compared to mine production data from the GlobalData database, allowing GHG intensities to be estimated. Table 4-2 provides an overview of the absolute and intensity levels organised by increasing mine production within each ore type category. All production values are based on raw coal amounts or ROM. Refer to Appendix B for additional information regarding the reporting mines. Note that where thermal coal is used to feed a mine mouth power plant, the generating station is considered a separate entity and is not included within the mine boundary.

GHG intensity levels are highest for bituminous mines. This is anticipated since these mines include coal processing facilities with energy intensive coal drying operations. Bituminous mines also have characteristically higher methane emission factors as evident from Table 4-1 above. Additionally, mine geology and topography

have an impact on strip ratio, or the volume of overburden/waste material removed per tonne of ore extracted, which tends to be higher in British Columbia where bituminous mines are concentrated.

According to the analysis presented in Table 4-2, the GHG intensity of Canadian surface bituminous mines ranged from 40-192 $kgCO_2e$ per tonne of ROM in 2017. A study published by the International Council on Mining & Metals (ICMM) in 2013 shows that global member companies have coal production GHG intensities ranging between 60-160 $kgCO_2e$ per tonne of clean coal with a weighted average of 90 $kgCO_2e$ per tonne of clean coal (ICMM, 2013). Assuming a typical clean coal yield from ROM production of 70%, these intensity levels translate to 42-112 $kgCO_2e$ per tonne of ROM with a weighted average of 63 $kgCO_2e$ per tonne of ROM.

Note that the ICMM data while representative of a global industry performance level, is not directly comparable to the Canadian data due to differences in process and product boundaries. For example, the ICMM analysis includes indirect emissions associated with electricity use. Additionally, ICMM covers all ore/mine types with varying methane emission factors.

Table 4-2: 2017 GHG Emissions and Intensities by Mine and Ore Type

Ore Type	Mine Name	Company	Province	Production (Mt ROM)	Emissions (tCO_2e)	2017 GHG Intensity ($kgCO_2e$/tROM)
Lignite	Poplar River	Westmoreland	SK	3.3	21,387	**7**
	Estevan	Westmoreland	SK	5.7	204,954	36 [1]
Sub-Bituminous	Paintearth	Westmoreland	AB	1.2	14,947	**12**
	Sheerness	Westmoreland	AB	3.2	37,687	**12**
	Genesee	Westmoreland	AB	5.0	44,154	**9**
	HighVale	TransAlta	AB	12.2	194,128	**16**
Bituminous	Grande Cache	CST Canada Coal	AB	0.0	4,583	N/A [2]
	Willow Creek	Conuma	BC	0.0	2,237	N/A [3]
	Brule/Dillon	Conuma	BC	1.2	186,586	**159**
	Wolverine	Conuma	BC	1.7	316,868	**192**
	Coal Valley	Westmoreland	AB	2.0	115,853	**59**
	Cardinal River	Teck	AB	2.1	95,875	**46**
	Coal Mountain	Teck	BC	2.7	108,124	**40**
	Line Creek	Teck	BC	3.6	187,483	**52**
	Greenhills	Teck	BC	5.0	449,058	**90**
	Elkview	Teck	BC	6.3	438,799	**69**
	Fording River	Teck	BC	9.1	521,744	**57**

[1] Reported emissions include mine operations and on-site char plant hence elevated GHG intensity

[2] Mine closed in 2015 due to poor economic conditions and was sold and reopened in 2018 – no production in 2017

[3] Mine idled in 2013 due to poor economic conditions and was reopened in 2018 – no production in 2017

Figure 4-1 is a graphical representation of the GHG intensities listed above with mines listed in the same order of increasing production within each ore type. A number of mine-specific conditions impact GHG performance hence the wide range of intensities observed within bituminous mines. These include: methane emission factors, strip ratios, haul distances and gradients, fuel used for coal drying, operator practices and equipment choices, and other mine design, scale and vintage aspects.

For example, considering the five Teck mines in British Columbia included in this analysis, Teck has informed Advisian that Greenhills is the highest coal consumer within its drying operations whereas Line Creek relies strictly on natural gas (Teck, 2019). Teck has also advised that Coal Mountain data for 2017 is likely not representative due to the mine nearing end of life at the time (Teck, 2019). Cardinal River presents a relatively low intensity consistent with a lower methane emission factor for bituminous surface mines in Alberta versus British Columbia. However, it is worthy to note that the mine utilizes coal for drying with no gas line connection to the mine (Teck, 2019).

The elevated intensity of Conuma's Brule and Wolverine mines is notable. Inspection of the reported emissions for these mines reveals disproportionately higher methane emissions. Figure 4-2 shows absolute mine emissions distinguishing between methane and the sum of all other GHGs attributed to fuel combustion. Brule and Wolverine exhibit significantly higher methane contributions compared to other mines at 72% and 86% respectively. Emission factors calculated based on these methane levels are 5-8 times higher than the National Inventory Report estimate for bituminous surface mines in British Columbia. It is possible that site measurements by the operator have indicated highly gassy coal seams in the area leading to higher than anticipated reported emissions at these mines.

Figure 4-1: 2017 GHG Intensities by Mine and Ore Type

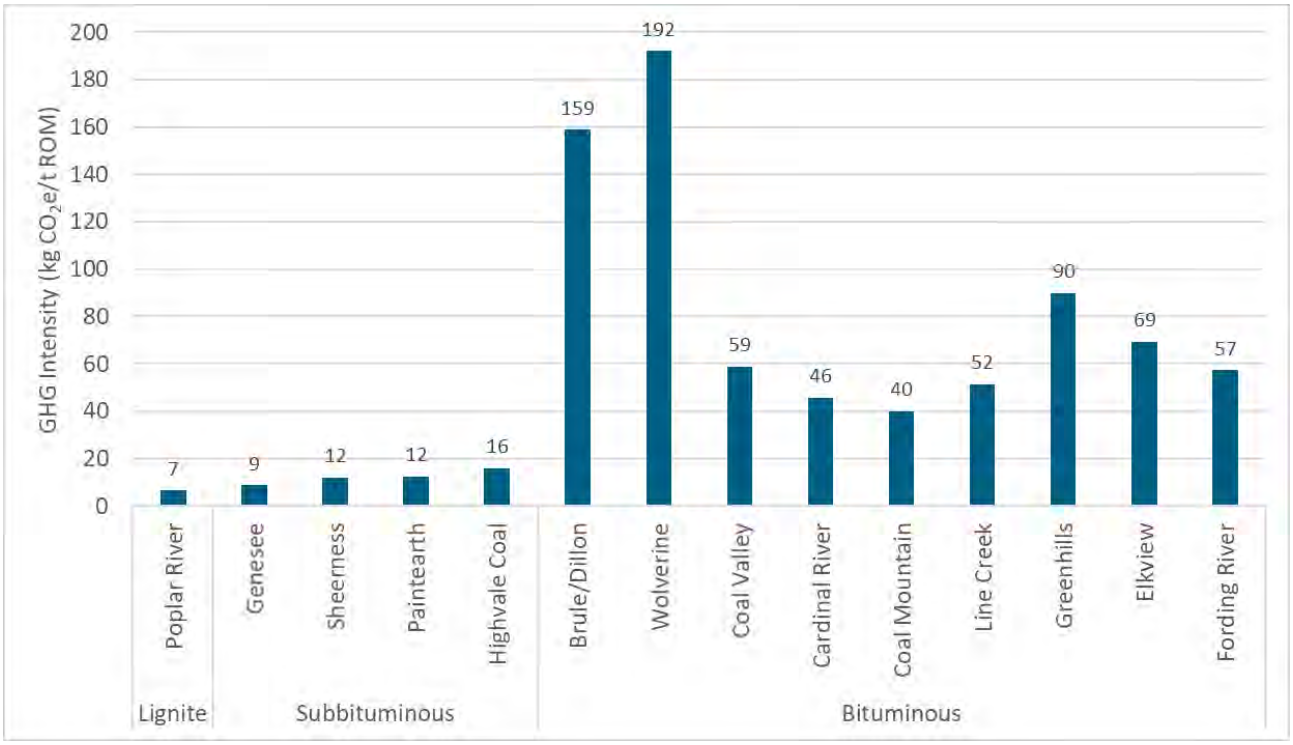
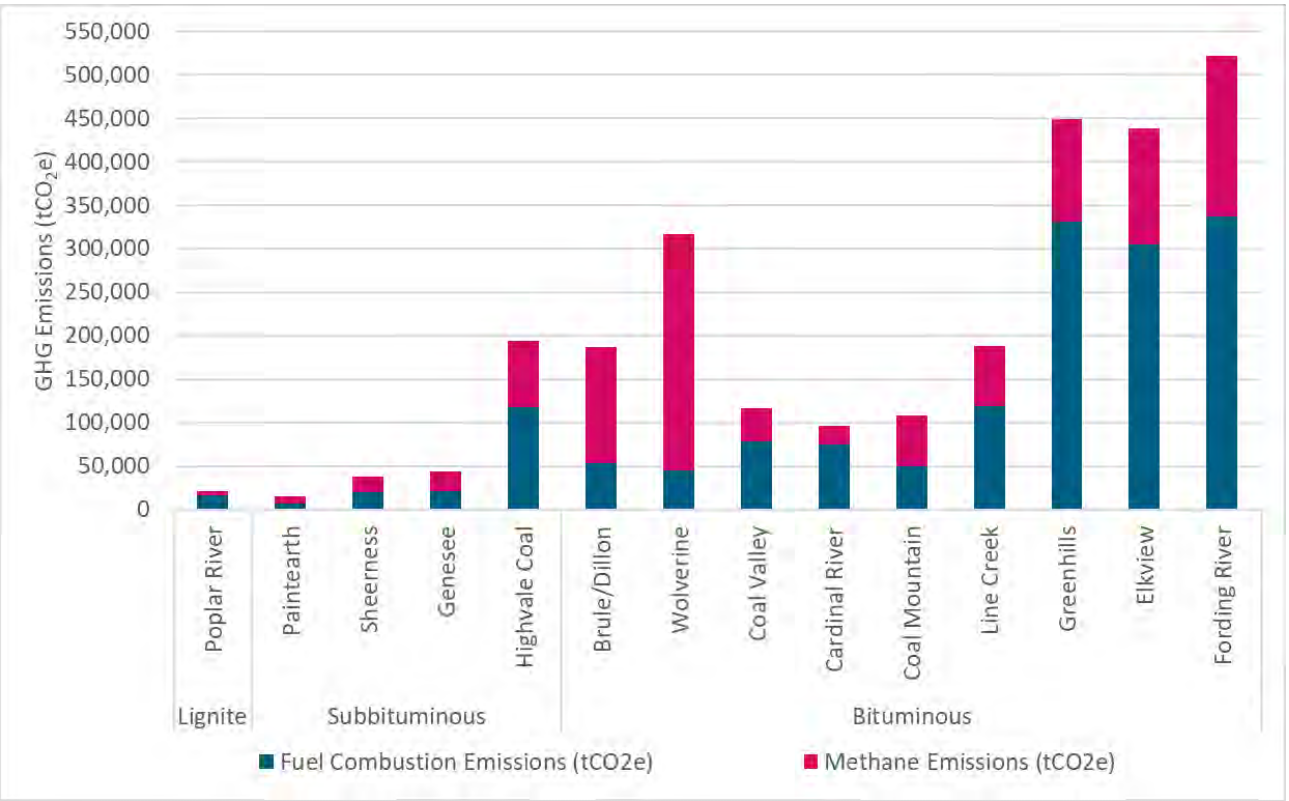


Figure 4-2: 2017 GHG Emissions by Mine and Ore Type



4.3 Surface Mining Emission Drivers

As evident from the emission levels presented in the previous sections, coal production in Canada has a highly variable GHG intensity. Considering surface mining and focusing on metallurgical mines typical of conditions in British Columbia, where most future coal mine developments are anticipated, Table 4-3 provides a breakdown of primary emission sources and their percent contributions to the total emission intensity.

A hypothetical surface mine with processing plant is used as a reference/baseline to establish the emission breakdown. Note that this is an assumed operation, i.e. not linked to any specific existing mine but representative of typical scale and performance. The energy/fuel consumption levels shown below are estimates developed by Advisian based on multiple sources including: (Goswami & Brent, 2016), (Kecojevic, Vukotic, & Komljenovic, 2013), (BCS Incorporated, 2002), input from Teck (Teck, 2019), and the Grassy Mountain Mine environmental impact assessment. The corresponding emission intensities are then derived using the conversion factors listed in Appendix C.

The following assumptions are made in establishing the hypothetical base case:

- Mine located in British Columbia
- Electricity imported from the BC Hydro grid – a low carbon intensity grid resulting in negligible contribution to total mine emissions

- Methane emission factor of 0.86 tCH_4/kt ROM according to the National Inventory Report and as listed in Table 4-1 for bituminous surface mines in British Columbia
- Electrically driven cable shovels for overburden removal per common practice
- Diesel fuelled machinery for coal removal and all other mine fleet operations per common practice
- Dual fuel burners for coal drying operating at a 50/50 split between coal and natural gas as a median case

Table 4-3: GHG Emission Breakdown – Surface Coal Mine and Processing Plant

Emission Source		Applicable Mine Activity/Equipment	Fuel/Energy Consumption	Energy Intensity (MJ/t ROM)	Emission Intensity ($kgCO_2e$/t ROM)	Percent Contribution
Mining	Methane	From Exposed Coal Seam	N/A	N/A	21.50	41.0%
	Diesel	Diesel Fuelled Mine Fleet	7.2 L/t ROM	276	18.94	36.1%
	Explosives	Overburden Blasting	2.0 kg/t ROM	7	0.40	0.8%
	Grid Electricity	Electrically Driven Shovels	15.0 kWh/t ROM	54	0.16	0.3%
Processing	Natural Gas	Coal Drying at CPP	2.3 m^3/t ROM	89	4.46	8.5%
	Coal	Coal Drying at CPP	3.0 kg/t ROM	89	6.64	12.7%
	Grid Electricity	Coal Sizing, Screening, Washing, Handling, etc. at CPP	31.0 kWh/t ROM	110	0.33	0.6%
Total		-	-	625	52.42	100%

The most significant contributors to GHG emissions from surface mines, and therefore the greatest opportunities for reduction, lie in coal mine methane and mobile fleet operation. Thermal drying at the processing plant is another material emitter. Given the assumption of a predominantly hydro powered grid, electricity consumption plays a small role in overall mine emissions. This is not true for mines connected to higher emitting grids, and emissions associated with electricity import become increasingly more material the higher the grid intensity.

4.4 Underground Mining Emission Drivers

Considering underground mining and focusing on metallurgical mines typical of conditions in British Columbia, where most future coal mine developments are anticipated, Table 4-4 provides a breakdown of primary emission sources and their percent contributions to the total emission intensity.

A hypothetical underground mine with processing plant is used as a reference/baseline to establish the emission breakdown. Note that this is an assumed operation, i.e. not linked to any specific existing mine but representative of typical scale and performance. The energy/fuel consumption levels shown below are estimates developed by Advisian based on multiple sources including: (BCS Incorporated, 2002), input from Teck (Teck, 2019), and the Donkin Coal Mine environmental impact assessment. The corresponding emission intensities are then derived using the conversion factors listed in Appendix C.

The following assumptions are made in establishing the hypothetical base case:

- Mine located in British Columbia
- Electricity imported from the BC Hydro grid – a low carbon intensity grid resulting in negligible contribution to total mine emissions
- Methane emission factor of 2.78 tCH_4/kt ROM according to the National Inventory Report and as listed in Table 4-1 for bituminous underground mines in British Columbia
- Diesel fuelled mobile support equipment and utility vehicles for miner transport per common practice
- Electrically driven conveyors for coal transport to surface and other auxiliary systems per common practice
- Room-and-Pillar operation using electrically driven continuous miner per existing Canadian mines
- Dual fuel burners for coal drying operating at a 50/50 split between coal and natural gas as a median case

Table 4-4: GHG Emission Breakdown – Underground Coal Mine and Processing Plant

Emission Source		Applicable Mine Activity/Equipment	Fuel/Energy Consumption	Energy Intensity (MJ/t ROM)	Emission Intensity ($kgCO_2e$/t ROM)	Percent Contribution
Mining	Methane	From Exposed Coal Seam	N/A	N/A	69.50	81.1%
	Diesel	Diesel Fuelled Mine Fleet	1.5 L/t ROM	57	3.95	4.6%
	Grid Electricity	Ventilation, Drainage, Roof Support, Coal Transport	70.0 kWh/t ROM	252	0.75	0.9%
		Continuous Miner	12.0 kWh/t ROM	43	0.13	0.1%
Processing	Natural Gas	Coal Drying at CPP	2.3 m^3/t ROM	89	4.46	5.2%
	Coal	Coal Drying at CPP	3.0 kg/t ROM	89	6.64	7.7%
	Grid Electricity	Coal Sizing, Screening, Washing, Handling, etc. at CPP	31.0 kWh/t ROM	110	0.33	0.4%
Total		-	-	641	86	100%

In underground mining, coal mine methane is the highest single source of GHG emissions followed by thermal drying at the processing plant and diesel consumption by the mobile fleet. Modern day underground mines are highly electrified; however, as with the surface mining case, electricity consumption plays a small role in terms of emissions due to the assumption of a largely renewable grid. This changes for mines connected to fossil fuel based grids, where the percent share of electricity emissions can be on par with methane emissions.

Note that the total emission intensity for the hypothetical underground mine is higher than that for the surface mine. This is driven by the substantial methane emissions typical of underground mines and in spite of the lower diesel requirements and higher degree of electrification compared to surface mines.

5 GHG-Reducing Opportunity Overview

This chapter provides an overview of GHG reduction opportunities in coal mines and introduces the technologies and practices selected for further evaluation in this study.

5.1 Primary Sources of Information

Advisian gathered information through desktop research of best available and emerging technologies and environmental practices identified in recent GHG emissions reduction research and technical studies. Advisian also sought out input and feedback on technology selection from industry stakeholders gaining insights from the Canadian and global contexts. Some of the primary sources of information were:

- Publications/activity by the Global Methane Initiative
- Publications/activity by the USEPA Coalbed Methane Outreach Program
- Publications/activity by Australia's national science research agency CSIRO
- The UNECE Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines (UNECE, 2016)
- A Rocky Mountain Institute Report on Bulk Material Handling Decarbonization Pathways (RMI, 2019)
- Input from the International Council on Mining and Metals (ICMM, 2019)
- Input from Canadian coal producers including Teck (Teck, 2019) and Westmoreland (Westmoreland, 2019)

5.2 Areas of GHG Reduction

In selecting GHG-reducing opportunities, Advisian considered the full scope of the coal mining and processing steps and energy inputs. Opportunities for GHG abatement exist in four key areas with varying degrees of potential as described in the following sections.

5.2.1 Methane Emission Abatement

As evident from the GHG emission breakdown presented in the previous chapter, CMM is the single largest source of GHG emissions in coal mining. Extracting coal through surface or underground mining methods releases methane gas trapped in the coal bed and surrounding strata. Abatement of such releases necessitates the degasification of the coal seam, coupled with either the destruction or utilization of the captured gas.

Degasification systems facilitate the removal of methane from a coal mine before, during, or after mining, and are generally classified as follows (refer to Appendix F for illustrations of various degasification schemes):

- **Pre-drainage** of CMM through a network of vertical wells drilled from the surface in advance of mining. In some cases, directional in-seam boreholes are also employed. Pre-drainage can be used for surface or underground mining. In both cases, drilling activities must be coordinated relative to the mining plan such that once a well is drilled sufficient time is allowed for drainage to justify the investment. Pre-drainage is generally more viable for seams with minimal faulting and of medium to high permeability, unless stimulation techniques such as hydraulic fracturing are used to improve gas flow (UNECE, 2016).

- **Ventilation** of underground mine workings is a critical aspect of any underground mine operation that is necessary for safety reasons. Ventilation systems consist of high capacity fans that draw clean air from the surface into the mine. Fresh air is distributed underground to dilute and remove methane at the mine working faces and all mine areas where miners are present. As a result, large volumes of ventilation air containing very low concentrations of methane, typically below 1%, are exhausted into the atmosphere. This ongoing release in underground coal mining is referred to as ventilation air methane (VAM), which may be abated through capture and treatment or utilization.

- **Post-drainage** of CMM is a technique specific to underground longwall mining in which methane is captured from the collapsed zone, known as gob, behind the mining face. Gob wells intercept and drain methane which would otherwise enter the mine airway, reducing the methane concentration near the active mine face. Post-drainage may be used by operators to supplement the ventilation system and is sometimes necessary to meet regulatory requirements for air quality at highly gassy mines. The captured gas is typically of lower concentration than what can be achieved via pre-drainage due to proximity to the working areas of the mine and contamination with large volumes of air. However, gas flow is enhanced due to caving and fracturing of the strata surrounding the coal as it is progressively mined (UNECE, 2016).

This study focuses on methane abatement through CMM pre-drainage and VAM treatment. Note that from a GHG reduction perspective, CMM pre-drainage is considered more advantageous than post-drainage. The primary difference is that pre-drainage yields higher methane concentrations and is therefore considered a best practice for methane abatement. Where post-drainage is necessitated, the captured gas may be destroyed or utilized using similar techniques as those discussed for pre-drainage while taking into consideration the lower methane concentrations typical of post-drainage.

Drainage of methane from coal mines is a proven technology that is applied in the United States, Australia, and recently in China. Many of the innovations in CMM production have been enabled by advancements in directional drilling and well completion technologies adapted from the oil and gas industry (Energy Edge, 2007). However, methane drainage is not widely adopted by the mining sector in Canada.

It is important to note that not all coal deposits are conducive to pre-drainage and therefore this abatement method is not applicable to every mine. Success of this technique may be hindered by low permeability or the presence of a heavily faulted deposit. Teck has indicated to Advisian that they recognize pre-drainage as a GHG reduction opportunity that requires further development for deployment in the British Columbia context (Teck, 2019). The mountainous topography of the region means that surface mines exhibit challenging geology with significant up-thrust/down-thrust and often narrow seams. Work is required to understand the continuity within the resource and gas movement characteristics and assess viability of this abatement method for existing and future mines in the province.

5.2.2 Mobile Fleet Emission Abatement

Various mobile equipment is used at both surface and underground mines to extract, handle and transport ore and waste rock throughout the mine. The mining industry is progressively moving toward electrification of their excavation and material handling operations such as with the use of draglines and electric cable shovels at surface mines, and continuous miners and electric shuttle cars at underground mines. However, diesel remains a primary energy source, especially in surface mining where is it responsible for the second largest share of GHG emissions.

Abatement of diesel-related GHG emissions may be done through further fleet electrification, meaning the conversion of additional classes of mobile equipment to electrically driven machines. Most notably are haul trucks used in surface mines and LHD units used in underground. Other abatement strategies include fuel switching to less carbon intensive fuels, as well as conveying the ore instead of hauling it to the CPP.

5.2.3 Coal Drying Emission Abatement

Coal drying is another source of emissions which occur during processing of the mined coal. Currently, conventional methods rely on fossil-fueled thermal dryers, many of which still burn coal. Commonly used thermal dryers, combust fuel to generate hot air that is then applied directly to the wet coal mass evapourating the entrapped moisture.

Fuel switching from coal to natural gas is a growing trend within the coal mining industry that reduces GHG emissions associated with product drying. Additionally, the use of mechanical drying techniques is an emerging approach that eliminates fossil fuel consumption altogether. Other abatement methods, including the use of biofuel/biomass, carbon capture and more, can be referenced under ECCC's BAT/BEP study for stationary combustion equipment (Hatch, 2019).

5.2.4 Integration of Renewable Generation

Electricity is a significant energy input in coal mining, especially underground mining due to the high power requirements of the ventilation system. The analysis presented in the previous chapter assumed a grid emission factor equivalent to that of a largely hydro powered grid such as in British Columbia. If a good-as-best-gas emission factor is used instead, which is the electricity generation benchmark in Alberta, the overall mining GHG intensity increases by 30% for the surface mine scenario and 50% for underground.

In such instances where the local grid is fossil fuel based, integration of renewable power generation at the mine site may be considered to lower the indirect GHG emissions associated with electricity import. The feasibility of this abatement strategy is highly dependent on site specific conditions such as quality of the renewable resource, and land use opportunities/limitations.

5.3 GHG-Reducing Measures

In selecting the measures to include in this study, Advisian considered a number of factors including: relevance and applicability to coal mining operations in Canada, GHG reduction effectiveness and materiality, as well as level of interest and momentum within the industry towards development/adoption. All selected BAT/BEPs are applicable in the Canadian context/climate. Information is as of 2019. The report does not consider policy announcements to exceed 2030 targets or goals to achieve net zero by 2050.

Table 5-1 and Table 5-2 list the GHG-reducing measures examined in this study for surface and underground mines respectively. The measures are organized by the targeted area of abatement. The technical readiness level (TRL) associated with each technology/practice is indicated based on the definitions in Appendix D. TRL 9 is the highest score indicating full commercialization. Note that the TRL is provided from a global perspective and is not intended to describe the degree of commerciality/adoption within the Canadian mining sector.

The measures are classified into two categories according to the level of analysis they receive in this study and where in the report they are discussed:

1. **BAT/BEP:** These are measures that are considered to be at the commercial or near-commercial stage with varying degrees of industry adoption and sufficient data to allow a cost-benefit analysis. These are described and evaluated in Chapters 7 through 10 with case studied presented in Chapter 11.

2. **Emerging Technology/Practice:** These are measures that are in the early stages of development or are yet to be adopted at a sector-wide commercial scale with limited availability of economic and performance data. These are discussed in Chapter 12.

Table 5-1: Surface Mining GHG-Reducing Measures

#	Area of Abatement	Measure	Short Name	Technical Readiness Level	Study Report Classification
1	Methane	CMM pre-drainage and injection in natural gas pipeline	CMMPipeline	9	BAT/BEP
2	Methane	CMM pre-drainage and utilization in power generation	CMMPowerGen	9	BAT/BEP
3	Methane	CMM pre-drainage and utilization in coal drying	CMMCoalDry	9	BAT/BEP
4	Methane	CMM pre-drainage and flaring	CMMFlaring	9	BAT/BEP
5	Mobile Fleet	Autonomous haul trucks	AutoHaul	9	BAT/BEP
6	Mobile Fleet	Mobile fleet LNG fuel blending	FleetLNG	9	BAT/BEP
7	Mobile Fleet	Mobile fleet fuel switching to B20 biodiesel	FleetB20	9	BAT/BEP
8	Mobile Fleet	Mobile fleet electrification using trolley assist	FleetTrolley	9	BAT/BEP
9	Mobile Fleet	Mobile fleet electrification using battery powered vehicles	N/A	5	Emerging
10	Mobile Fleet	Mobile fleet electrification using hydrogen powered vehicles	N/A	5	Emerging
11	Mobile Fleet	Use of overland conveyor for transporting ore to CPP	Conveyor	9	BAT/BEP
12	Mobile Fleet	Use of surface miners for material extraction and loading	N/A	5	Emerging
13	Coal Drying	Elimination of coal firing in coal dryers	DryerGasOnly	9	BAT/BEP
14	Coal Drying	Use of mechanical dewatering instead of thermal coal drying	N/A	5	Emerging
15	RE Integration	On-Site Solar Power Generation	Solar	9	BAT/BEP
16	RE Integration	On-Site Wind Power Generation	Wind	9	BAT/BEP
17	RE Integration	Small Modular Nuclear Reactor (SMNR)	N/A	2	Emerging

Table 5-2: Underground Mining GHG-Reducing Measures

#	Area of Abatement	Measure	Short Name	Technical Readiness Level	Study Report Classification
1	Methane	CMM pre-drainage and injection in natural gas pipeline	CMMPipeline	9	BAT/BEP
2	Methane	CMM pre-drainage and utilization in power generation	CMMPowerGen	9	BAT/BEP
3	Methane	CMM pre-drainage and utilization in coal drying	CMMCoalDry	9	BAT/BEP
4	Methane	CMM pre-drainage and flaring	CMMFlaring	9	BAT/BEP
5	Methane	VAM destruction using oxidization	VAMOxidizer	9	BAT/BEP
6	Methane	VAM utilization as principal/ancillary fuel	N/A	5	Emerging
7	Mobile Fleet	Mobile fleet fuel switching to B20 biodiesel	FleetB20	9	BAT/BEP
8	Mobile Fleet	Mobile fleet electrification using cable powered vehicles	FleetElecCable	9	BAT/BEP
9	Mobile Fleet	Mobile fleet electrification using battery powered vehicles	N/A	5	Emerging
10	Mobile Fleet	Mobile fleet electrification using hydrogen powered vehicles	N/A	5	Emerging
11	Coal Drying	Elimination of coal firing in coal dryers	DryerGasOnly	9	BAT/BEP
12	Coal Drying	Use of mechanical dewatering instead of thermal coal drying	N/A	5	Emerging
13	RE Integration	On-Site Solar Power Generation	Solar	9	BAT/BEP
14	RE Integration	On-Site Wind Power Generation	Wind	9	BAT/BEP
15	RE Integration	Small Modular Nuclear Reactor (SMNR)	N/A	2	Emerging

5.4 Compatibility Among GHG-Reducing Measures

Some of the technologies/practices listed above are complementary to one another and may be implemented in tandem to maximize the GHG benefit, while others are competitive abatement options that a producer must choose between. In general, technologies/practices within the same area of abatement are likely to compete for the total sum of emissions.

Producers should seek to have an abatement strategy in place for each of the key emission sources with a focus on areas where they can reduce the most emissions. For example, a mine may undergo CMM drainage and utilization to reduce methane emissions, mobile fleet electrification to reduce diesel emissions from mobile sources, and fuel switching in coal dryers to reduce emissions associated with the stationary combustion of coal.

Within methane emission abatement, injecting CMM into a commercial natural gas pipeline, utilizing it for power generation, and utilizing it for coal drying would be considered mutually exclusive alternatives. Additional infrastructure compared to the base case and relatively high capital investments are required for the pipeline and power options which is conducive to implementing a single diversion strategy for the drained gas. Flaring on the other hand, may be used in conjunction with CMM utilization as a means of handling excess gas or unutilized gas during shutdown or upset conditions.

A particularly gassy underground mine may benefit from implementing both CMM and VAM abatement projects. However, it is important to note that pre-drainage of a coal seam is bound to reduce the methane concentration at the working mine face. Therefore, it is important to analyse the predicted gas distribution and confirm the viability of VAM destruction/utilization at anticipated flow rates and concentrations.

Within mobile fleet emission abatement, LNG blending, trolley assists, battery powered vehicles, hydrogen powered vehicles and conveyors are considered singular solutions for surface mines, given their impact on the mine plan/operation. LNG blending and trolley assists require truck retrofits and significant infrastructure to supply the LNG and electric power respectively. Battery packs and hydrogen fuel cells have diverging implications to truck design and operating procedures such as charging/fuelling and maintenances activities. Furthermore, using hydrogen as fuel requires capital-intensive hydrogen generation facilities. The use of conveyors reduces the size of the mine mobile fleet considerably, and therefore diminishes the GHG reduction potential of other fleet related measures. Rarely would it make economic sense to apply a combination of the aforementioned technologies at a single mine operation except where justified for different phases of the mine development.

Similarity, it is unlikely that an underground mine would gain an advantage by investing in cable powered, battery powered and hydrogen powered vehicles simultaneously. In contrast, fuel switching to biodiesel is an adaptable abatement strategy that may be applied at various scales to displace petroleum diesel consumption not abated through electrification or other means.

Whether implementing multiple GHG reduction strategies or undertaking a single exclusive abatement project, it is necessary for producers to conduct feasibility studies that take into consideration mine-specific conditions, local energy costs, local resources, production rates and mine development plans to ensure emission reduction goals can be successfully met. In other words, it is important for producers to assess the technical and financial viability of BAT/BEPs for their specific mine as part of a holistic mine design and decision-making process.

Note that the premise for the BAT/PEP evaluation in this study is that the mining project proponent is in the development phase and is faced with the choice to either incorporate a given BAT/BEP in the design or not, i.e. implementation is not mandated for regulatory compliance or other drivers. Therefore, a sound business case is necessary to motivate adoption.

6 BAT/BEP Assessment Methodology

This chapter describes the methodology used to perform a quantitative assessment of the GHG-reducing BAT/BEPs selected for this study.

6.1 Overview

Advisian performed a cost-benefit analysis involving lifecycle financial modelling and GHG quantification. Using a spreadsheet tool, Advisian developed annual cashflows and GHG emissions for a surface mine base case, an underground mine base case, and each of the BAT/BEPs under review.

These models are constructed using lifecycle profiling of key project costs and benefits. The objective of the analysis is to examine the GHG performance and financial implications of implementing each of the BAT/BEPs in question relative to the base case. The following outputs are produced as evaluation metrics:

- Change in facility level GHG emission intensity and absolute emissions
- Change in net present value (NPV) of the mining project
- Total abatement potential and abatement cost per tonne of CO2e represented using Marginal Abatement Cost Curves (MACC)

6.2 Modelling Criteria

Project costs and benefits are used as modelling criteria that are tracked over the project lifecycle. Table 6-1 lists the criteria incorporated in the cost-benefit analysis organized by type of cashflow stream.

Table 6-1: Modelling Criteria

$ Stream	Criteria	Units	Comments
CAPEX	Initial Capital Costs	$	Mine and processing facilities
CAPEX	Sustaining Capital Costs	$/yr	Mine and processing facilities
Energy OPEX	Diesel Input	kL/yr	Based on process demand
Energy OPEX	Natural Gas Input	GJ/yr	Based on process demand
Energy OPEX	Thermal Coal Input	t/yr	Based on process demand
Energy OPEX	Explosives Input	t/yr	Based on process demand
Energy OPEX	Electricity Import from Grid	MWh/yr	Based on process demand
GHG OPEX	Energy GHG Emissions	tCO_2e/yr	Based on net energy consumption
GHG OPEX	Methane GHG Emissions	tCO_2e/yr	Methane emissions from coal deposit
OPEX	Operations & Maintenance Cost	$/yr	Includes labour
OPEX	Supplies/Chemicals Cost	$/yr	Based on process demand
OPEX	Closure Cost	$	At end of life
Revenue	Clean Coal Sold to Market	t/yr	Based on production capacity and yield rate

In the model, criteria are assigned base quantities which are then distributed over the lifecycle based on development curves that consider project construction, ramp up to production, production plateau, wind down phases and closure. Some criteria are inherently defined on a monetary basis such as capital costs and closure costs. Others, such as fuel input and GHG emissions, are profiled according to physical units, which are then multiplied by a cost per unit yielding the necessary cashflow streams.

Once the base surface and underground models were developed, modelling of the BAT/BEPs involved capturing the incremental change introduced to each of the criteria above, where applicable, as a result of implementing the BAT/BEP to the greenfield mining project. All cashflows and associated financial evaluation criteria are reported before tax and royalties. All carbon pricing is applied as non-rebated cost, where the full amount of the Carbon Levy is applied to each tonne of applicable GHG emission.

In addition to financial cashflows, annual GHG emissions were tallied considering consumption of diesel, natural gas, thermal coal, explosives and grid electricity, plus methane emissions. The GHG emissions reductions associated with the different BAT/BEPs are engineering estimates based on anticipated performance (e.g. amount of fossil fuel displacement, amount of methane capture, etc.) and are bound by the assumptions made for each scenario as outlined in the subsequent chapters.

6.3 Modelling Assumptions

The cost-benefit analysis relies on a number of input assumptions to construct the lifecycle models. Assumptions that are applicable across all or a group of BAT/BEPs are listed in Table 6-2. Assumptions specific to individual BAT/BEPs are discussed in the subsequent chapters. Fuel and grid emission factors and other values used in the analysis are listed in Appendix C.

Table 6-2: Modelling Assumptions

Parameter	Value	Source/Comment
General		
Mine Location	British Columbia	Assumed based on coal mining activity in Canada
Mine Life	4 yrs → 30 yrs → 1 yr	Construction → Operation → Decommissioning
Discount Rate	10%	Industry Typical
Clean Coal Yield from ROM – Surface	70%	
Clean Coal Yield from ROM – Underground	80%	
Methane Emission Factor – Surface	0.86 tCH_4/ktROM	Assumed based on bituminous mines in BC (Environment and Climate Change Canada, 2019)
Methane Emission Factor – Underground	2.78 tCH_4/ktROM	
Commodity and Emission Pricing		
Cost of Diesel	$0.84/L	(Kent Group, 2019)
Cost of Natural Gas	$1.93/GJ	(Sproule, 2019)
Cost of Thermal Coal	$92.64/t	(KPMG, 2019)
Cost of Electricity Import	$82/MWh	(AESO, 2019a)
Sale Price of Metallurgical Coal	$209.9/t	(KPMG, 2019)
Carbon Levy	$30/$tCO_2e$ in 2020 $40/$tCO_2e$ in 2021 $50/$tCO_2e$ after 2021	Assumed based on federal carbon pollution pricing (Government of Canada, 2019a)

Parameter	Value	Source/Comment
Pre-drainage System		
Pre-drainage Period	2 yrs	Assumed based on information from Teck (Teck, 2019)
Pre-drainage Well Spacing	305 m	Assumed based on default used in (USEPA, 2016)
Coal Bed Height - Surface	10 m	Assumed based on typical cumulative coal seam thicknesses
Coal Bed Height - Underground	2 m	Assumed based on a single room-and-pillar seam thickness
Well Depth - Surface	60 m	Assumed based on maximum depth for surface mining
Well Depth - Underground	305 m	Assumed based on default used in (USEPA, 2016)
Gathering Pipeline Length	4000 m	Assumed based on default used in (USEPA, 2016)
End-Use Pipeline Length	6000 m	Assumed based on default used in (USEPA, 2016)
Methane Concentration in Captured Gas	80%	Assumed based on good practice pre-drainage techniques
Pre-drainage Efficiency - Surface	40%	Assumed based on medium mine gassiness
Pre-drainage Efficiency - Underground	60%	Assumed based on high mine gassiness

6.3.1 Mine Life

The analysis is based on a hypothetical greenfield mining project starting in the year 2020. Four years are allowed for construction including procurement of material and equipment, site preparation, and erection of mine facilities and supporting infrastructure. The operating life of the mine is assumed to be 30 years followed by one year for decommissioning activities.

6.3.2 Discount Rate

The Discount Rate is an important aspect of financial modelling and is defined as the rate of return used to discount future cashflows to their present value. This rate accounts for the compounded time value of money and the cost of capital for an investment. In a discounted cashflow analysis, the value of future costs and revenues generated by a project along its lifecycle are diminished when expressed in current value. The higher the discount rate, the greater those differences. Companies use different discount rates based on their internal required rate of return and cost of borrowing. Generally, a 10% discount rate is common in the industry.

6.3.3 Commodity Pricing

The commodity prices shown in Table 6-2 are the most current forecasts for 2020. Refer to Appendix E for the full lifecycle price projections used in the model when computing project cashflows. These projections are based on short- and long-term market forecasts where such information is available, followed by constant escalation at an inflation rate of 2%.

6.3.4 Emissions Pricing

In this study, GHG emissions are priced according to the federal Output-Based Pricing System (OBPS) under the Greenhouse Gas Pollution Pricing Act. The OBPS regulations (SOR/2019-266) provide a regulatory carbon pricing framework for large industry sectors, designed to put a price on carbon pollution while maintaining market competitiveness (Government of Canada, 2019a).

The OBPS sets a performance standard for each sector, specified as an emission intensity per unit of product. Facilities pay for emissions over the standard and receive credits which they can sell if they perform better than the standard. For metallurgical coal production, the federal output-based standard is 0.0499 tonnes of CO_2e per tonne of metallurgical coal – understood to be on a clean or processed coal basis (Government of Canada, 2019a). No distinction is made between surface and underground mining or by mine location. Both combustion and non-combustion emissions are covered within this regulatory framework.

Using coal processing yields of 70% and 80% and converting emissions to kg, the adjusted federal output-based standard becomes 34.9 and 39.9 $kgCO_2e$ per tonne of ROM for surface and underground mining respectively. In the cost-benefit analysis models, mine emissions above these levels are priced at the carbon levy shown in Table 6-2. Emission reductions below these levels are assumed to be traded at the same price of carbon.

While emissions pricing methodologies may vary across provincial jurisdictions, the federal OBPS is deemed adequate for the purposes of this study. Note that the price of carbon has an important bearing on the final abatement costs determined for the GHG-reducing BAT/BEPs examined in this report. However, the value of the output-based standard adopted as the threshold for GHG charges/credits is of less significance due to the comparative nature of the analysis relative to the predefined base cases.

6.3.5 Pre-Drainage System

Several of the BAT/BEPs examined in this study involve CMM pre-drainage followed by various approaches for abatement of the captured gas. These BAT/BEPs are modelled according to the following common assumptions:

- The first set of wells are drilled during the construction phase, two years ahead of mining and continue to be drilled on an annual basis in new areas of the mine advancing at the same rate as mining activities. This allows a two year drainage period for each well. According to Teck, a minimum of 18 months is required for optimal performance (Teck, 2019).

- Wells are drilled vertically in a grid pattern at a fixed spacing of 305 m. In practice, well locations are selected more strategically based on the underlying geology and may include a network of vertical and lateral in-seam drilling. However, this is a simplification for the purposes of the analysis.

- The mining rate in km^2/yr, and therefore number of wells required per year, is determined based on the mine ROM capacity in t/yr and mineable coal height beneath the surface. Assumptions for the latter was made by examining the seam characteristics of several Canadian surface and underground mines. For the surface mining case, a cumulative seam thickness of 10 m was used. For the underground mining case, a single 2 m high seam typical of room-and-pillar operations was used.

- The cost of drilling is directly proportional to the depth of the vertical wells, assumed to be 60 m and 305 m for surface and underground mining respectively.

- Interconnecting piping is required between the wells and a central compressor station, assumed to be 4000 m away; and between the compressor station and end-use technology, assumed to be 6000 m away.

- A high quality gas is captured containing 80% methane. In its natural state, the gas contained in coal deposits is typically 80-95% methane with lower proportions of ethane, propane, nitrogen and trace

amounts of carbon dioxide (USEPA, 2016). By employing good practice pre-drainage techniques, leakage of air into the drainage boreholes and pipelines can be minimized and methane concentrations of 80% or higher are anticipated.

- Drainage efficiencies of 40% and 60% are achieved for surface and underground mining respectively. This is the share of total mine methane emissions that is captured through drainage rather than being emitted to the atmosphere as fugitive gas during operation. Drainage efficiency is impacted by mine gassiness given that gassier mines have inherently greater gas movement (USEPA, 2016). IPCC guidelines suggest that drainage efficiencies can be classified as low, medium or high at 20%, 40% and 60% respectively (Irving & Tailakov, 2001). A medium efficiency was assumed for the surface mine and high efficiency for the underground mine given their relative gassiness and considering that adequate time is allowed for drainage in this analysis.

6.4 Cost Estimation

The capital and operational costs used in this analysis should be considered as "Class 5" which is an order of magnitude level. Each input should be considered as having a potential variation of -50% to +100% (AACE International, 2016). This reflects the following limitations:

- Base cases are conceptual representations of the mines according to previously designed facilities assuming that they would be implemented soon. Due to the long design and implementation periods for projects the decisions accompanying previously designed facilities reflect different market conditions, regulatory drivers, and project sites.
- Best available technologies are conceptual representations of previously implemented schemes. The technologies may have been implemented concurrently with other projects and at different phases within the base facilities life cycle.
- Capital costs may be based on implementation of equipment provided by vendors. Although the vendor supply costs may appear firm, the costs for implementing the equipment encompasses many other costs. This includes engineering costs, owners' costs, freight, site preparation, installation, and commissioning. At the concept stage these costs are estimated using factors which are highly variable. In the experience of owners, these factors are frequently underestimated.

The uncertainties of individual costs estimates are somewhat mitigated through maintaining a comparative perspective. Technologies may be compared using their relative merits and performance rather than absolute and isolated performance outputs.

7 Assessment Details for Surface Mining BAT/BEPs

This chapter outlines the cost-benefit analysis details for the selected surface mining BAT/BEPs. A base case is defined followed by a description of the BAT/BEPs including key modelling input parameters. Each model is assigned a short name as an identifier used thereafter.

7.1 Base Case (SurfaceBase)

The surface mine base case is a hypothetical bituminous coal mine with ROM capacity of 5.0 Mt per year. The mine includes a CPP in which the raw coal is sized and washed through a series of separation processes then dried using thermal dryers. The energy input to the dryers is 50% natural gas and 50% thermal coal. At a clean coal yield rate of 70%, the mine produces 3.5 Mt of metallurgical coal per year.

The mine operates two to three active coal faces at any given time using open-pit mining methods. The mine is a truck and shovel operation in which the overburden is drilled and blasted then waste rock is dug using electric cable shovels and loaded into haul trucks. Waste material is transported a short distance and used to backfill the advancing pit. Bulldozers push the exposed coal into piles and front-end loaders load it into haul trucks that transport it to the CPP. The average haul distance from pit to CPP is 8 km.

The diesel operated mine fleet includes 28 290 tonne capacity end dump trucks, three loaders, six dozers, and a number of support equipment such as graders, scrapers, surface drills, and a water truck. The average diesel consumption per haul truck is assumed to be 187 L per operating hour at an average utilization of 75% (operating hours per year), making haul trucks the largest consumer of diesel at 1.23 million litres per truck per year (InterGroup Consultants, 2017).

Table 7-1 provides a list of key input data used to construct the base case model. All BAT/BEPs are modelled using the base case as a starting point and adjusting modelling parameters that are impacted by implementing the measure in question. Only those parameters that differ from the base case are listed in the subsequent sections for each of the BAT/BEPs.

Table 7-1: Model Data and Assumptions for SurfaceBase

Parameter	Value	Comments
Initial capital	$670 million	Distributed over first 4 years
Sustaining capital	$37 million/yr	Base value profiled over operating life
Natural Gas Input	445,000 GJ/yr	Base value profiled over operating life
Thermal Coal Input	15,188 t/yr	Base value profiled over operating life
Diesel Input	36,000,000 L/yr	Base value profiled over operating life
Electricity Import	230,000 MWh/yr	Base value profiled over operating life
Explosives Input	10,000 t/yr	Base value profiled over operating life
O&M Cost	$128 million/yr	Base value profiled over operating life
Chemicals Cost	$101 million/yr	Base value profiled over operating life
Closure Cost	$168 million	Assumed to be expended on year 35

7.2 CMM Pre-Drainage and Injection in Natural Gas Pipeline (CMMPipeline)

This abatement measure involves the drainage of methane from the coal seam in advance of mining according to the assumptions discussed in Section 6.3.5, followed by treatment of the captured gas and injection into a commercial natural gas pipeline. Where on-site utilization is limited or not possible, pipeline injection offers an alternative to the undesirable release of methane and introduces a new revenue stream from the sale of the gas.

Gas suitable for commercial distribution must have a minimum methane concentration of 96% and contain no more than 1 ppm oxygen (USEPA, 2019a). Captured CMM requires some processing to reduce nitrogen and carbon dioxide down to a 4% inert level and remove any oxygen and water content; however, it is typically free of hydrogen sulphide and other impurities found in natural gas (USEPA, 2019a). The quality of the gas resource is an important consideration for determining the suitability of this abatement measure as well as availability of a secure market demand for the produced gas.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMPipeline measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 9,000 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,117,000 based on the drained gas flow rate and assumed piping length.
- The mining rate is estimated to be approximately 370,000 m^2/y based on the mine ROM production rate and assumed cumulative seam thickness within a pit. The number of wells required to per year is found to be 4 wells based on that mining rate and assumed spacing between wells.
- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $765,000 per year based on the required number of wells and assumed well depth and piping length.

Pipeline Injection Costs

- Initial capex required for the oxygen removal system is a fixed amount of $1,250,000.
- Initial capex of other components of the gas upgrade facility is determined as a function of the gas flow rate into the facility and evaluated at $936,000.
- Initial capex of the high pressure pipeline required to connect the upgrade facility to the commercial natural gas pipeline is estimated at $765,000 based on an assumed distance of 1000 m.
- Annual opex to operate and maintain the pipeline injection system is determined based on a fixed cost plus a variable cost relative to gas flow rate into the facility amounting to $501,000 per year.

Abatement and Energy Balance

- Methane losses of 10% are assumed during the gas upgrade process.
- Methane losses of 10% are assumed during transport from the mine to the point of sale.
- The methane flow rate effectively captured and available for export is estimated at 5,800 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas. This amount is sold to market introducing revenue to the project. This amount also represents the nominal realized abatement which corresponds to 34,830 tCO_2e/y of avoided CMM emissions.
- The equipment added by this measure including blowers, compressor station and gas upgrade facility are considered new electrical loads estimated to consume an additional 1,000 MWh/y.

7.3 CMM Pre-Drainage and Utilization in Power Generation (CMMPowerGen)

As with the previous measure, CMMPowerGen involves the drainage of methane from the coal seam in advance of mining except that the captured gas is utilized to generate electricity for mine use rather than being sent off-site. The same drainage principles discussed above apply to this measure.

The drained methane is used to fire internal combustion engines which drive generators to produce electricity. Internal combustion engines are commercially available for this scale of operation and able to handle methane concentrations as low as 30% (USEPA, 2019a). Minimal gas processing is required upstream of the engines primarily to remove solids and water. Given the relatively high power demand of coal mines, the generated electricity can be used to offset purchased electricity from the grid.

An important consideration for power generation in this application is the unavoidable fluctuation in gas supply due to mining variabilities. When sizing CMM-fired power equipment, it is advisable to design the engine capacity for a continuous base load in terms of gas availability and avoid oversized and underperforming systems (UNECE, 2016). A flare may be used in conjunction with the power generation system to destroy peak flows and minimize emissions.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMPowerGen measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 9,000 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,117,000 based on the drained gas flow rate and assumed piping length.

- The mining rate is estimated to be approximately 370,000 m^2/y based on the mine ROM production rate and assumed cumulative seam thickness within a pit. The number of wells required to per year is found to be 4 wells based on that mining rate and assumed spacing between wells.

- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $765,000 per year based on the required number of wells and assumed well depth and piping length.

Power Generation Costs

- Methane losses of 12% are assumed due to natural variances in the volume and quality of methane that may lead to lower effective recovery and destruction.

- The methane flow rate effectively captured and available for power generation is estimated at 6,300 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.

- The power generation capacity is calculated to be 0.7 MW based on the available methane flow rate and assumed electrical power efficiency of 30%.

- Initial capex required for power generation including gas pre-treatment, internal combustion engines and generators, and electrical interconnection to the power grid is estimated at $1,109,000 based on the determined generation capacity.

- Annual opex to operate and maintain the power generation equipment is determined based on the amount of energy generation and is estimated at $169,000 per year.

Abatement and Energy Balance

- By combusting the captured methane in the engines and converting it to carbon dioxide, a nominal abatement corresponding to 33,754 tCO_2e/y of avoided CMM emissions is achieved.

- A net electricity generation of 6,400 MWh/y, after drainage power demands, is produced by the power generation system offsetting electricity imports by the project. This is a financial benefit to the project with minimal abatement potential for projects connected to low intensity grids.

7.4 CMM Pre-Drainage and Utilization in Coal Drying (CMMCoalDry)

CMMCoalDry is a direct-use abatement measure in which captured methane is directed to the coal dryers at the CPP displacing a portion of purchased natural gas. The presence of this heat demand within mine operations makes coal drying a good application for drained CMM.

The assumption is made that the drained gas quality is adequate for the intended use and does not require further processing to serve as fuel to the dryers. Additionally, beyond the drainage and recovery system, this abatement measure does not require the installation of new equipment since existing dryers are assumed to have dual burners capable of firing both natural gas and coal.

Design and operation of the drainage system follows that same philosophy as the other CMM abatement measures above, with the exception that drilling and drainage is assumed to start the first year of production as the dryers come online rather than during construction when no such sink exists. First wells are drilled in an area planned for mining two years into production and new wells continue to be drilled on an annual basis following mine advancement. This arrangement has the slight disadvantage of delaying methane abatement, meaning that coal mined in the first two years of production is not degasified and therefore mining activities during that period emit methane at the full mine emission rate.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMCoalDry measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 9,000 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,117,000 based on the drained gas flow rate and assumed piping length.
- The mining rate is estimated to be approximately 370,000 m^2/y based on the mine ROM production rate and assumed cumulative seam thickness within a pit. The number of wells required to per year is found to be 4 wells based on that mining rate and assumed spacing between wells.
- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $765,000 per year based on the required number of wells and assumed well depth and piping length.

Abatement and Energy Balance

- Methane losses of 12% are assumed due to natural variances in the volume and quality of methane that may lead to lower effective recovery and destruction.
- The methane flow rate effectively captured and available for power generation is estimated at 6,300 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.
- By combusting the captured methane in the coal dryers and converting it to carbon dioxide, a nominal abatement corresponding to 33,754 tCO_2e/y of avoided CMM emissions is achieved.
- Natural gas demand is offset by 90,000 GJ/y which is a financial benefit to the project as well as additional abatement through displacement of this energy input and associated emissions.
- The drainage blowers and compressor station added by this measure are considered new electrical loads estimated to consume an additional 145 MWh/y.

7.5 CMM Pre-Drainage and Flaring (CMMFlaring)

Destruction of drained CMM gas through flaring is a simple abatement strategy which may be suited for mine applications where utilization cannot be reliably achieved. Flaring can be safely done at methane concentrations as low as 30% (USEPA, 2019a). The drainage system is the same as that for CMMPipeline and CMMPowerGen.

This scenario assumes the installation of one or more open flame burners atop fare stacks based on the anticipated gas flow. The capital cost of the flare system includes the firing equipment as well as monitoring and metering devices to validate methane destruction levels. Annual operation and maintenance costs cover activities associated with the burners, pilots, instrumentation, automatic flare lockout controls, and flame arrestors (USEPA, 2016).

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMFlaring measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 9,000 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,117,000 based on the drained gas flow rate and assumed piping length.
- The mining rate is estimated to be approximately 370,000 m^2/y based on the mine ROM production rate and assumed cumulative seam thickness within a pit. The number of wells required to per year is found to be 4 wells based on that mining rate and assumed spacing between wells.
- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $765,000 per year based on the required number of wells and assumed well depth and piping length.

Flaring Costs

- Initial capex required for the flare system is estimated at $51,000 based on the inlet gas rate.
- Annual opex to operate and maintain the flare system is a fixed cost of $19,000 per year.

Abatement and Energy Balance

- Methane losses of 12% are assumed due to natural variances in the volume and quality of methane that may lead to lower effective recovery and destruction.
- The methane flow rate effectively captured and available for flaring is estimated at 6,300 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.

- By combusting the captured methane in the flare system and converting it to carbon dioxide, a nominal abatement corresponding to 33,754 tCO_2e/y of avoided CMM emissions is achieved.
- The drainage blowers and compressor station added by this measure are considered new electrical loads estimated to consume an additional 145 MWh/y.

7.6 Autonomous Hauling (AutoHaul)

Autonomous haul trucks are driverless trucks operated by specialized computer systems. Compared to manually driven trucks, autonomous haulers are outfitted with a control cabinet, wireless antennas, a guided positioning system, and a set of gyroscopes, radar, and lasers. Additionally, an in-office command station provides central monitoring and control of the autonomous fleet.

Autonomous haul trucks have higher utilization and availability compared to their manned counterparts since they are capable of operating 24 hours a day only stopping for refuelling. This means that by adopting this technology operators can reduce their fleet size. Autonomy also means less un-productive fuel burn and more efficient travel which results in fuel savings. Other benefits of the technology include less tire wear and greater machine reliability. The technology is also considered by the mining industry as a way to reduce human exposure and improve mine safety. Conversely, the technology is perceived by some members of the public as a threat to the labour force due to driver job cuts replaced by autonomy.

Autonomous hauling has been operational in several parts of the world for over 10 years including at a Codelco copper mine in Chile and several Rio Tinto iron ore mines in Australia. Suncor was the first to introduce the technology to North America in 2015 with its six-truck pilot fleet at its oil sands Base Mine. In January 2018, after demonstrating that the technology can be safely deployed in Alberta's climate and mining conditions, Suncor announced the commercial roll out of autonomous hauling systems across its mining operations. Several prominent global coal producers have announced decisions to implement or further evaluate autonomous hauling for their operations including BHP, Anglo American, and Whitehaven.

The key assumptions and input data used to construct the cost-benefit analysis model for the AutoHaul measure are outlined below.

Technology Costs

- Autonomous hauling promises productivity gains of 15-20% per truck resulting in an equivalent reduction in fleet size (Gleeson, 2019a). A productivity gain of 15% is assumed for this analysis bringing the haul truck fleet size required to move the same amount of ore down from 28 trucks to 25 trucks.
- At a unit cost of $4,800,000 per manual truck (Parreira, 2013), the avoided initial capital for 28 manual trucks is $134,400,000.
- At a unit cost of 6,000,000 per autonomous truck (Parreira, 2013), the new initial capital for 25 autonomous trucks is $150,000,000.
- Operation of autonomous trucks requires additional telecommunication infrastructure and digital hardware estimated to have a capital cost of $25,000,000.

- Sustaining capex is adjusted by a proportionate increase to maintain the same ratio of sustaining capex to net initial capex as the base case.

- Annual opex savings of $1.26/tROM is anticipated through reduced maintenance and labour costs when operating on autonomous trucks (Gleeson, 2019a).

Diesel Savings

- Autonomous trucks can yield fuel savings of 10-15% as a result of decreased idle time and more efficient travel patterns for the same throughput (CIBC, 2017). Fuel savings of 10% is assumed for this analysis yielding a reduction in diesel consumption of 3.44 million litres per year.

7.7 Mobile Fleet LNG Fuel Blending (FleetLNG)

This measure involves the use of natural gas to displace a portion of the diesel consumption by mine fleet haul trucks. This can be achieved by converting conventional diesel engines to dual-fuel engines. A second fuel tank for liquified natural gas (LNG) is added along with onboard electronics programmed to control fuel blending ratios based on operating conditions. For optimal performance, the engine is run on 100% diesel at low-speed and high-torque conditions, such as on inclines or when idling during a shovel load. The control system introduces LNG at higher speeds as certain engine permissive are met. LNG is vaporized into a gaseous state and blended with diesel allowing for up to 70% substitution.

The average diesel displacement rate over a shift varies depending on mine topography and other mine-specific operating parameters; however, results ranging between 30-50% average displacement have been reported (based on input from vendor and Salehi, et al., 2016). LNG can be supplied through a third-party or by installing an onsite micro LNG plant. The latter was assumed for this analysis as it is anticipated to be the more economical option given the remote locations typical of mine sites.

This technology was recently piloted by Teck at Fording River coal mine as well as by Alpha Coal West at the Powder River Basin in Wyoming. Results from these pilots have not been publicly published; however, Teck has indicated that the technology underachieved and expressed the following challenges and concerns to Advisian regarding future implementation (Teck, 2019):

- At its current state of development, the technology does not have adequate response time in terms of injecting the appropriate amount of gas to meet instantaneous power demands under typical duty cycles of haul trucks in the mining industry. The delayed response time can lead to increased diesel demand to compensate for insufficient gas blending. This may also result in a risk of methane slip due to incomplete combustion.

- The substitution rate observed in the pilot project was lower than advertised. Substitution rates upwards of 90% are required for material GHG reductions considering Teck's current targets. However, these models are not commercial yet and are not anticipated in the near future making investment in the technology less attractive compared to other competing technologies for mine fleet emission abatement.

- The technology poses challenges with regards to securing economically attractive LNG supply given the high transportation costs from remote liquefication plants and high capital required for on-site compression.

In Canada, aftermarket commercial conversion kits are available through GFS Corporation which offers a fully integrated field installed system for a range of truck models including the Komatsu 930E (290 tonne payload) used in the Teck pilot. Caterpillar is also working on dynamic gas blending retrofit kits for some of their models that service the mining industry. Note that in addition to GHG reduction due to fuel switching to a less carbon intensive fuel, dual-fuel engines offer reductions in the emission of nitrogen oxides and particulate matter emissions.

The key assumptions and input data used to construct the cost-benefit analysis model for the FleetLNG measure are outlined below.

Technology Costs

- The cost of the LNG conversion kit per truck is $400,000 (obtained by Advisian from vendor). For a fleet of 28 trucks, the initial capital required to convert the fleet for LNG blending is $11,200,000.
- Considering the base case fleet size and fuel consumption per truck, the initial capital cost of the onsite micro LNG plant and refuelling stations is estimated at $30,100,000 based on economic analysis presented in (Salehi, et al., 2016) and (Christopher, et al., 2015).
- Sustaining capex is adjusted by a proportionate increase to maintain the same ratio of sustaining capex to net initial capex as the base case.
- Annual opex associated with the new infrastructure and converted fleet is estimated at $5,805,000 per year, scaled from estimate provided in (Salehi, et al., 2016) and (Christopher, et al., 2015) for the base case operating conditions.

Energy Balance

- Assuming an average substitution rate of 40%, a reduction in diesel consumption of 13.76 million litres per year is achieved.
- The equivalent amount of natural gas required to deliver the same energy input to the engine is calculated to be 527,000 GJ/y.
- The electrical load for LNG compression at the micro LNG plant is estimated at 4,100 MWh/y based on LNG demand and a nominal power requirement of 0.89 W for a 1 GJ/y LNG supply rate.

7.8 Mobile Fleet Fuel Switching to B20 Biodiesel (FleetB20)

Biodiesel is a renewable diesel replacement fuel derived from biogenic sources such as vegetable oil, soybean oil or animal fats. Biodiesel-based fuels are available in different blends identified by the proportion of pure biodiesel in the fuel. A common biodiesel fuel is B20 which is 20% biodiesel and 80% petroleum diesel. B20 is readily available through normal fuel distributors, often at the same price point as diesel.

Note that different jurisdictions typically require fuel suppliers to incorporate a minimum renewable fuel content in their products. For example, in British Columbia diesel fuel supply is B4 and in Alberta it is B2. Pure biodiesel is considered carbon-neutral because crops used to produce it act as a carbon sink offsetting the emissions

released upon combustion. As such, the emissions benefit per litre of fuel is roughly commensurate with the blend ratio. However, biodiesel is slightly less energy dense than petroleum diesel which introduces a fuel consumption penalty of 2% when using B20 versus pure petroleum diesel (USDoE, 2019).

The emission factors used in the analysis for B4 and B20 and calculated to be 2.630 $kgCO_2e/L$ and 2.22 $kgCO_2e/L$ respectively using BC guidelines for GHG quantification (Government of British Columbia, 2017). The base case surface mine consumes 36,000,000 L of B4 per year. The FleetB20 scenario was modelled by replacing that with 36,720,000 L of B20 per year. Both fuels were assumed to cost the same per litre. No incremental capital or operating costs were applied.

B20 is more commonly used in the transport sector versus higher blends because it offers a good balance of cost, emission reduction, cold-weather performance and materials compatibility (USDoE, 2019). B20 can be use in existing engines with no modifications therefor operators interested in adopting this technology need only make supply chain changes to secure the sourcing and transportation of the fuel leading to immediate emission reductions (RMI, 2019). Higher biodiesel blends while attractive from a GHG reduction perspective present operational risks including: faster degradation of rubber components such as fuel hoses and pump seals, partial solidification of the fuel in extended storage, and unfavourable cold temperature flow properties (RMI, 2019).

7.9 Mobile Fleet Electrification Using Trolley Assist (FleetTrolley)

This measure involves the use of a trolley assist system to power haul trucks for a portion of their travel distance from pit to CPP. Trolley assists are overhead electric lines to which vehicles can connect to receive electric power during operation. These systems are commercially available and are utilized in several mining applications around the world.

Trolley assists reduce emissions by displacing the carbon intensive diesel fuel used in haul trucks with a more efficient and typically less carbon intensive form of energy, electricity. The greener the source of electricity, the greater the GHG reductions. Adoption of this technology is hindered by the high upfront capital and the fact that trolley lines have fixed locations and are impractical to redeploy according to changing mining demands. As such, the mine plan is a critical aspect of implementing this technology. Investment in a trolley assist system should be supported by a mine plan and layout that allows high utilization of the line throughout the mine life.

In this scenario, the trolley is assumed to be installed on a 6 km stretch covering 75% of the average 8 km haul distance between the active mining area and CPP. The trolley supplies power to loaded trucks travelling uphill en route to the CPP. One of the advantages of the trolley technology is that it allows haul trucks to travel at higher speeds otherwise limited by the capacity of the diesel engine – 30 km/h versus 12-17 km/hr. This translates to shorter cycle times and therefore higher productivity as trucks take less time per return trip.

A trolley assist system requires haul trucks to be fitted with electrical infrastructure to connect to the trolley line. This equipment adds 4-10 tonnes to the truck reducing its payload carrying capacity by the same amount – a marginal penalty of using the technology. Additionally, the technology requires the installation of the trolley line along the designated road and a transformer/substation at roughly 800 m intervals. The power supply to the trolley is designed based on the maximum number of trucks anticipated to be on the line at any given time.

The key assumptions and input data used to construct the cost-benefit analysis model for the FleetTrolley measure are outlined below.

Technology Costs

- Of the base case fleet of 28 haul trucks, 22 are assumed to be used for ore transport to the CPP, while the remaining 6 are assumed to transport waste rock within the pit.
- Using trolley assist is estimated to reduce the required ore transport fleet size from 22 trucks down to18. This is attributed to the productivity gain realized in the form of shorter cycle times while also considering the productivity loss due to the lower payload capacity of the electrically fitted trucks.
- The avoided initial capital for the 4 eliminated trucks is estimated at $19,200,000 based on a unit truck cost of $4,800,000 (Parreira, 2013).
- The new initial capital required for outfitting 18 trucks to use the trolley line is estimated at $9,000,000 based on a unit modification cost of $500,000 (high level estimate obtained by Advisian from industry).
- The new initial capital required for the trolley line and substations is estimated at $28,000,000 based on a unit cost for the line of $2,000,000/km and a unit cost for the substations of $2,000,000/substation (high level estimates obtained by Advisian from industry).
- Both sustaining capex and annual opex are adjusted by a proportionate increase to maintain the same ratios to net initial capex as the base case.

Energy Balance

- A reduction in diesel consumption of 15.9 million litres, equivalent to 59% of base case diesel consumption for ore transport, is estimated considering the following:
  - Loaded uphill travel accounts for up to 85% of fuel consumption for ore transport
  - The percentage of diesel consumption during loaded uphill travel subject to reduction is equivalent to the percentage of travel distance equipped with trolley, 75% assumed for this scenario
  - While a truck is on trolley, the diesel engine is set on low idle consuming roughly 40 L/h versus 500 L/h during normal loaded uphill travel, i.e. 92% reduction
- The electricity demand required by the trolley line is estimated at 71,300 MWh/y. This is determined based on delivering the same output energy as the displaced diesel at an assumed electric motor efficiency of 90% versus a typical diesel engine efficiency of 35%. This load corresponds to a trolley line capacity of roughly 8 MW enough for 2 trucks travelling simultaneously on the line.

7.10 Use of Overland Conveyor for Transporting Ore to CPP (Conveyor)

This measure involves the use of an overland conveyor to replace the use of haul trucks for a portion of the transport distance from pit to CPP. Because the maximum material size that can be handled by conveyors is typically smaller than the as-mined rock sizes, a primary crusher or breaker must be installed at the mouth of the conveyor to size the ore down to a conveyable material size. Overland conveyors are particularly functional when the mine plan and layout is such that there is a central location relative to the various coal faces where the crusher/breaker can be situated, feeding ore onto the conveyor.

Conveyors come in different forms, from traditional belt conveyors to low profile steel carts with articulated connections such as the Rail-Veyor® system. Ultimately conveyors electrify material transport thereby reducing GHG emissions. The extent of GHG reduction depends on how clean the electricity generation is. Conveyors also have the added advantage of reducing manned vehicle traffic and therefore increasing mine safety. Air quality improvements as a result of decreased haul road dust is another benefit.

The use of conveyors in mining is a well-established and proven practice; however, compared to trucking conveyors have the following limitations (RMI, 2019):

- They are limited in placement and movement and are only employable for certain mine plans
- They may require need to be relocated once or twice over the life of the mine
- They are a potential single-point of failure system which is subject to downtimes due to belt tearing, belt misalignment, and/or relocation

In this scenario, the conveyor is assumed to be installed on a 6 km stretch covering 75% of the average 8 km haul distance between the active mining area and CPP. The model assumes a belt conveyor and incorporates the cost for belt replacement several times over the life of the mine. The mine plan is assumed to be favourable for conveyance and the conveyor is assumed to remain at the same location for the life of the mine. No additional capital is required for the crusher/breaker feeding the conveyor as this is assumed to replace the first stage of material sizing otherwise happening at the CPP for the base case.

The key assumptions and input data used to construct the cost-benefit analysis model for the Conveyor measure are outlined below.

Technology Costs

- Of the base case fleet of 28 haul trucks, 22 are assumed to be used for ore transport to the CPP, while the remaining 6 are assumed to transport waste rock within the pit.
- Using conveyor technology as outlined above can theoretically reduce the required ore transport fleet size from 22 trucks down to 14. This is based on eliminating haulage between the crusher and CPP and only requiring trucks to move ore from the pit to the crusher. In practice, allowance must be made for conveyor downtime and the need to maintain production. Therefore, a fleet size of 16 trucks is assumed for ore transport in the conveyor scenario.
- The avoided initial capital for the 6 eliminated trucks is estimated at $28,800,000 based on a unit truck cost of $4,800,000 (Parreira, 2013).
- The new initial capital required for the conveyor and associated capital spares is estimated at $31,800,000 based on an installed cost of $5000/m (high level estimate from previous study work by Advisian).
- Sustaining capex of $9,000,000 is applied every 6th year for conveyor belt replacement. Sustaining capex savings proportional to the truck capex reduction is also applied.
- Annual opex for operating and maintaining the conveyor is estimated at $1,890,000 per year. Annual opex savings proportional to the truck capex reduction is also applied.

Energy Balance

- A reduction in diesel consumption of 18.2 million litres, equivalent to 68% of base case diesel consumption for ore transport, is estimated based on the eliminated loaded and unloaded travel distances as a result of installing the conveyor.
- The electricity demand required by the conveyor is estimated at 43,800 MWh/y. This is determined based on a sized drive capacity of 5.MW required to meet mine ROM capacity.

7.11 Elimination of Coal Firing in Coal Dryers (DryerGasOnly)

This measure involves the substitution of natural gas for thermal coal used as fuel in the CPP coal dryers. Energy input to the dryers is held constant, and dryer efficiency is assumed to be unchanged maintaining the same drying capacity as the base case facility. Coal fuel is replaced with an equivalent amount of natural gas based on their respective energy densities. The reduced carbon content of the natural gas results in a lower GHG emission rate and therefore a cleaner coal drying process.

In discussions with coal operations, most existing dryers have the ability to accommodate both coal and natural gas fuels. Within previous periods drying was done using predominantly coal with some gas input (≈10% by energy content). More recently, the operational trend has been to switch to natural gas. The limiting factor in some facilities is a connection to the natural gas commercial grid especially in the case of remote facilities.

The key assumptions and input data used to construct the cost-benefit analysis model for the DryerGasOnly measure are outlined below.

Technology Costs

- It is assumed that the base case facility can accommodate natural gas and no retrofit of the coal dryers is necessary. Therefore, no additional capex is included.
- Although there may be changes in operating procedures due to reduced handling of coal fuel and ash, it is assumed that there are no overall changes in non-energy opex.
- Energy opex related to the eliminated thermal coal is reduced, while energy opex related to natural gas increases. Under current pricing assumptions this results in a small net decrease in energy costs (<7%).

Energy Balance

- Coal consumption of 15,188 t/yr is eliminated based on the original fuel intake of the base case.
- Natural gas consumption of 445,000 GJ/yr is added based on the energy input being substituted.

7.12 On-Site Solar Power Generation (Solar)

This measure involves the installation of a photovoltaic solar farm (Solar PV) within proximity of the CPP. A representative 10 MW generation facility is assumed, offsetting a portion of the 26 MW total electric load

associated with the surface mine base case. The capacity factor of solar farms in Canada ranges between 9-18% of installed nameplate capacity (Canada Energy Regulator, 2019). In this scenario, a capacity factor of 15% is assumed, representing an average performance within the expected project area in southern British Columbia (World Bank Group, 2019a).

Solar PV is considered as a fuel displacement power generation option with the electric load being supplied (with back-up) by a continuous power supply. The continuous full-backup supply is necessary to compensate for the short-term intermittency of this renewable energy source.

A PV power plant does not produce any GHG emissions or criteria air contaminants as the system is generating electricity. Emissions primarily occur during other stages of the solar panel lifecycle. Minimal emissions are associated with maintenance due to vehicle traffic and during construction phases of the project.

Technical considerations reflected in the analysis for a conceptual design of the Solar PV option include:

- The PV panel, inverter, and racking system is from a tier 1 supplier at current industry standard sizes.
- A single-axis tracking system is chosen as an average design in terms of cost, performance, and land usage.
- There may be further advantages for a fixed-tilt system or double-axis tracking system in terms of mitigating low sun angle, shading, and snow build-up. A more detailed comparative analysis of the mounting system for specific sites would be undertaken if PV is considered.
- The PV nameplate capacity is sized for a proportion of the total average load to avoid disruption of the facility power as the solar farm output fluctuates and to avoid exceeding total facility demand.
- Technical challenges include land suitability and availability, airport zoning, glint/glare impacting flight paths, corrosion, shadowing, low temperatures, and low solar resource.
- Additional local factors impacting the capacity factor include climate, topographic shading (such as with mountainous terrains), and tall vegetation.

The potential application areas have severe environmental conditions that contribute to power losses and require additional maintenance or structural design considerations. This includes dusting and soiling, snow build-up, high wind loads, corrosion, and low temperatures. These technical challenges are mitigatable as demonstrated through the successful deployment of PV systems around the world under similarly challenging conditions.

Land use is the most significant environmental concern associated with Solar PV. The 10 MW farm considered in this scenario is expected to occupy a footprint of roughly 40 hectares based on an average land requirement of 4 hectares per MW of capacity (Ong, et al., 2013). This may include geotechnically suitable post-mining areas. A PV power block requires a significant surface footprint which may have environmental or cultural concerns depending on the region and surrounding communities. No significant regulatory concerns are anticipated for a PV facility.

The key assumptions and input data used to construct the cost-benefit analysis model for the Solar PV measure are outlined below.

Technology Costs

- A capital cost factor of $1,613 per kW capacity was used for the full Solar PV system, based on an installation in 2020. Further annual declines of over 2% in Solar PV capital costs are predicted between 2020 and 2030 (National Energy Board, 2018).
- A fixed operating & maintenance cost of $23/kW was used for the full solar PV system with no applicable variable operating costs (National Energy Board, 2018).
- The following factors are generally considered but may cause escalation in project costs if local conditions are extreme:
  - Regular washing and snow removal of the PV panels is necessary to reduce power losses.
  - Additional structural support for snow buildup is not incorporated so design relies on snow shedding.
  - Low temperatures improve PV cell efficiency, so they are only a concern for the inverters and ancillary equipment. Standard inverters are rated to -15°C, but there are inverters on the market with optional features for lower temperatures down to -40°C.

Energy Balance

- The Solar PV system will be installed in a behind the meter configuration so the output will directly offset a portion of the electricity demand at the facility.
- The Solar PV electricity contribution will not exceed the average minimum demand of the facility, so no electricity export is considered.
- Considering the installation size (10 MW) and capacity factor (15%), 13,140 MWh/yr of grid electricity will be displaced by on-site solar power.
- Within British Colombia the GHG offset potential is minimized due to the existing low carbon intensity of the predominantly hydroelectric powered grid.

7.13 On-Site Wind Power Generation (Wind)

This measure involves the installation of a wind farm close to the CPP. A representative 10 MW generation facility is assumed, offsetting a portion of the 26 MW total electric load associated with the surface mine base case. The capacity factor of wind farms in Canada ranges between 30-40% of installed nameplate capacity (GE Energy Consulting, 2016). In this scenario, a capacity factor of 30% is used assuming favourable co-siting of the coal and wind resources within the expected project area in southern British Columbia (World Bank Group, 2019b).

Assessing the feasibility of the wind involves identifying an optimal location, considering both the quality of the wind resource, and power connection requirements. Future mine sites are likely to be located in areas with variable terrain with corresponding variable suitability for turbine placement. Ridges and plateaus provide higher capacity factors but may be less proximate to project sites. For the purposes of this analysis, the Wind option is assumed to be deployed where a reasonably good wind resource exists in close proximity to the coal mine.

Wind Power is considered as a fuel displacement power generation option with the electric load being supplied (with back-up) by a continuous power supply. The continuous full-backup supply is necessary to compensate for the short-term intermittency of this renewable energy source.

Wind Power does not produce any GHG emissions or criteria air contaminants when the system is generating electricity. Emissions primarily occur during other stages of the turbine and transmission life cycle. Minimal emissions are associated with maintenance due to vehicle traffic and during construction phases of the project.

Technical considerations reflected in the analysis for a conceptual design of the Wind Power option include:

- Conventional horizontal-axis, upwind-rotor turbines and associated transmission requirements is assumed.
- The nameplate capacity is sized for a proportion of the total average load to avoid disruption of the facility power as the wind output fluctuates and avoid exceeding total facility demand.
- Wind turbines will be located to balance high resource potential and proximity to site including sufficient area available to meet the capacity requirements and minimum capacity factor.
- Site access for installation and operation of the required equipment and infrastructure may be difficult but it is assumed that installation equipment may be mobilized to site, and that year-round site access is feasible for operation.

Land use impacts of wind power will depend on size and scale of the facility; a single turbine will permanently disturb just under half a hectare (Denholm, et al., 2009) while surrounding area of the wind farm may still be used for productive purposes. Because turbines must be spaced hundreds of meters apart, wind farms require large parcels of land. The 10 MW farm considered in this scenario is expected to occupy a footprint of roughly 350 hectares based on an average land requirement of 35 hectares per MW of capacity (Denholm, et al., 2009). This is the total area inside a perimeter surrounding all of the turbines within the project. Where possible, installation in geotechnically suitable post-mining areas should be considered.

Wildlife and habitat are a concern for wind farms, particularly in relation to deaths of birds and bats due to collisions with wind turbines and the change in air pressure from the rotation of the turbines (NWCC, 2010). Sound, visual impact and aesthetics can be a community and public health concern wind farms. While public health issues have been disputed, community concern related to aesthetics and/or land value have been shown to have a direct impact on the ability to obtain necessary approvals (Batel, et al., 2013).

The key assumptions and input data used to construct the cost-benefit analysis model for the Wind Power measure are outlined below.

Technology Costs

- A capital cost factor of $1,541 per kW capacity was used for the full wind power system, based on an installation in 2020. Further annual declines of over 1% in wind power capital costs are predicted between 2020 and 2030 (National Energy Board, 2018).
- A fixed operating & maintenance cost of $40/kW was used for the full wind power system with no applicable variable operating costs (National Energy Board, 2018).

- Low temperatures increase air density to improve wind turbine efficiency, so they are only a concern for the inverters and ancillary equipment. Standard inverters are rated to -15°C, but there are inverters on the market with optional features for lower temperatures down to -40°C.

Energy Balance

- The wind power will be installed in a behind the meter configuration so the output will directly offset a portion of the electricity demand at the facility.
- The wind power electricity contribution will not exceed the average minimum demand of the facility, so no electricity export is considered.
- Considering the installation size (10 MW) and capacity factor (30%), 26,280 MWh/yr of grid electricity will be displaced by on-site wind power.
- Within British Colombia the GHG offset potential is minimized due to the existing low carbon intensity of the predominantly hydroelectric powered grid.

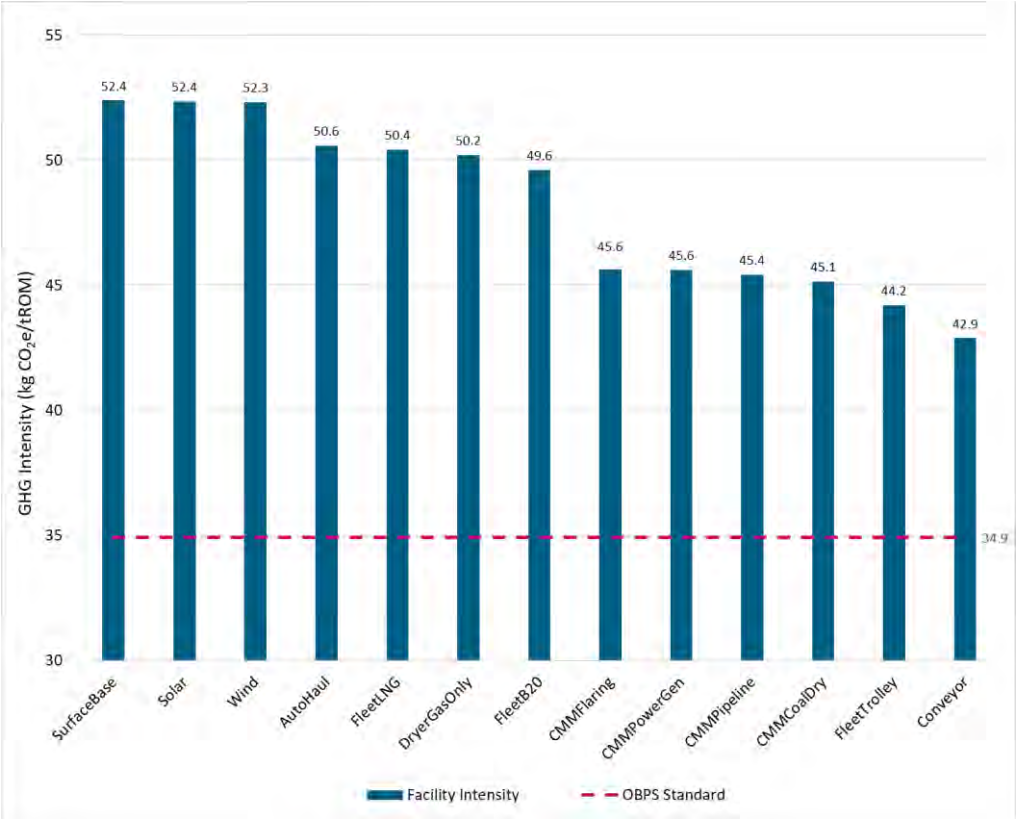
8 Assessment Results for Surface Mining BAT/BEPs

This chapter presents the results and key findings from the cost-benefit analysis conducted for surface mining BAT/BEPs.

8.1 GHG Intensity Reduction

To examine the effectiveness of the surface mining BAT/BEPs in reducing GHG emissions, the lifecycle GHG intensities were computed and plotted relative to the base case surface mine with accompanying percent reductions as shown in Figure 8-1. As a reference the federal OBPS benchmark, described in Section 6.3.4, is also included. Note that none of the BAT/BEPs are anticipated to impact ROM production if designed and sized to match the desired mine capacity.

Figure 8-1: Surface Mining Lifecycle GHG Intensity



Measure	Solar	Wind	AutoHaul	FleetLNG	DryerGasOnly	FleetB20	CMMFlaring	CMMPowerGen	CMMPipeline	CMMCoalDry	FleetTrolley	Conveyor
Reduction	0.05%	0.11%	3.5%	3.8%	4.2%	5.3%	12.9%	12.9%	13.3%	13.8%	15.6%	18.1%

The lifecycle intensity is determined based on the anticipated emissions over the operating life of the facility divided by the total ROM coal production over the same timeframe. In the figure above, BAT/BEPs are arranged in decreasing order of intensity to exhibit the relative performance of the technologies.

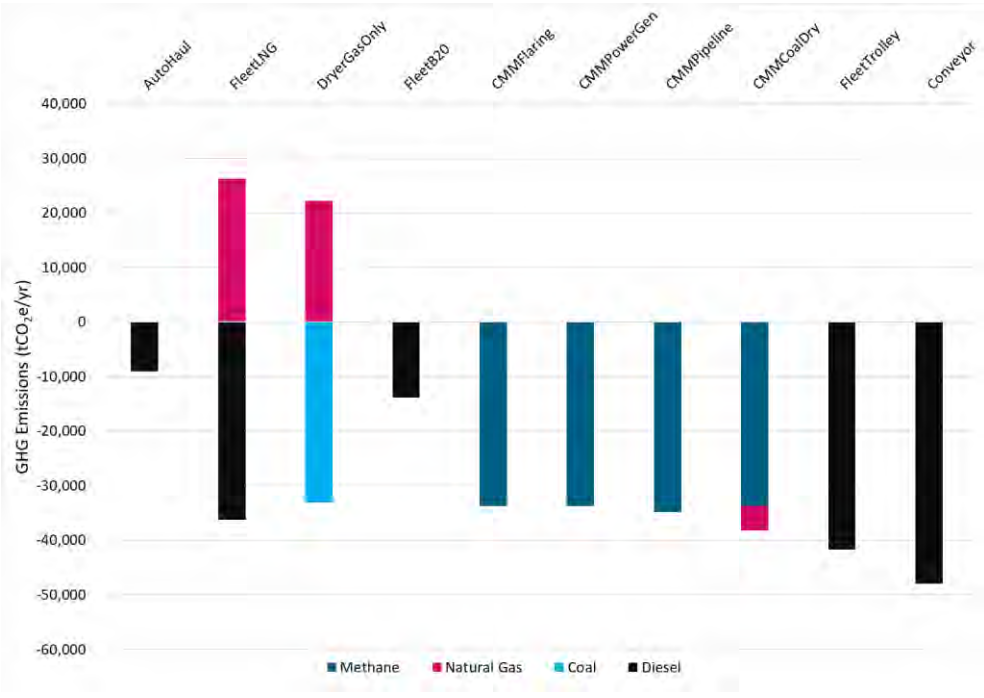
Solar and Wind offer negligible GHG advantage over the base case, given the assumption of a renewable grid. If the grid emission intensity were equivalent to a good-as-best-gas intensity of 370 kgCO_2e/MWh instead, implementing Solar and Wind can be expected to reduce the mine lifecycle GHG intensity by 1.4% and 2.8% respectively. The good-as-best-gas intensity is the benchmark that the electricity sector in Alberta is subject to for emission reduction purposes and is therefore representative of a future state of the Alberta grid. Using the current Alberta grid emission factor of 570 kgCO_2e/MWh (Government of Alberta, 2019a), the GHG intensity reductions attainable through the Solar and Wind options are found to be 1.9% and 3.8% respectively.

All other BAT/BEPs offer measurable GHG reductions with significant step changes occurring within CMM abatement technologies as well as the trolley assist and conveyer options for material handling.

8.2 Annual GHG Emission Reduction

To further examine the BAT/BEPs, the change in annual emissions relative to the base case is presented in Figure 8-2. Emissions are broken down by source in the chart to highlight the means of GHG reduction associated with each measure, and are also listed as a net change in the table. The base case surface mine emits 259,346 tCO_2e/yr nominally per operating year. The incremental change in these emissions as a result of implementing a given BAT/BEP is calculated with respect to each individual emission source. A negative value represents a GHG reduction and a positive value represents a GHG increase. Note that electricity is not included as an emission source in the chart due to the low GHG materiality associated with the electric grid assumed for this analysis.

Figure 8-2: Surface Mining Annual GHG Emission Change



BAT/BEP	Net GHG Change (tCO_2e/yr)
AutoHaul	-9,047
FleetLNG	-9,869
DryerGasOnly	-10,922
FleetB2O	-13,898
CMMFlaring	-33,753
CMMPowerGen	-33,822
CMMPipeline	-34,819
CMMCoalDry	-38,225
FleetTrolley	-40,931
Conveyor	-47,516

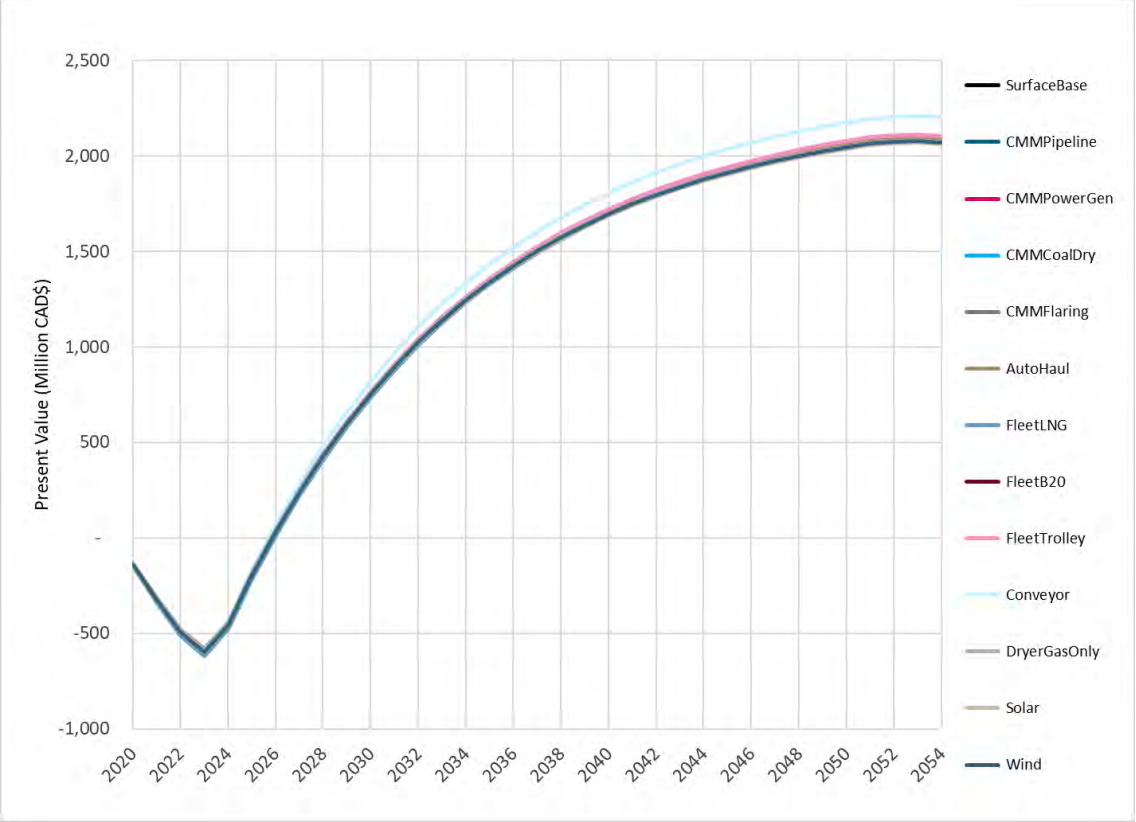
Surface coal mines can realize significant GHG reductions by targeting coal drying emissions, CMM emissions and electrifying coal transport through trolley assist or conveyors. A combination of measures directed at different emission sources may be implemented to maximize GHG reduction.

8.3 Financial Performance

To examine the financial attractiveness of the various BAT/BEPs, the financial model was used to calculate the net present value (NPV) of a mining project incorporating each of the BAT/BEPs in comparison to the base case. NPV is the net sum of costs and revenues discounted through the life of the project and expressed as a present value. A profitable project has an NPV above zero. The higher the NPV, the greater the profit.

Figure 8-3 is a plot of the discounted cumulative cashflow of the base case surface mine as well as each of the BAT/BEPs considered. The final cashflow value is the mine NPV in 2020 dollars with a lifecycle running to the end of 2054. The year in which the cashflow curve crosses the x-axis denotes the payback period of the mining project, i.e. the point at which the mine recoups initial capital and begins to generate profit.

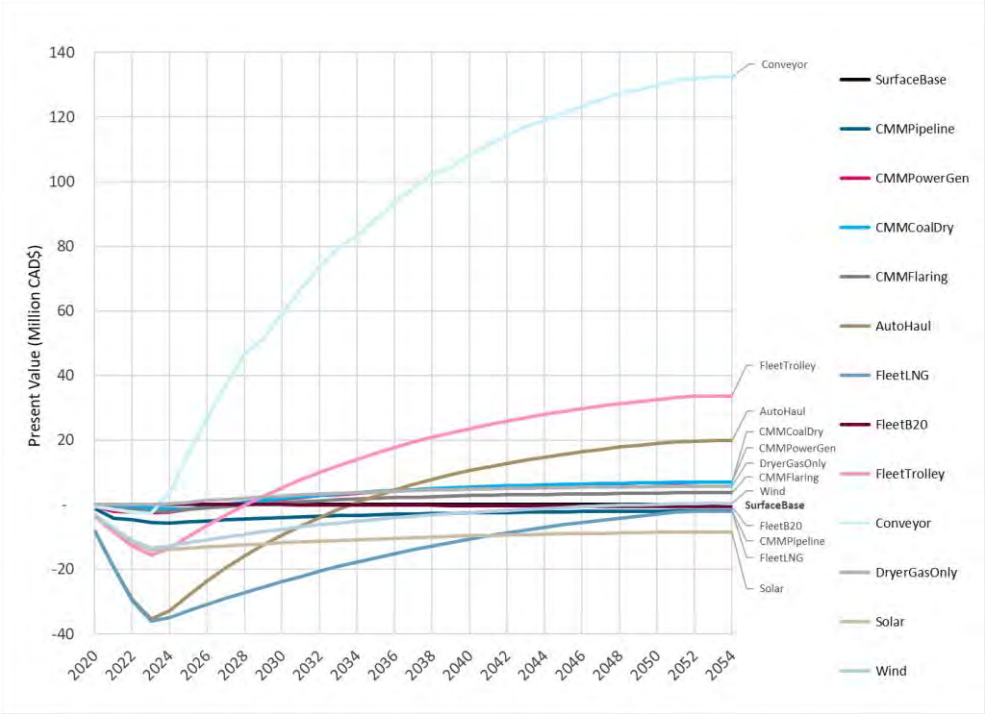
Figure 8-3: Surface Mining Cumulative Cashflow in Present Value



All BAT/BEPs are found to have positive NPVs around the base case of $2.096 billion with the majority exceeding that value. The graph also shows that the BAT/BEPs have little impact on the overall payback of the mining project which remains around 3 years of operation. This is due to the relative magnitude of the BAT/BEP costs to the overall mine development investment.

Figure 8-4 provides a closer look at the relative performance of the BAT/BEPs by plotting the differential cumulative cashflow above/below the base case. This diagram represents the cumulative costs and savings associated with implementing the individual BAT/BEPs. The year in which the curve crosses the x-axis for a given BAT/BEP, reflects the payback period for the investment associated with that measure, independent to the base case mine costs and revenues, as summarized in the table.

Figure 8-4: Surface Mining Differential Cumulative Cashflow in Present Value



BAT/BEP	Payback (# years of operation)
CMMPipeline	N/A
CMMPowerGen	4
CMMCoalDry	4
CMMFlaring	5
AutoHaul	11
FleetLNG	N/A
FleetB20	N/A
FleetTrolley	6
Conveyor	1
DryerGasOnly	0
Solar	N/A
Wind	27

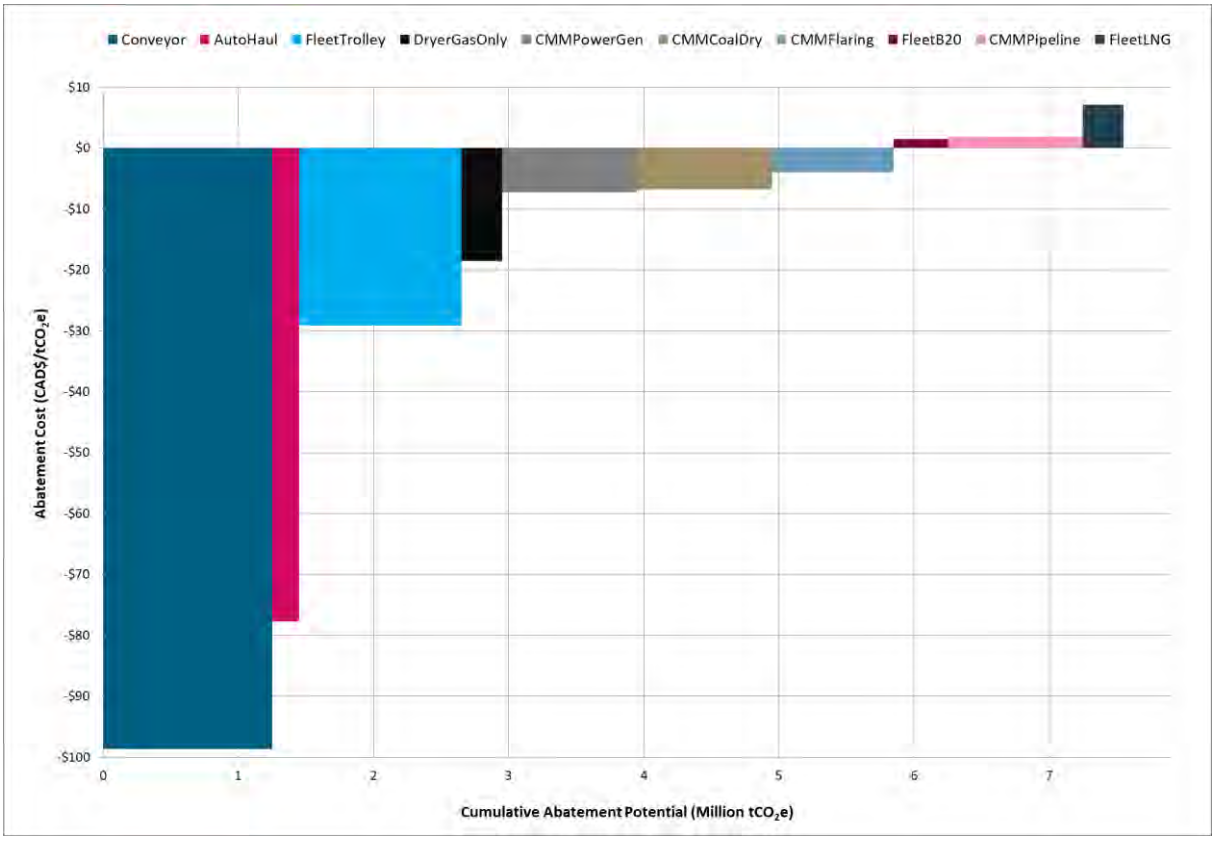
In increasing order of profitability, the following technologies prove to measurably improve the economics of a surface mining project while reducing the GHG emissions of mining activities: CMMFlaring, DryerGasOnly, CMMPowerGen, CMMCoalDry, AutoHaul, FleetTrolley, and Conveyor. Notice that FleetTrolley and Conveyor are also the top performers in terms of GHG intensity reduction among the BAT/BEPs. Wind NPV is only marginally above the base case whereas FleetB20, CMMPipeline, FleetLNG, and Solar have NPVs lower than the base case.

8.4 Marginal Abatement Cost Curve

In this section the GHG-reducing BAT/BEPs are assessed by looking at the cost of abatement and magnitude of abatement in unison. The developed cost and benefit data for the technology options was used to produce a MACC for GHG reduction options in surface coal mines.

The MACC ranks the BAT/BEPs from most to least economically attractive in terms of $/tCO$_2$e and plots these values against the corresponding tCO$_2$e reductions. Note that a negative $/tCO$_2$e value denotes a saving per ton abated, whereas a positive $/tCO$_2$e denotes an abatement cost. The surface mining MACC is shown in Figure 8-5. Note that per industry practice, the analysis was done using the discounted total lifecycle cost and undiscounted total emissions. The base case surface mine lifecycle emissions amount to 7.3 million tCO2e.

Figure 8-5: Surface Mining Marginal Abatement Cost Curve



The selected BAT/BEPs cover a range of abatement performance. Technologies that manifest themselves as negative slivers on the MACC, such as AutoHaul and DryerGasOnly are those that yield small incremental reductions at a cost saving. Others such as the CMM abatement technologies offer larger reductions at almost parity or a small cost saving. Among these measures, utilization of the captured methane for power generation and coal drying offer the greatest benefit.

FleetB20 and FleetLNG offer small abatements and reflect net positive abatement costs. Conveyor and FleetTrolley display promising potential in terms of dollar savings and abatement magnitude. The conveyor option in particular, when coupled with a well-suited mine plan, can transport ore at significant cost savings and emission reductions.

8.5 Summary of Findings

A range of technologies covering multiple emission sources were considered in this analysis. In order to collate the analysis results and key findings, the BAT/BEPs were measured against the following four criteria and rated as low, medium or high performers according to the scale and colour coding shown in Table 8-1:

1. GHG Benefit – change in facility intensity relative to the base case
2. Profitability – change in facility NPV relative to the base case

3. Sustainability – other environmental/social benefits or potential risks to the technology
4. Technological Readiness – degree of readiness for adoption in the Canadian context

Table 8-1: BAT/BEP Assessment Criteria

Criteria	Low Performer	Medium Performer	High Performer
GHG Benefit	<5% intensity decrease	5-15% intensity decrease	>15% intensity decrease
Profitability	NPV decrease	Minor NPV increase	Substantial NPV increase
Sustainability	No environmental/social benefits, significant risks	1-2 environmental/social benefits, moderate risks	>2 environmental/social benefits, low risks
Technological Readiness	Requires field piloting / demonstration in Canada	Applicability/Performance challenges	Readily deployable to most Canadian mines

Using the criteria identified above, key findings of the analysis performed on the surface mining GHG-reducing measures considered in this study are presented in matrix form in Table 8-2. The table is populated based on the cost-benefit assessment results and other considerations highlighted in the preceding sections. The

Measure	Solar	Wind	AutoHaul	FleetLNG	DryerGasOnly	FleetB20	CMMFlaring	CMMPowerGen	CMMPipeline	CMMCoalDry	FleetTrolley	Conveyor
Reduction	0.05%	0.11%	3.5%	3.8%	4.2%	5.3%	12.9%	12.9%	13.3%	13.8%	15.6%	18.1%

Measure	GHG Benefit	Profitability	Sustainability	Technological Readiness	Considered BAT/BEP?
Conveyor	-18%	+$132M	increased safety, improved air quality (less diesel and road dust)	limited applicability	Yes
FleetTrolley	-16%	+$34M	improved air quality (less diesel)	limited applicability	Yes
CMMCoalDry	-14%	+$7M	harnessing wasted energy	drainage not demonstrated in Canada	Yes
CMMPowerGen	-13%	+$7M	harnessing wasted energy	drainage not demonstrated in Canada	Yes
DryerGasOnly	-4%	+$4M	supports retirement of coal firing (positive public perception)	deployable	Yes
AutoHaul	-3%	+$20M	increased safety, job loss challenges	deployable	Yes
CMMFlaring	-13%	+$4M	negative perceptions towards flaring	drainage not demonstrated in Canada	Yes
CMMPipeline	-13%	-$2M	harnessing wasted energy	drainage not demonstrated in Canada	No, poor economics
FleetB20	-5%	-$1M	supports renewable fuel industry (positive public perception)	deployable	No, poor economics
FleetLNG	-4%	-$2M	improved air quality (less diesel)	technical performance issues	No, poor economics
Wind	-0.11%	$0M	footprint and co-siting challenges	deployable	No, limited GHG benefit
Solar	-0.05%	-$9M	footprint and co-siting challenges	deployable	No, limited GHG benefit

Conveyors and trolley assists are the two technologies that offer the greatest GHG reduction in surface mining coupled with a sound business case financially. However, both technologies have limited applicability especially as retrofits to exiting projects or project expansions; they are best suited for specific mine plans that tend to centralize and heavily utilize a single route from pit to CPP. For new mines, these are important consideration in the design phase and producers are encouraged to adopt mine plans that allow the integration of either of these technologies given their recognizable value both from an environmental and economic perspective. Note that the GHG benefit of electrification technologies is contingent on the mine having access to an electric grid with a low emission intensity to supply its power.

Of the CMM abatement technologies evaluated, utilization in coal drying and power generation are the best alternatives considering all four evaluation criteria. Further development efforts and investments are required in this area to initiate piloting of drainage projects in Canada. This is necessary in order to de-risk the technology and support a better understanding of the GHG abatement potential of improved CMM management within the coal mining industry.

AutoHaul is a commercially available and financially sound technology; however, GHG reductions are marginal and upfront capital is high. The retirement of coal firing in coal dryers is a readily deployable GHG reduction strategy that requires zero capital. Technologies at the bottom of the list are deemed unqualified as BAT/BEPs for surface coal mines within the assumptions of the analysis.

9 Assessment Details for Underground Mining BAT/BEPs

This chapter outlines the cost-benefit analysis details for the selected underground mining BAT/BEPs. A base case is defined followed by a description of the BAT/BEPs including key modelling input parameters. Each model is assigned a short name as an identifier used thereafter.

9.1 Base Case (UndergroundBase)

The underground mine base case is a hypothetical bituminous coal mine with ROM capacity of 5.0 Mt per year. The mine includes a CPP in which the raw coal is sized and washed through a series of separation processes then dried using thermal dryers. The energy input to the dryers is 50% natural gas and 50% thermal coal. At a clean coal yield rate of 80%, the mine produces 4.0 Mt of metallurgical coal per year.

The mine is a multi-continuous miner operation extracting coal using the room-and pillar mining method. At full production, 6 continuous miner sections are in operation mining the production panels. A section consists of one continuous miner, one roof bolter, three shuttle cars and two LHD units, the latter being the primary diesel consumer in addition to man transport vehicles and other support equipment.

A conveyor transports the mined ore to the surface where additional conveyors move it all the way to the CPP. Surface facilities include a roughly 40 MW ventilation system to control methane levels at underground mine workings.

Table 9-1 provides a list of key input data used to construct the base case model. All BAT/BEPs are modelled using the base case as a starting point and adjusting modelling parameters that are impacted by implementing the measure in question. Only those parameters that differ from the base case are listed in the subsequent sections for each of the BAT/BEPs.

Table 9-1: Model Data and Assumptions for UndergroundBase

Parameter	Value	Comments
Initial capital	$685 million	Distributed over first 4 years
Sustaining capital	$20 million/yr	Base value profiled over operating life
Natural Gas Input	445,000 GJ/yr	Base value profiled over operating life
Thermal Coal Input	15,188 t/yr	Base value profiled over operating life
Diesel Input	7,500,000 L/yr	Base value profiled over operating life
Electricity Import	565,000 MWh/yr	Base value profiled over operating life
O&M Cost	$126 million/yr	Base value profiled over operating life
Chemicals Cost	$116 million/yr	Base value profiled over operating life
Closure Cost	$20 million	Assumed to be expended on year 35

9.2 CMM Pre-Drainage and Injection in Natural Gas Pipeline (CMMPipeline)

This abatement measure involves the drainage of methane from the coal seam in advance of mining according to the assumptions discussed in Section 6.3.5, followed by treatment of the captured gas and injection into a commercial natural gas pipeline. Where on-site utilization is limited or not possible, pipeline injection offers an alternative to the undesirable release of methane and introduces a new revenue stream from the sale of the gas.

Gas suitable for commercial distribution must have a minimum methane concentration of 96% and contain no more than 1 ppm oxygen (USEPA, 2019a). Captured CMM requires some processing to reduce nitrogen and carbon dioxide down to a 4% inert level and remove any oxygen and water content; however, it is typically free of hydrogen sulphide and other impurities found in natural gas (USEPA, 2019a). The quality of the gas resource is an important consideration for determining the suitability of this abatement measure as well as availability of a secure market demand for the produced gas.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMPipeline measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 43,500 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,228,000 based on the drained gas flow rate and assumed piping length.
- The mining rate is estimated to be approximately 1.8 km^2/y based on the mine ROM production rate and assumed coal panel height. The number of wells required to per year is found to be 20 wells based on that mining rate and assumed spacing between wells.
- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $4,250,000 per year based on the required number of wells and assumed well depth and piping length.

Pipeline Injection Costs

- Initial capex required for the oxygen removal system is a fixed amount of $1,250,000.
- Initial capex of other components of the gas upgrade facility is determined as a function of the gas flow rate into the facility and evaluated at $938,000.
- Initial capex of the high pressure pipeline required to connect the upgrade facility to the commercial natural gas pipeline is estimated at $765,000 based on an assumed distance of 1000 m.
- Annual opex to operate and maintain the pipeline injection system is determined based on a fixed cost plus a variable cost relative to gas flow rate into the facility amounting to $933,000 per year.

Abatement and Energy Balance

- Methane losses of 10% are assumed during the gas upgrade process.
- Methane losses of 10% are assumed during transport from the mine to the point of sale.
- The methane flow rate effectively captured and available for export is estimated at 28,200 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas. This amount is sold to market introducing revenue to the project. This amount also represents the nominal realized abatement which corresponds to 168,885 tCO_2e/y of avoided CMM emissions.
- The equipment added by this measure including blowers, compressor station and gas upgrade facility are considered new electrical loads estimated to consume an additional 5,000 MWh/y.

9.3 CMM Pre-Drainage and Utilization in Power Generation (CMMPowerGen)

As with the previous measure, CMMPowerGen involves the drainage of methane from the coal seam in advance of mining except that the captured gas is utilized to generate electricity for mine use rather than being sent off-site. The same drainage principles discussed above apply to this measure.

The drained methane is used to fire internal combustion engines which drive generators to produce electricity. Internal combustion engines are commercially available for this scale of operation and able to handle methane concentrations as low as 30% (USEPA, 2019a). Minimal gas processing is required upstream of the engines primarily to remove solids and water. Given the relatively high power demand of coal mines, the generated electricity can be used to offset purchased electricity from the grid.

An important consideration for power generation in this application is the unavoidable fluctuation in gas supply due to mining variabilities. When sizing CMM-fired power equipment, it is advisable to design the engine capacity for a continuous base load in terms of gas availability and avoid oversized and underperforming systems (UNECE, 2016). A flare may be used in conjunction with the power generation system to destroy peak flows and minimize emissions.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMPowerGen measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 43,500 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,228,000 based on the drained gas flow rate and assumed piping length.

- The mining rate is estimated to be approximately 1.8 km^2/y based on the mine ROM production rate and assumed coal panel height. The number of wells required to per year is found to be 20 wells based on that mining rate and assumed spacing between wells.

- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $4,250,000 per year based on the required number of wells and assumed well depth and piping length.

Power Generation Costs

- Methane losses of 12% are assumed due to natural variances in the volume and quality of methane that may lead to lower effective recovery and destruction.

- The methane flow rate effectively captured and available for power generation is estimated at 30,700 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.

- The power generation capacity is calculated to be 3.6 MW based on the available methane flow rate and assumed electrical power efficiency of 30%.

- Initial capex required for power generation including gas pre-treatment, internal combustion engines and generators, and electrical interconnection to the power grid is estimated at $5,377,000 based on the determined generation capacity.

- Annual opex to operate and maintain the power generation equipment is determined based on the amount of energy generation and is estimated at $819,000 per year.

Abatement and Energy Balance

- By combusting the captured methane in the engines and converting it to carbon dioxide, a nominal abatement corresponding to 163,668 tCO_2e/y of avoided CMM emissions is achieved.

- A net electricity generation of 30,900 MWh/y, after drainage power demands, is produced by the power generation system offsetting electricity imports by the project. This is a financial benefit to the project with minimal abatement potential for projects connected to low intensity grids.

9.4 CMM Pre-Drainage and Utilization in Coal Drying (CMMCoalDry)

CMMCoalDry is a direct-use abatement measure in which captured methane is directed to the coal dryers at the CPP displacing a portion of purchased natural gas. The presence of this heat demand within mine operations makes coal drying a good application for drained CMM.

The assumption is made that the drained gas quality is adequate for the intended use and does not require further processing to serve as fuel to the dryers. Additionally, beyond the drainage and recovery system, this abatement measure does not require the installation of new equipment since existing dryers are assumed to have dual burners capable of firing both natural gas and coal.

Design and operation of the drainage system follows the same philosophy as the other CMM abatement measures above, with the exception that drilling and drainage is assumed to start the first year of production as the dryers come online rather than during construction when no such sink exists. First wells are drilled in an area planned for mining two years into production and new wells continue to be drilled on an annual basis following mine advancement. This arrangement has the slight disadvantage of delaying methane abatement, meaning that coal mined in the first two years of production is not degasified and therefore mining activities during that period emit methane at the full mine emission rate.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMCoalDry measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 43,500 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,228,000 based on the drained gas flow rate and assumed piping length.
- The mining rate is estimated to be approximately 1.8 km^2/y based on the mine ROM production rate and assumed coal panel height. The number of wells required to per year is found to be 20 wells based on that mining rate and assumed spacing between wells.
- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $4,250,000 per year based on the required number of wells and assumed well depth and piping length.

Abatement and Energy Balance

- Methane losses of 12% are assumed due to natural variances in the volume and quality of methane that may lead to lower effective recovery and destruction.
- The methane flow rate effectively captured and available for power generation is estimated at 30,700 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.
- By combusting the captured methane in the coal dryers and converting it to carbon dioxide, a nominal abatement corresponding to 163,668 tCO_2e/y of avoided CMM emissions is achieved.
- Natural gas demand is offset by 435,000 GJ/y which is a financial benefit to the project as well as additional abatement through displacement of this energy input and associated emissions.
- The drainage blowers and compressor station added by this measure are considered new electrical loads estimated to consume an additional 701 MWh/y.

9.5 CMM Pre-Drainage and Flaring (CMMFlaring)

Destruction of drained CMM gas through flaring is a simple abatement strategy which may be suited for mine applications where utilization cannot be reliably achieved. Flaring can be safely done at methane concentrations as low as 30% (USEPA, 2019a). The drainage system is the same as that for CMMPipeline and CMMPowerGen.

This scenario assumes the installation of one or more open flame burners atop fare stacks based on the anticipated gas flow. The capital cost of the flare system includes the firing equipment as well as monitoring and metering devices to validate methane destruction levels. Annual operation and maintenance costs cover activities associated with the burners, pilots, instrumentation, automatic flare lockout controls, and flame arrestors (USEPA, 2016).

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the CMMFlaring measure are outlined below.

Drainage and Recovery Costs

- The drained gas flow rate is estimated at 43,500 m^3/d based on the mine methane emission rate and assumed pre-drainage efficiency.
- Initial capex for the drainage and recovery system includes costs for wellhead blowers, a satellite compressor station and interconnecting pipelines between the compressor station and end-use abatement technology. This is estimated at $1,228,000 based on the drained gas flow rate and assumed piping length.
- The mining rate is estimated to be approximately 1.8 km^2/y based on the mine ROM production rate and assumed coal panel height. The number of wells required to per year is found to be 20 wells based on that mining rate and assumed spacing between wells.
- Sustaining capex for the drainage and recovery system includes the ongoing cost of drilling new wells and installing gathering pipelines between the wellhead blowers and compressor station. This is estimated at $4,250,000 per year based on the required number of wells and assumed well depth and piping length.

Flaring Costs

- Initial capex required for the flare system is estimated at $248,000 based on the inlet gas rate.
- Annual opex to operate and maintain the flare system is a fixed cost of $19,000 per year.

Abatement and Energy Balance

- Methane losses of 12% are assumed due to natural variances in the volume and quality of methane that may lead to lower effective recovery and destruction.
- The methane flow rate effectively captured and available for flaring is estimated at 30,700 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.

- By combusting the captured methane in the flare system and converting it to carbon dioxide, a nominal abatement corresponding to 163,668 tCO_2e/y of avoided CMM emissions is achieved.
- The drainage blowers and compressor station added by this measure are considered new electrical loads estimated to consume an additional 701 MWh/y.

9.6 VAM Destruction Using Oxidization (VAMOxidizer)

This measure involves the destruction of VAM, i.e. the methane content within the ventilation air that moves through underground mine workings. The air exhausted at the ventilation exit is routed to an adjacent oxidizer that combusts the methane into carbon dioxide.

Regenerative Thermal Oxidation (RTO) is a commercial technology currently operational at various underground mines around the world. The technology has long been utilized for odour and pollution abatement purposes in the manufacturing sector and has now been successfully adapted for underground mining operations with installations in the United States, Australia and China (USEPA, 2019b). Regenerative Catalytic Oxidation (RCO) is an advancement to thermal oxidation which involves the use of a catalyst to lower the autoignition temperature of methane. Catalytic oxidizers have been demonstrated but not widely adopted yet (USEPA, 2019b). The analysis presented herein is based on the installation of a thermal oxidizer as an abatement measure for VAM emissions. Refer to Appendix G for a list of exemplar VAM oxidizer systems and projects.

VAM oxidation is technically feasible at methane concentrations greater than 0.25% (USEPA, 2019a). VAM concentrations observed in the field are typically in the range of 0.1-1% depending on how gassy a mine is, and the ventilation system capacity designed to achieve a desired air quality (UNECE, 2016). For the purposes of this analysis a concentration of 0.5% is assumed based on coal mining occupational health and safety regulations (Governmment of Canada, 2019b).

The analysis also assumes a ventilation efficiency of 80%. This represents the share of total mine emissions expected to be released through the ventilation system. In the absence of any methane drainage, IPCC guidelines suggest that ventilation accounts for 100% of underground methane emissions (Irving & Tailakov, 2001). The analysis assumes that VAM oxidation is implemented as the only methane abatement activity. However, by using 80% ventilation efficiency, the analysis conservatively allows for releases from uncontrolled mine areas. The greater the methane efficiency, the greater the return on investment of VAM oxidation as an abatement technology.

This option is modelled using costs derived from the from the USEPA's Coalbed Methane Outreach Program Project Cashflow Model (USEPA, 2016). The key assumptions and input data used to construct the cost-benefit analysis model for the VAMOxidizer measure are outlined below.

Technology Costs

- The ventilation air flow rate is estimated at 107 m^3/s based on the mine methane emission rate and assumed ventilation efficiency and methane concentration.
- Initial capex required for the thermal oxidizer unit and associated ductwork, blowers and other peripherals is estimated at $6,772,000 based on the ventilation system air flow rate.

- Sustaining capex to move the oxidizer unit and peripherals as mining advances and the mine vent shaft relocates is estimated at $1,178,000 applied at 5 year increments.

- Annual opex to operate and maintain the oxidizer unit and peripherals is estimated at $383,000 per year.

Abatement and Energy Balance

- Methane losses of 12% are assumed during recovery and destruction of the methane.

- The methane flow rate effectively captured and available for flaring is estimated at 30,700 m^3/d after accounting for losses and based on the assumed methane concentration in the drained gas.

- By destructing the methane content of the ventilation air in the VAM oxidizer, a nominal abatement corresponding to 218,224 tCO_2e/y of avoided CMM emissions is achieved.

- The oxidizer blowers added by this measure are considered a new electrical load estimated to consume an additional 9,000 MWh/y.

9.7 Mobile Fleet Fuel Switching to B20 Biodiesel (FleetB20)

Biodiesel is a renewable diesel replacement fuel derived from biogenic sources such as vegetable oil, soybean oil or animal fats. Biodiesel-based fuels are available in different blends identified by the proportion of pure biodiesel in the fuel. A common biodiesel fuel is B20 which is 20% biodiesel and 80% petroleum diesel. B20 is readily available through normal fuel distributors, often at the same price point as diesel.

Note that different jurisdictions typically require fuel suppliers to incorporate a minimum renewable fuel content in their products. For example, in British Columbia diesel fuel supply is B4 and in Alberta it is B2. Pure biodiesel is considered carbon-neutral because crops used to produce it act as a carbon sink offsetting the emissions released upon combustion. As such, the emissions benefit per litre of fuel is roughly commensurate with the blend ratio. However, biodiesel is slightly less energy dense than petroleum diesel which introduces a fuel consumption penalty of 2% when using B20 versus pure diesel (USDoE, 2019).

The emission factors used in the analysis for B4 and B20 and calculated to be 2.630 $kgCO_2e$/L and 2.22 $kgCO_2e$/L respectively using BC guidelines for GHG quantification (Government of British Columbia, 2017). The base case underground mine consumes 7,500,000 L of B4 per year. The FleetB20 scenario was modelled by replacing that with 7,650,000 L of B20 per year. Both fuels were assumed to cost the same per litre. No incremental capital or operating costs were applied.

B20 is more commonly used in the transport sector versus higher blends because it offers a good balance of cost, emission reduction, cold-weather performance and materials compatibility (USDoE, 2019). B20 can be use in existing engines with no modifications therefor operators interested in adopting this technology need only make supply chain changes to secure the sourcing and transportation of the fuel leading to immediate emission reductions (RMI, 2019). Higher biodiesel blends while attractive from a GHG reduction perspective present operational risks including: faster degradation of rubber components such as fuel hoses and pump seals, partial solidification of the fuel in extended storage, and unfavourable cold temperature flow properties (RMI, 2019).

9.8 Mobile Fleet Electrification Using Cable Powered Vehicles (FleetElecCable)

This measure involves the use of electrically driven LHD units powered through a trailing cable as an alternative to the industry standard of using LHDs with diesel power trains. Tethered vehicles are equipped with a cable reel which connects the moving machine to a power source. Such units are commercially available through multiple heavy equipment OEMs that offer common standard capacities in both diesel and electric models. The vehicle's operating range is limited by the cable length which is limited by the size of the cable reel. It is interesting to note however that tethered units weigh less empty than their battery powered counterparts (Paraszczak, et al., 2014).

In addition to the reduced operational flexibility compared to diesel vehicles, tethered LHDs are subject to utilization loss due to the high of risk cable damages in the harsh underground mining environment. On the other hand, electric vehicles contribute to clean air quality in the mine workings. Cable-powered electic LHDs are especially functional in mine areas with short repetitive trams; hence their viability is highly dependent on mine-specific conditions and they are not a solution for every mine (Paraszczak, et al., 2014).

The key assumptions and input data used to construct the cost-benefit analysis model for the FleetElecCable measure are outlined below.

Technology Costs

- The initial capex increment required to switch all 12 base case diesel LHDs to cable-powered units is estimated at $2,500,000 based on a unit cost for diesel units of $1,044,000 and a cost increase factor of 1.2 for going electric for the same payload capacity (Jacobs, 2013).
- The initial capex required to upgrade the electrical infrastructure to meed the additional load introduced by the electric LHDs is estimated at $6,000,000 based on incorporating 3 new substations. This is such that each substation is dedicated to a maximum of 4 units (Jacobs, 2013). The substation unit cost is assumed at $2,000,00/substation (high level estimate obtained by Advisian from industry).
- Sustaining capex and annual opex are adjusted by a proportionate increase to maintain the same ratio of sustaining capex to net initial capex as the base case.

Energy Balance

- The base case mine is assumed to operate 12 diesel LHD units with output power capacity of 127 kW.
- By switching to electric LHD units, the avoided diesel consumption is calculated to be 3.6 million litres per year assuming and diesel engine efficiency of 35% and electric motor efficiency of 90%.
- The equivalent amount of electricity input required to run the electric LHDs is 14,800 MWh/y.

9.9 Elimination of Coal Firing in Coal Dryers (DryerGasOnly)

This measure involves the substitution of natural gas for thermal coal used as fuel in the CPP coal dryers. Energy input to the dryers is held constant, and dryer efficiency is assumed to be unchanged maintaining the drying

capacity of the facility. Coal fuel is replaced with an equivalent amount of natural gas based on their respective energy densities. The reduced carbon content of the natural gas results in a lower GHG emission rate and therefore a cleaner coal drying process.

In discussions with coal operations, most existing dryers have the ability to accommodate both coal and natural gas fuels. Within previous periods drying was done using predominantly coal with some gas input (≈10% by energy content). More recently, the operational trend has been to switch to natural gas. The limiting factor in some facilities is a connection to the natural gas commercial grid especially in the case of remote facilities.

The key assumptions and input data used to construct the cost-benefit analysis model for the DryerGasOnly measure are outlined below.

Technology Costs

- It is assumed that the base case facility can accommodate natural gas and no retrofit of the coal dryers is necessary. Therefore, no additional capex is included.
- Although there may be changes in operating procedures due to reduced handling of coal fuel and ash, it is assumed that there are no overall changes in non-energy opex.
- Energy opex related to the eliminated thermal coal is reduced, while energy opex related to natural gas increases. Under current pricing assumptions this results in a small net decrease in energy costs (<7%).

Energy Balance

- Coal consumption of 15,188 t/yr is eliminated based on the original fuel intake of the base case.
- Natural gas consumption of 445,000 GJ/yr is added based on the energy input being substituted.

9.10 On-Site Solar Power Generation (Solar)

This measure involves the installation of a photovoltaic solar farm (Solar PV) within proximity of the CPP. A representative 10 MW generation facility is assumed, offsetting a portion of the 64 MW total electric load of the underground mine base case. The capacity factor of solar farms in Canada ranges between 9-18% of installed nameplate capacity (Canada Energy Regulator, 2019). In this scenario, a capacity factor of 15% is assumed, representing an average performance within the expected project area in southern British Columbia (World Bank Group, 2019a).

Solar PV is considered as a fuel displacement power generation option with the electric load being supplied (with back-up) by a continuous power supply. The continuous full-backup supply is necessary to compensate for the short-term intermittency of this renewable energy source.

A PV power plant does not produce any GHG emissions or criteria air contaminants as the system is generating electricity. Emissions primarily occur during other stages of the solar panel lifecycle. Minimal emissions are associated with maintenance due to vehicle traffic and during construction phases of the project.

Technical considerations reflected in the analysis for a conceptual design of the Solar PV option include:

- The PV panel, inverter, and racking system is from a tier 1 supplier at current industry standard sizes.
- A single-axis tracking system is chosen as an average design in terms of cost, performance, and land usage.
- There may be further advantages for a fixed-tilt system or double-axis tracking system in terms of mitigating low sun angle, shading, and snow build-up. A more detailed comparative analysis of the mounting system for specific sites would be undertaken if PV is considered.
- The PV nameplate capacity is sized for a proportion of the total average load to avoid disruption of the facility power as the solar farm output fluctuates and to avoid exceeding total facility demand.
- Technical challenges include land suitability and availability, airport zoning, glint/glare impacting flight paths, corrosion, shadowing, low temperatures, and low solar resource.
- Additional local factors impacting the capacity factor include climate, topographic shading (such as with mountainous terrains), and tall vegetation.

The potential application areas have severe environmental conditions that contribute to power losses and require additional maintenance or structural design considerations. This includes dusting and soiling, snow build-up, high wind loads, corrosion, and low temperatures. These technical challenges are mitigatable as demonstrated through the successful deployment of PV systems around the world under similarly challenging conditions.

Land use is the most significant environmental concern associated with Solar PV. This scenario's 10 MW farm is expected to occupy a footprint of roughly 40 hectares based on an average land requirement of 4 hectares per MW of capacity (Ong, et al., 2013). This may include geotechnically suitable post-mining areas. A PV power block requires a significant surface footprint which may have environmental or cultural concerns depending on the region and surrounding communities. No significant regulatory concerns are anticipated for a PV facility.

The key assumptions and input data used to construct the cost-benefit analysis model for the Solar PV measure are outlined below.

Technology Costs

- A capital cost factor of $1,613 per kW capacity was used for the full Solar PV system, based on an installation in 2020. Further annual declines of over 2% in Solar PV capital costs are predicted between 2020 and 2030 (National Energy Board, 2018).
- A fixed operating & maintenance cost of $23/kW was used for the full solar PV system with no applicable variable operating costs (National Energy Board, 2018).
- The following factors are generally considered but may cause escalation in project costs if local conditions are extreme:
  - Regular washing and snow removal of the PV panels is necessary to reduce power losses.
  - Additional structural support for snow buildup is not incorporated so design relies on snow shedding.
  - Low temperatures improve PV cell efficiency, so they are only a concern for the inverters and ancillary equipment. Standard inverters are rated to -15°C, but there are inverters on the market with optional features for lower temperatures down to -40°C.

Energy Balance

- The Solar PV system will be installed in a behind the meter configuration so the output will directly offset a portion of the electricity demand at the facility.
- The Solar PV electricity contribution will not exceed the average minimum demand of the facility, so no electricity export is considered.
- Considering the installation size (10 MW) and capacity factor (15%), 13,140 MWh/yr of grid electricity will be displaced by on-site solar power.
- Within British Colombia the GHG offset potential is minimized due to the existing low carbon intensity of the predominantly hydroelectric powered grid.

9.11 On-Site Wind Power Generation (Wind)

This measure involves the installation of a wind farm close to the CPP. A representative 10 MW generation facility is assumed, offsetting a portion of the 64 MW total electric load of the underground mine base case. The capacity factor of wind farms in Canada ranges between 30-40% of installed nameplate capacity (GE Energy Consulting, 2016). In this scenario, a capacity factor of 30% is used assuming favourable co-siting of the coal and wind resources within the expected project area in southern British Columbia (World Bank Group, 2019b).

Assessing the feasibility of the wind involves identifying an optimal location, considering both the quality of the wind resource, and power connection requirements. Future mine sites are likely to be located in areas with variable terrain with corresponding variable suitability for turbine placement. Ridges and plateaus provide higher capacity factors but may be less proximate to project sites. For the purposes of this analysis, the Wind option is assumed to be deployed where a reasonably good wind resource exists in close proximity to the coal mine.

Wind Power is considered as a fuel displacement power generation option with the electric load being supplied (with back-up) by a continuous power supply. The continuous full-backup supply is necessary to compensate for the short-term intermittency of this renewable energy source.

Wind Power does not produce any GHG emissions or criteria air contaminants when the system is generating electricity. Emissions primarily occur during other stages of the turbine and transmission life cycle. Minimal emissions are associated with maintenance due to vehicle traffic and during construction phases of the project.

Technical considerations reflected in the analysis for a conceptual design of the Wind Power option include:

- Conventional horizontal-axis, upwind-rotor turbines and associated transmission requirements is assumed.
- The nameplate capacity is sized for a proportion of the total average load to avoid disruption of the facility power as the wind output fluctuates and avoid exceeding total facility demand.
- Wind turbines will be located to balance high resource potential and proximity to site including sufficient area available to meet the capacity requirements and minimum capacity factor.
- Site access for installation and operation of the required equipment and infrastructure may be difficult but it is assumed that installation equipment may be mobilized to site, and that year-round site access is feasible for operation.

Land use impacts of wind power will depend on size and scale of the facility; a single turbine will permanently disturb just under half a hectare (Denholm, et al., 2009) while surrounding area of the wind farm may still be used for productive purposes. Because turbines must be spaced hundreds of meters apart, wind farms require large parcels of land. This scenario's 10 MW farm is expected to occupy a footprint of roughly 350 hectares based on an average land requirement of 35 hectares per MW of capacity (Denholm, et al., 2009). This is the total area inside a perimeter surrounding all of the turbines within the project. Where possible, installation in geotechnically suitable post-mining areas should be considered.

Wildlife and habitat are a concern for wind farms, particularly in relation to deaths of birds and bats due to collisions with wind turbines and the change in air pressure from the rotation of the turbines (NWCC, 2010). Sound, visual impact and aesthetics can be a community and public health concern wind farms. While public health issues have been disputed, community concern related to aesthetics and/or land value have been shown to have a direct impact on the ability to obtain necessary approvals (Batel, et al., 2013).

The key assumptions and input data used to construct the cost-benefit analysis model for the Wind Power measure are outlined below.

Technology Costs

- A capital cost factor of $1,541 per kW capacity was used for the full wind power system, based on an installation in 2020. Further annual declines of over 1% in wind power capital costs are predicted between 2020 and 2030 (National Energy Board, 2018).
- A fixed operating & maintenance cost of $40/kW was used for the full wind power system with no applicable variable operating costs (National Energy Board, 2018).
- Low temperatures increase air density to improve wind turbine efficiency, so they are only a concern for the inverters and ancillary equipment. Standard inverters are rated to -15°C, but there are inverters on the market with optional features for lower temperatures down to -40°C.

Energy Balance

- The wind power will be installed in a behind the meter configuration so the output will directly offset a portion of the electricity demand at the facility.
- The wind power electricity contribution will not exceed the average minimum demand of the facility, so no electricity export is considered.
- Considering the installation size (10 MW) and capacity factor (30%), 26,280 MWh/yr of grid electricity will be displaced by on-site wind power.
- Within British Colombia the GHG offset potential is minimized due to the existing low carbon intensity of the predominantly hydroelectric powered grid.

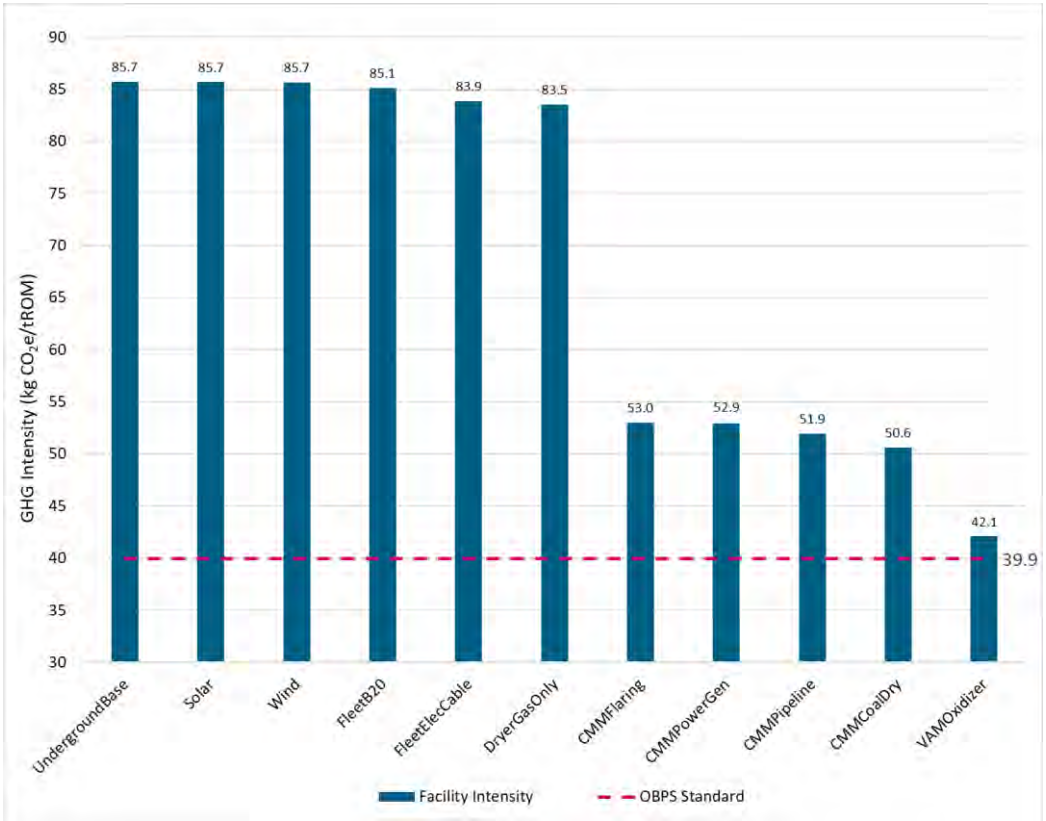
10 Assessment Results for Underground Mining BAT/BEPs

This chapter presents the results and key findings from the cost-benefit analysis conducted for underground mining BAT/BEPs.

10.1 GHG Intensity Reduction

To examine the effectiveness of the underground mining BAT/BEPs in reducing GHG emissions, the lifecycle GHG intensities were computed and plotted relative to the base case underground mine with accompanying percent reductions as shown in Figure 10-1. As a reference the federal OBPS benchmark, described in Section 6.3.4, is also included. Note that none of the BAT/BEPs are anticipated to impact ROM production if designed and sized to match the desired mine capacity.

Figure 10-1: Underground Mining Lifecycle GHG Intensity



Measure	Solar	Wind	FleetB20	FleetElecCable	DryerGasOnly	CMMFlaring	CMMPowerGen	CMMPipeline	CMMCoalDry	VAMOxidizer
Reduction	0.03%	0.07%	0.7%	2.2%	2.5%	38.2%	38.3%	39.4%	41.0%	50.9%

The lifecycle intensity is determined based on the anticipated emissions over the operating life of the facility divided by the total ROM coal production over the same timeframe. In the figure above, BAT/BEPs are arranged in decreasing order of intensity to exhibit the relative performance of the technologies.

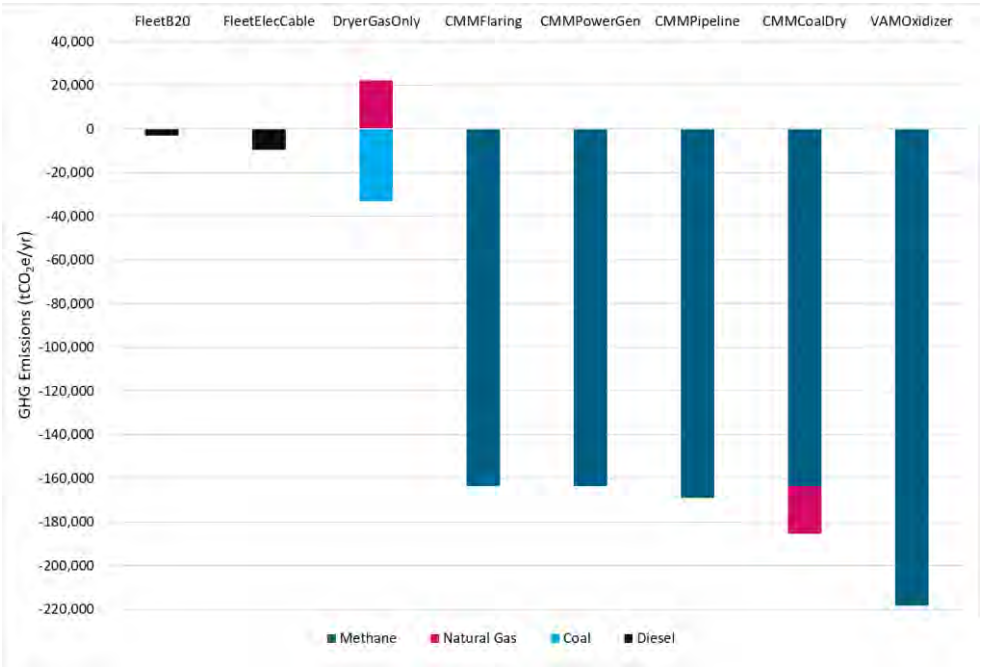
Solar and Wind offer negligible GHG advantage over the base case, given the assumption of a renewable grid. If the grid emission intensity were equivalent to a good-as-best-gas intensity of 370 kgCO2e/MWh instead, implementing Solar and Wind can be expected to reduce the mine lifecycle GHG intensity by 0.8% and 1.5% respectively. The good-as-best-gas intensity is the benchmark that the electricity sector in Alberta is subject to for emission reduction purposes and is therefore representative of a future state of the Alberta grid. Using the current Alberta grid emission factor of 570 kgCO2e/MWh (Government of Alberta, 2019a), the GHG intensity reductions attainable through the Solar and Wind options are found to be 1.0% and 2.0% respectively.

All other BAT/BEPs offer GHG reductions relative to the base case with significant step changes occurring within CMM and VAM abatement technologies.

10.2 Annual GHG Emission Reduction

To further examine the BAT/BEPs, the change in annual emissions relative to the base case is presented in Figure 10-2. Emissions are broken down by source in the chart to highlight the means of GHG reduction associated with each measure, and are also listed as a net change in the table. The base case underground mine emits 425,966 tCO2e/yr nominally per operating year. The incremental change in these emissions as a result of implementing a given BAT/BEP is calculated with respect to each individual emission source. A negative value represents a GHG reduction and a positive value represents a GHG increase. Note that electricity is not included as an emission source in the chart due to the low GHG materiality associated with the electric grid assumed for this analysis.

Figure 10-2: Underground Mining Annual GHG Emission Change



BAT/BEP	Net GHG Change (tCO_2e/yr)
FleetB20	-2,895
FleetElecCable	-9,242
DryerGasOnly	-10,922
CMMFlaring	-163,661
CMMPowerGen	-163,998
CMMPipeline	-168,832
CMMCoalDry	-185,348
VAMOxidizer	-218,129

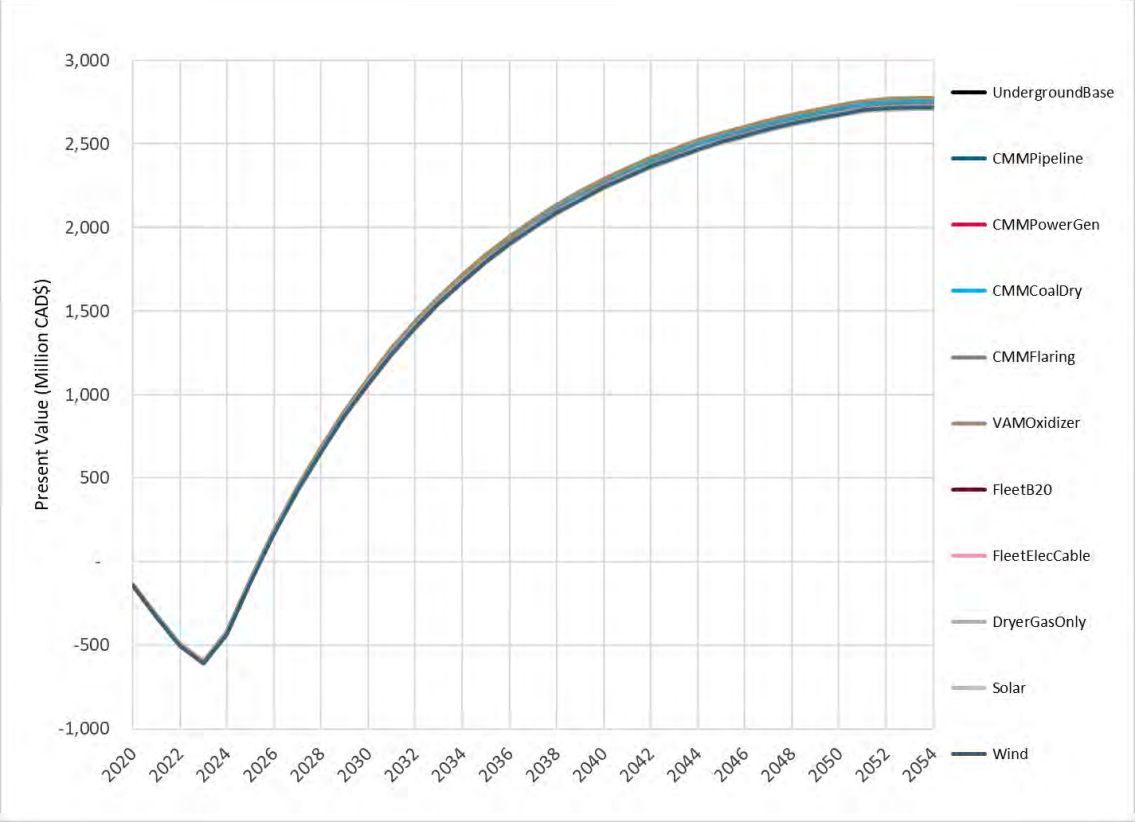
The biggest opportunity for underground coal mines lies in abatement of methane emissions through CMM and VAM management strategies. Further innovation and development in the sector should be directed at bringing these technologies and associated expertise to the Canadian market.

10.3 Financial Performance

To examine the financial attractiveness of the various BAT/BEPs, the financial model was used to calculate the net present value (NPV) of a mining project incorporating each of the BAT/BEPs in comparison to the base case. NPV is the net sum of costs and revenues discounted through the life of the project and expressed as a present value. A profitable project has an NPV above zero. The higher the NPV, the greater the profit.

Figure 10-3 is a plot of the discounted cumulative cashflow of the base case surface mine as well as each of the BAT/BEPs considered. The final cashflow value is the mine NPV in 2020 dollars with a lifecycle running to the end of 2054. The year in which the cashflow curve crosses the x-axis denotes the payback period of the mining project, i.e. the point at which the mine recoups initial capital and begins to generate profit.

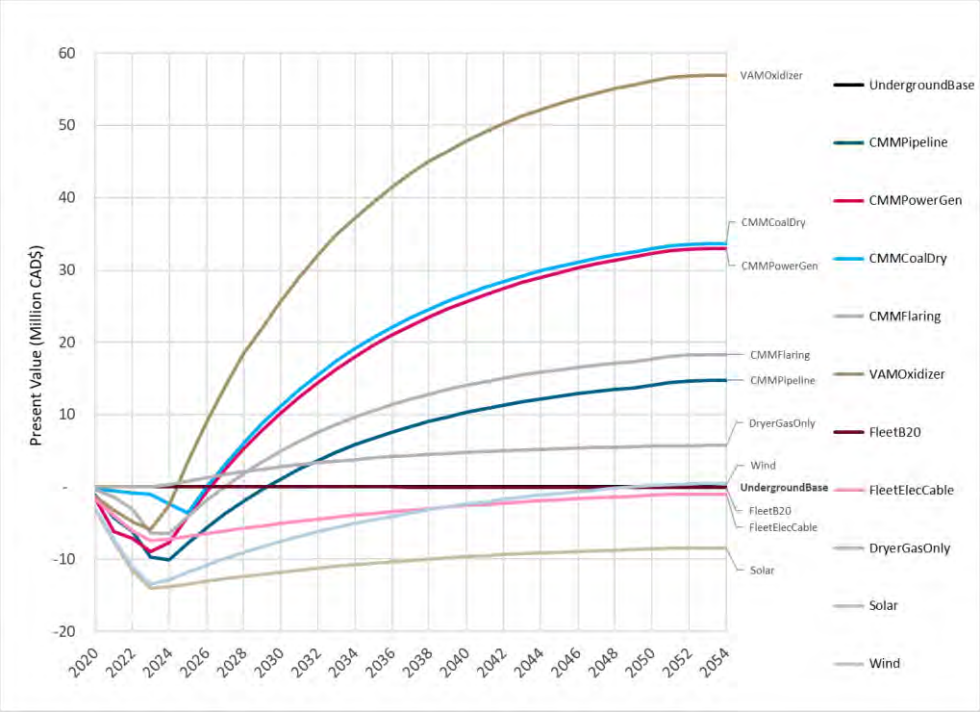
Figure 10-3: Underground Mining Cumulative Cashflow in Present Value



All BAT/BEPs are found to have positive NPVs around the base case of $2.734 billion with the majority exceeding that value. The graph also shows that the BAT/BEPs have little impact on the overall payback of the mining project which remains around 3 years of operation. This is due to the relative magnitude of the BAT/BEP costs to the overall mine development investment.

Figure 10-4 provides a closer look at the relative performance of the BAT/BEPs by plotting the differential cumulative cashflow above/below the base case. This diagram represents the cumulative costs and savings associated with implementing the individual BAT/BEPs. The year in which the curve crosses the x-axis for a given BAT/BEP, reflects the payback period for the investment associated with that measure, independent to the base case mine costs and revenues, as summarized in the table.

Figure 10-4: Underground Mining Differential Cumulative Cashflow in Present Value



BAT/BEP	Payback (# years of operation)
CMMPipeline	6
CMMPowerGen	3
CMMCoalDry	3
CMMFlaring	4
VAMOxidizer	2
FleetB20	N/A
FleetElecCable	N/A
DryerGasOnly	0
Solar	N/A
Wind	27

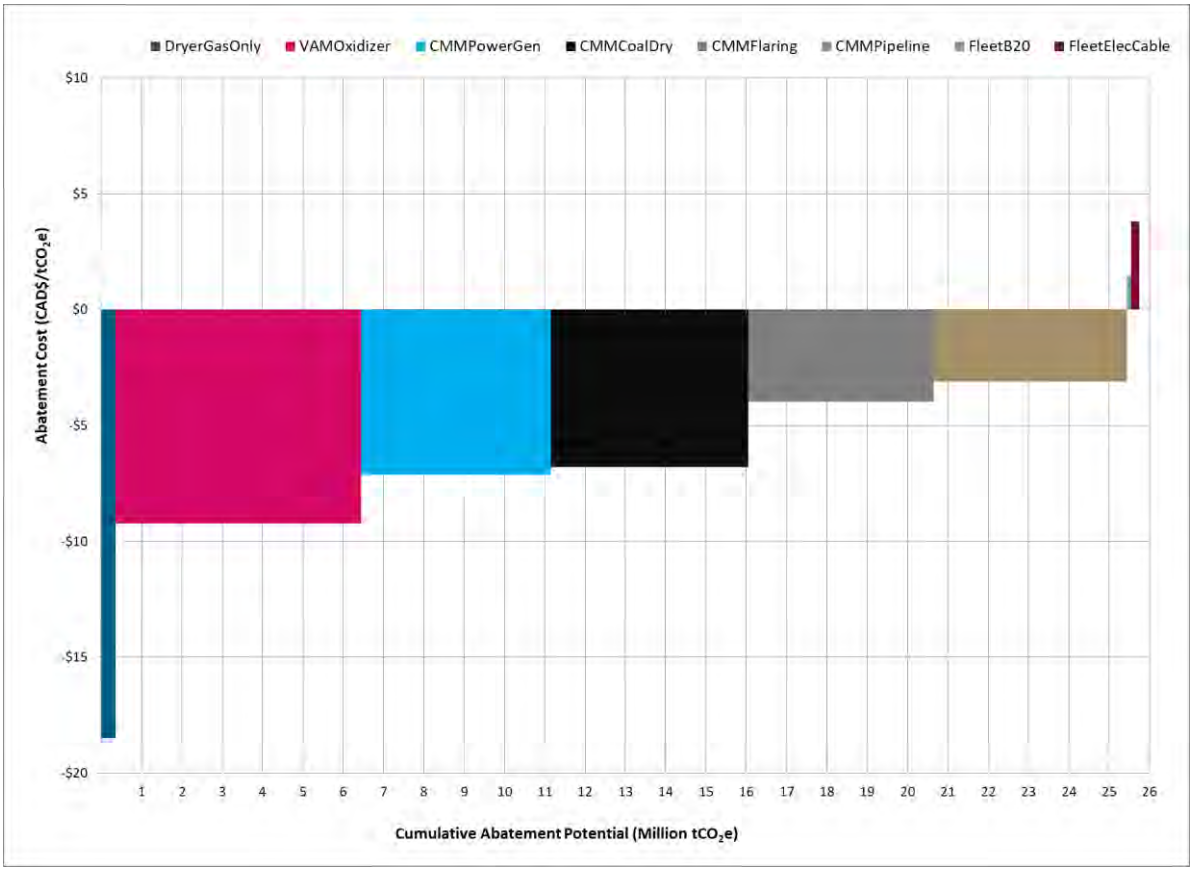
In increasing order of profitability, the following technologies prove to measurably improve the economics of an underground mining project while reducing the GHG emissions of mining activities: DryerGasOnly, CMMPipeline, CMMFlaring, CMMPowerGen, CMMCoalDry, and VAMOxidizer. Wind NPV is only marginally above the base case whereas FleetB20, FleetElecCable and Solar have NPVs lower than the base case.

10.4 Marginal Abatement Cost Curve

In this section the GHG-reducing BAT/BEPs are assessed by looking at the cost of abatement and magnitude of abatement in unison. The developed cost and benefit data for the technology options was used to produce a MACC for GHG reduction options in underground coal mines.

The MACC ranks the BAT/BEPs from most to least economically attractive in terms of $/tCO$_2$e and plots these values against the corresponding tCO$_2$e reductions. Note that a negative $/tCO$_2$e value denotes a saving per ton abated, whereas a positive $/tCO$_2$e denotes an abatement cost. The underground mining MACC is shown in Figure 10-5. Note that per industry practice, the analysis was done using the discounted total lifecycle cost and undiscounted total emissions. The base case underground mine lifecycle emissions amount to 12.0 million tCO2e.

Figure 10-5: Underground Mining Marginal Abatement Cost Curve



The selected BAT/BEPs cover a range of abatement performance. VAM and CMM technologies offer significant abatement potential over the life of the mine with VAMOxidizer, CMMPowerGen and CMMCoalDry showing the greatest cost savings per tCO_2e. Given the sensitivity of the analysis to capital costs, difference in performance between these measures is considered to be within the margin of error and therefore choice of method should be made based on mine-specific conditions.

Technologies that manifest themselves as negative slivers on the MACC, such as AutoHaul and DryerGasOnly are those that yield small incremental reductions at a cost saving. Others such as the CMM abatement technologies offer larger reductions at almost parity or a small cost saving. Among these measures, utilization of the captured methane for power generation and coal drying offer the greatest benefit.

FleetB20 and FleetElecCable offer small abatements and reflect net positive abatement costs. DryerGasOnly offers a slight GHG benefit at a strong cost saving.

10.5 Summary of Findings

A range of technologies covering multiple emission sources were considered in this analysis. In order to collate the analysis results and key findings, the BAT/BEPs were measured against the following four criteria and rated as low, medium or high performers according to the scale and colour coding shown in Table 10-1:

1. GHG Benefit – change in facility intensity relative to the base case
2. Profitability – change in facility NPV relative to the base case
3. Sustainability – other environmental/social benefits or potential risks to the technology
4. Technological readiness – degree of readiness for adoption in the Canadian context

Table 10-1: BAT/BEP Assessment Criteria

Criteria	Low Performer	Medium Performer	High Performer
GHG Benefit	No intensity decrease	Single digit intensity decrease	Double digit intensity decrease
Profitability	NPV decrease	Minor NPV increase	Substantial NPV increase
Sustainability	No environmental/social benefits, significant risks	1-2 environmental/social benefits, moderate risks	>2 environmental/social benefits, low risks
Technological Readiness	Requires field piloting / demonstration in Canada	Applicability/Performance challenges	Readily deployable to most Canadian mines

Using the criteria identified above, key findings of the analysis performed on the underground mining GHG-reducing measures considered in this study are presented in matrix form in Table 10-2. The table is populated based on the cost-benefit assessment results and other considerations highlighted in the preceding sections. The measures are arranged in order of decreasing overall performance such that technologies with the greatest potential for success in the coal mining industry are at the top. Both the number of criteria and magnitude of impact were considered. Additionally, measures that may be described as BAT/BEP are identified as such in the table. This is determined based on the measure's combined GHG reduction success and ability to achieve profitable financial returns similar to or greater than the base case.

Table 10-2: Underground Mining BAT/BEP Assessment Matrix

Measure	GHG Benefit	Profitability	Sustainability	Technological Readiness	Considered BAT/BEP?
VAMOxidizer	-51%	+$57M	harnessing wasted energy	deployable	Yes
CMMCoalDry	-41%	+$34M	harnessing wasted energy	drainage not demonstrated in Canada	Yes
CMMPowerGen	-38%	+$33M	harnessing wasted energy	drainage not demonstrated in Canada	Yes
CMMPipeline	-39%	+$15M	harnessing wasted energy	drainage not demonstrated in Canada	Yes
CMMFlaring	-38%	+$18M	negative perceptions towards flaring	drainage not demonstrated in Canada	Yes
DryerGasOnly	-3%	+$4M	supports retirement of coal firing (positive public perception)	deployable	Yes
FleetElecCable	-2%	-$1M	Improved air quality	deployable	No, poor economics
FleetB20	-1%	$0M	supports renewable fuel industry (positive public perception)	deployable	No, poor economics
Wind	-0.03%	$0M	footprint and co-siting challenges	deployable	No, limited GHG benefit
Solar	-0.07%	-$9M	footprint and co-siting challenges	deployable	No, limited GHG benefit

Within the assessed measures it is evident that VAM and CMM abatement technologies can improve the GHG performance of an underground mining facility without compromising other key profitability and sustainability objectives. Further development efforts and investments are required in this area to initiate piloting of drainage projects in Canada. This is necessary in order to de-risk the technology and support a better understanding of the GHG abatement potential of improved CMM management within the coal mining industry.

VAM is a deployable technology that lacks widespread adoption by the industry. Policy and innovative initiatives that encourage greater market penetration and skill transfer of this technology into the Canadian mining sector is highly warranted.

The retirement of coal firing in coal dryers is an obvious choice for new and existing mines at zero upfront capital. Technologies at the bottom of the list are deemed unqualified as BAT/BEPs for underground coal mines within the assumptions of the analysis.

11 Case Studies

This chapter further examines a selection of the BAT/BEPs evaluated above through case studies in various mining applications. The objective of the case studies is to expand on the technical features of each of the technologies, highlight key benefits and impact on the industry, as well as discuss challenges and potential barriers to adoption.

Table 11-1 provides a cross reference between the case studies presented in this chapter and the top performing surface and underground BAT/BEPs presented in Sections 8.5 and 10.5.

Table 11-1: Case Study to BAT/BEP Cross Reference

Mining Method	BAT/BEP Short Name	Case Study Title	Area of Abatement
Surface	Conveyor	Conveyor Systems	Mobile Fleet
	FleetTrolley	Trolley Assist	Mobile Fleet
	CMMCoalDry	N/A	Methane
	CMMPowerGen	N/A	Methane
	AutoHaul	N/A	Mobile Fleet
	DryerGasOnly	Coal-to-Gas Conversion	Coal Drying
	CMMFlaring	N/A	Methane
Underground	VAMOxidizer	VAM Abatement	Methane
	CMMCoalDry	N/A	Methane
	CMMPowerGen	CMM Abatement	Methane
	CMMPipeline	N/A	Methane
	CMMFlaring	N/A	Methane
	DryerGasOnly	Coal-to-Gas Conversion	Coal Drying

11.1 Conveyor Systems

Transporting ore and waste rock is one of the most crucial elements of an open-pit mining operation. A successful haulage system can make the difference between a mine that is consistently profitable and one that is struggling to meet its marginal costs (Topf, 2017). Operational costs, worker safety and GHG emissions are challenges faced by most mines today. Conveyor systems cut truck haulage to a minimum and build operational resilience that can help operators address these issues (Heiertz, 2018).

Although the traditional truck haulage is widely accepted in the mining industry, it contributes up to 60% of the operating cost of mining. Haul trucks have generally been favoured based on their flexibility of operation. More recently, diesel emission regulations have resulted in mining operators investigating solutions that emit less pollutants while retaining performance and productivity. Conveyor systems substantially reduce operational expenditures, primarily because they require less maintenance and labour and are able to move material in more energy efficient manner, plus they hold other environmental and safety benefits (Heiertz, 2018).

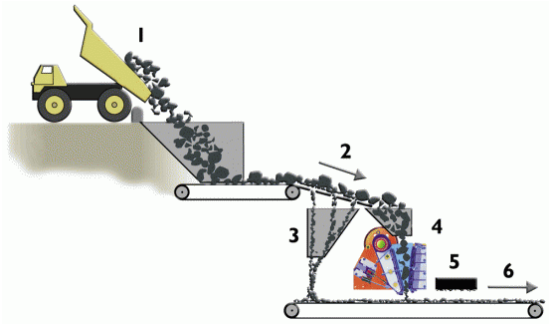
Because conveyors are typically designed to handle material smaller than 300 mm in size, a crusher is necessary at the feed end of the conveyor (Awuah-Offei, 2017). Conveyors can be employed ex-pit in what's known as overland crushing and conveying, or within the pit in what's called in-pit crushing and conveying (IPCC). Both configurations are described below. Ex-pit haulage typically constitutes the larger portion of the total distance travelled by ore from ground to CPP. By displacing trucking over the ex-pit stretch of material transport, overland conveyors offer measurable cost savings and GHG reductions.

Where suited, IPCC has the potential to further reduce cost and emissions; however, that will depend on the amount of trucking eliminated which in turn varies widely based on the degree of mobility of the system and pit geometry as described below. In general, mining operations should endeavour to put material on a conveyor as early in the mining process as practically feasible.

Overland Crushing and Conveying

There are various types of crushing systems available and this depends on the characteristics of the orebody. An example of a crusher and overland conveyor are described below where the trucks haul the ore out of the pit and dumps it directly into a crusher which feeds the conveyor. This typical layout using a jaw crusher is illustrated in Figure 11-1.

Figure 11-1: Typical Crushing and Loading Arrangement



(Waihi Gold, 2019)

In this example, material is loaded into the crusher bin (1) by trucks or loaders. Prior to entering the jaw crusher, the rock moves across a grizzly (2). The grizzly has a series of slots in it allowing the smaller pieces of rock to fall through (3). The remaining oversized material passes through the jaw crusher (4) and is sized down to the required specification. If it is required an electromagnet (5) can remove impurities like tramp steel. The material is then transported (6) to the main overland conveyor via a transfer station which load rock onto the conveyor (Waihi Gold, 2019).

There can be more than one overland conveyor and crushing system in a mine site depending on the relative location of the active mine pits and whether the waste also gets conveyed to waste rock embankments or remains in the pit. The mine case study described in Section 11.1.1 relates to an overland crushing and conveying system.

In-Pit Crushing and Conveying (IPCC)

Another conveyor system which has been introduced successfully on many open pit mines over the past decades is IPCC. The purpose of an IPCC system is to allow the ore to be crushed in the pit and transported out using a conveyor system once ROM has been reduced to a conveyable size. An IPCC system can generally be classified into three types, the characteristics and limitations of which are briefly discussed below (Nehring, Knights, Kizil, & Hay, 2018):

- **Fixed In-Pit Crushing and Conveying (FIPCC).** These systems are characterized by the crushing unit being situated in one location for an extended period. This location is usually at some point near the crest of the pit, near the haul road exit point. Conventional truck haulage is used within the pit to move material from the working face to the crushing unit. Once the material has been crushed, it is fed onto a conveying network which transports it to the required destination. Fixed systems have their best application in deep, pre-existing pits, with low vertical advance rates, where a single crusher location can service the operation for an extended time, usually greater than five years.

- **Semi-Mobile In-Pit Crushing and Conveying (SMIPCC).** These systems are like fixed systems in that the crushing unit remains in one location for a period of time with conventional truck haulage feeding it. The differences occur in the length of time in which the crusher remains in each location, and the locations that the crusher is situated. As the mine deepens, the crusher is relocated deeper into the pit which typically occurs every two to five benches (depending on the vertical advance rate) to maintain a short haul for the truck portion of the system and maximize the use of conveying that can be reasonably used. SMIPCC systems are the most flexible, and most readily adaptable to existing operations due to their continued use of trucks and the ability to install the crusher at suitable locations.

- **Fully Mobile In-Pit Crushing and Conveying (FMIPCC).** These systems remove the requirement for truck haulage during steady state operation. It is suggested that truck haulage may still be required during each sinking phase of a mine, though haul distance may be minimized by using the trucks to dump into the fully-mobile crusher near the sinking activity. These systems are characterized by the loading unit dumping directly into the hopper of a fully-mobile crushing unit that follows it. Once crushed, the material is passed onto a network of conveyors to be hauled to its destination. Due to the significant difference in mine design and layout of FMIPCC systems, they are best suited to greenfield operations. For many decades the flexibility of truck and shovel mining systems allowed the mining system to be suited to the pit; however, as FMIPCC is significantly less flexible, the mine design must cater to the requirements of the system.

11.1.1 Exxaro - Grootegeluk Coal Mine

Grootegeluk Coal Mine is situated 20 km from Lephalale in South Africa's Limpopo province. This open-pit mine by Exxaro produces 26 Mt per year in final coal products using a conventional truck and shovel operation. This mine has an estimated minable coal reserve of 3261 Mt and a total measured coal resource of 4719 Mt, from which thermal and metallurgical coal can be produced.

Some 22 Mt of annual production is thermal coal, transported directly to two mine mouth power stations 7 km away per the existing long-term supply contract. Additional production is sold domestically to the metal industry and others on short-term contracts.

In 2019 Exxaro completed a crushing and conveying study focused on the transport of three of their coal benches as well as overburden. The study included various trade-offs to determine the most economically viable option to transport the coal and waste to its various destinations compared to the current truck and shovel operation. The results of an overland crusher and conveyor option compared to trucking are discussed below.

In order to transport the coal and overburden of the existing operation to the planned locations, the mine will need to ramp up the current number of trucks from 56 to approximately 80 within the next few years. With the volatility of the diesel price as well as the focus on reduction of GHG emissions, the mine investigated the option of transporting both the overburden as well as the coal from three of its seams by means of overland conveyors. To do this the mine needs to purchase two crushers to be situated outside of the pit as well as approximately 7.5 km of overland conveyors for the overburden and 12 km of overland conveyors for the coal seams.

The implementation of the overland conveyors would reduce the amount of trucks required by approximately 20 trucks over the life of the mine. Although there is a capital cost associated with the initial purchase of the crushing and conveying equipment, operating cost savings of approximately $136 million can be realized over the life of the mine. Each of the trucks uses approximately 600,000 litres of diesel per annum which amount to a diesel reduction of 12 million litres per annum by implementing the overland conveyors. This reduction significantly reduces the operational costs, work safety, dust and GHG emissions of the operation.

11.1.2 Advantages and Disadvantages

There are several advantages of a crushing and conveying system over a haul truck system. The first and most obvious is a marked reduction in operational costs due to less need for road and truck maintenance as well as drivers - note that a small number of haul trucks are retained in a crushing and conveying operation. Conveyors also require less skilled labour for maintenance than trucks. Crushing and conveying systems are typically run on electrical power, which reduces a mine's dependency on diesel fuel. Diesel fuel is a major contributor to the cost of truck haulage. It is estimated that OPEX of conveyor haulage can be as low as one-third of a comparable truck haulage system (Nehring, Knights, Kizil, & Hay, 2018).

Other benefits of using crushing and conveying systems include (Heiertz, 2018 and Nordell, 2011):

- Potential to reduce GHG emissions by up to 40% under optimal design conditions.
- Reduced manpower (40-60%).
- Reduced noise emissions (up to 35%).

- Reduced haul road dust.
- Reduced spare part requirements.
- Improved safety with fewer moving vehicles.
- Easily move large and steady tonnages of material.
- Conveyors can often be routed in a more direct path than the road haulage thereby reducing the kilometre penalty. The path may include bridges over rivers, roads, railroads, etc.
- Conveyors can negotiate rough terrain to 18 degrees or more making for shorter paths and avoid tunnelling otherwise required by trucks.
- Conveyor designs have become more efficient with new rubber compounds and new design methods that lower rolling energy by 50% or more compared to rubbers from several years ago. Trucks have not seen such improvements in rolling losses.
- New conveyor configurations can be found with better trough shapes, pipe, and semi-pipe designs that add to belt conveyor transport efficiency.
- Conveyors can achieve maximum operational availability because of greater independence from weather conditions such as fog, rain, snow, and frost.

The compounded benefit resulting from these financial, environmental and social advantages of crushing and conveying systems provides justification for their integration in mining operations and more extensive use within the mining industry in general.

In terms of disadvantages, it primarily comes down to versatility (Topf, 2017). This is especially important when considering future mine development/advancement. Setting up a crushing and conveying system makes the operation more "permanent", versus haul trucks which can be easily deployed to any part of the pit or site. Their relative lack of mobility also means crushing and conveying requires a lot more forward planning, right from the mine's inception. And when a crushing and conveying system is inserted into a brownfield operation, there may need to be a lot of adjustments made to the mine plan. Conveyors also need an acceptable right of way and can only negotiate a route within set limits.

Although the OPEX of crushing and conveying systems can be reduced significantly below that of a truck haulage method, CAPEX required to use an IPCC system is often higher (Nehring, Knights, Kizil, & Hay, 2018). Contractor mining using truck and shovel is also more readily available and can reduce the upfront capital burden of a project which is not necessarily the case with conveyors.

In-pit crushing and conveying work well where there is horizontal movement of the mine faces, but not so great in deep open pit mines with a lot of benches. Given these constraints, it is understandable why many mine operators choose to stay within the trodden paths of haul trucks (Topf, 2017).

11.1.3 Barriers to Adoption

For crushing and conveying systems to serve as an appropriate alternative to conventional truck haulage, some key design parameters must be considered. These parameters range from fundamental requirements, to practicalities, and preferences, including (Nehring, Knights, Kizil, & Hay, 2018):

- Material movement of over 4 Mt/yr is desirable to justify initial CAPEX; upwards of 10 Mt/yr is preferable.
- A mine life greater than 10 years for the lower OPEX to pay back the higher initial CAPEX.
- Electricity costs ($/kWh) less than 25% of diesel cost ($/L).

Generally, the use of crushing and conveying systems is increasingly cost effective under the following circumstances (Heiertz, 2018):

- High capacity
- Deeper pits
- Long mine life
- Longer haulage distance
- High fuel cost
- High labour cost
- Remote operation
- Stringent environmental policy

Typically, material movement options are critically analyzed through a cost-benefit analysis during the design stage of a greenfield mine, and often as part of mine expansion studies in brownfield applications. The planning of open pit operations utilizing crushing and conveying systems cannot simply be based upon truck and shovel designs (Nehring, Knights, Kizil, & Hay, 2018). It may be necessary to employ a completely different approach to mine planning. This is principally due to the unique shape and sequencing constraints associated with the introduction of conveyors either inside or outside the pit. For some operators, this might mean exploring new practices outside their proven experience and therefore poses a barrier to adoption.

Another risk factor for operators is the loss of flexibility as a result of replacing truck haulage with conveyor haulage. Truck and shovel mining offers maneuverability, scalability and resilience to system failure that is difficult to match with conveyance systems.

11.2 Trolley Assist

Trolley Assist is a technology whereby electric haulers are assisted on mine ramps using an external electricity supply. Trolley assist has been utilized at mining sites around the world since the early 1980s (Rensburg, 2017). The electricity supply takes the form of a direct current (DC) overhead line. The idea behind the trolley assist system is to substitute diesel fuel by cheaper more environmentally friendly electric supply.

Instead of generating electricity from the diesel engine and generator on the truck, the electric energy is supplied from a dedicated substation and fed to the electric drive and motors of the truck via overhead feeder lines. The dedicated substation and equipment are robust and designed to cope with rough environmental and operational conditions. This includes the continuously varying load conditions of between zero and 150%, depending on the duty cycle of the trucks (Rensburg, 2017). The electric hauler connects itself to the line by means of pantographs, as illustrated in Figure 11-2.

Figure 11-2: Illustration of Mining Truck Riding in Trolley Mode



(Brodkorb, 2014)

The electric supply relieves a big portion of the load on the truck's diesel engine, resulting in substantial fuel savings. Furthermore, the electric wheel motors are normally sized with power rating up to twice the nominal power delivered by the diesel engine. Supplied by the overhead lines, the wheel motors can run at higher horsepower, which translates to higher hauling speeds on the ramp and resultant productivity gains in tonnes of material hauled per truck operating hour.

Despite the relative success of the technology, its application remains limited due to multiple factors including its high power demand and the unavailability of the necessary electricity supply in some operational locations. Nevertheless, several haul truck manufacturers offer the technology as an add-on option. A utilization factor of more than 80% for the trolley assist system can be achieved.

11.2.1 Barrick Gold Corporation - Lumwana Copper Mine

Lumwana is an open pit copper mine located about 100 km west of Solwezi in Zambia's Copperbelt. It is reported to be one of Africa's largest copper mines. The mine was officially inaugurated in April 2009 by Equinox Minerals. Equinox Minerals was acquired by Barrick Gold Corporation in July 2011.

The Malundwe and Chimiwungo deposits, which are 7 km apart, are being mined sequentially by open-pit methods. The mine is a conventional truck and shovel operation. Haul roads have a maximum grade of 10% and are 50 m wide. To transport ore from pit to crushing stations, Siemens supplied the equipment required for the electrification of 27 haul trucks along with the associated in-pit trolley assist system which was installed during 2008 and 2009. All trucks were equipped with the latest alternating current (AC) drive technology. The number of AC-driven trucks have since then increased to approximately 32 trucks. The route length at Lumwana is approximately 4 km having a substation rating of 10 MVA (Brodkorb, 2014).

Lumwana uses Hitachi 4500 dump trucks retrofit with Siemens drive technology. The system includes the overhead lines, trolley poles and cantilevers. By adopting the trolley assist technology, the average diesel consumption rate was reduced from approximately 360 l/hr to 45 l/hr when using the trolley system, and the average speed was increased from 8 km/h to approximately 24 km/h on the ramp (Siemens, 2011). Due to the increased productivity, the mine has a reduced truck fleet.

Overall, the diesel-electric drive concept, was found to reduce operational costs by 7%. The investment in the trolley assist technology means that GHG emissions over the life of the mine are reduced by approximately 9% (Siemens, 2011).

11.2.2 Advantages and Disadvantages

As described above, the speed of a truck on a gradient is normally limited by the diesel engine. If the same truck could get more power by connecting to an overhead electric feeder line while travelling uphill, it could sustain a higher speed. The diesel engine would be idling, and fuel consumption would be reduced by up to 95%, greatly reducing noise and emissions to the environment (Rensburg, 2017).

Although trolley assist powered trucks are not "zero-emission" vehicles, they generate materially less GHG emissions than fully diesel-powered haul trucks. Billions of litres of diesel are consumed annually by the global mining industry, which is under severe pressure from weak commodity prices and rising environmental standards. Loaded haul trucks on uphill gradients typically accounts for 70 – 80% of a truck's total fuel consumption. A trolley assist solution can be installed on any uphill stretch between the loading area (pit) and off-loading points (processing plant) to offset some of that fuel usage.

Additionally, the technology enables vehicles to move faster while travelling loaded up the ramp, which results in quicker turnaround times and higher productivity for the mining operation. For example, if the duty cycle time is reduced by 20% because of the increase in speed on the uphill gradient, a fleet of 32 trucks on trolley can produce the same results as 40 trucks operating on diesel. This results in reduced truck capital and operating costs.

The technology has been supplied to open pit mines across the world and currently new business interest has been on the rise. The goal of mining corporations is always to reduce the cost per tonne of the commodity produced over the life cycle of the assets, and the trend is clearly toward larger trucks, shorter cycle times with a leaner fleet and overall lower cost of ownership, all of which can be realized through the benefits of a trolley assist solution.

The major disadvantage of haul trucks using trolley assist is the high upfront capital compared to diesel vehicles. This is because they are powered by an overhead trolley system that must be installed along the length of selected haul road. Additional cost is also necessary per haul truck due to the trolley-assist add-on package. Another consideration is the fixed nature of the trolley line and the subsequent reduced mobility/versatility of truck movement within the mine in order to maximize benefit from the installed line.

11.2.3 Barriers to Adoption

Although trolley assist systems have been available for over 40 years and despite interesting operational and environmental benefits, few operations have employed them to date. The decision to install a trolley assist

system is heavily dependent on the size and overall mine plan of an operation. Longer hauls and steeper grades present an opportunity for trolley assisted haulage. Typical truck payload requires a huge power source (up to 4 MW per truck) that must be efficiently used.

Keeping the gross vehicle weight for haul trucks as low as possible is also important such that power consumption is limited to just ore transport. Every tonne of infrastructure added to the truck is one less tonne of material the truck can haul. Several mines globally are located in remote areas (deserts, forests, elevated mountainous regions, etc.) and the trucks have to contend with extreme environmental conditions. These parameters make electronic packaging a fundamental component in haul truck design because of the small space left to place adequate power source drivers.

Additionally, these systems involve significant capital investments and require technical expertise to efficiently design, plan and maintain. Note that the economics of the trolley option improves with scale. Thus, it is a less attractive solution for smaller pits.

Trolley assist technology is worth considering if a mine has (Brodkorb, 2014):

- High differential between electrical power and diesel fuel price
- Deep pit with long ramps
- Long life of ramps
- Semi-permanent ramp network
- Well-constructed and maintained haul roads

When considering the trolley assist technology, it is necessary that a site-specific evaluation is done since mines can differ in significant ways. An evaluation would typically include haul profile data, cycle times, production requirements and energy prices.

11.3 VAM Abatement

Methane gas present in underground coal seams poses is a safety hazard to miners because it is explosive at concentrations ranging between 5-15% in air (USEPA, 2019b). Gassy underground coal mines employ large scale ventilation systems to move fresh air into the mine. These systems dilute methane released into the mine workings as coal is extracted and remove the gas from the mine, thereby maintaining safe working conditions. In-mine methane concentrations must be maintained well below the lower explosive limit, so ventilation air exhausts contain very dilute concentrations of methane (typically less than 1% and often less than 0.5%) (USEPA, 2019b). However, because mine exhaust flow rates are very high, ventilation air methane (VAM) constitutes the largest source of methane emissions at most mines.

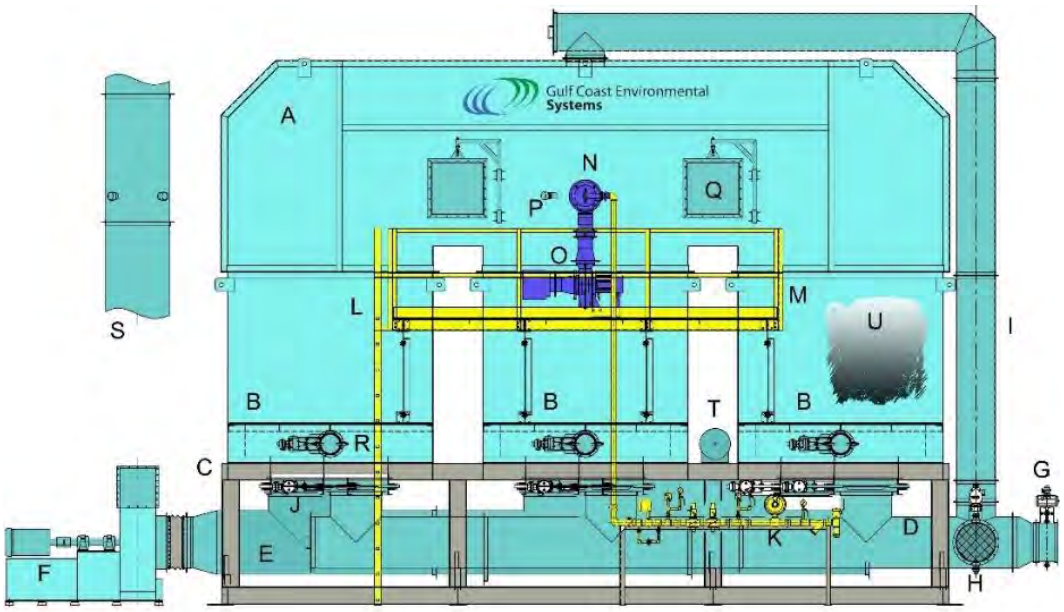
Releasing VAM to the atmosphere wastes a clean energy resource and produces significant GHG emissions. Methane is a potent greenhouse gas with a global warming potential 25 times that of carbon dioxide. Deploying technologies that chemically destroy VAM into carbon dioxide or convert VAM into useful forms of energy can yield substantial GHG emission reductions.

Regenerative Thermal Oxidation (RTO) is currently the only commercially operational technology capable of destructing VAM emissions (USEPA, 2019b). An illustration of an RTO is presented in Figure 11-3. Ducts direct a

slip stream of exhaust air from the ventilation fan to the oxidizer unit. Air velocity is maintained in the ducting by use of a smaller fan that creates vacuum pressure. This provides a steady flow of mine ventilation air into the oxidizer and ensures that there is no back pressure on the mine shaft fan.

When entering an RTO, gas encounters a bed or column of heat exchange material, usually ceramic media that has been preheated to the oxidation temperature of methane (1000° C). The VAM enters the oxidation chamber where it is oxidized and releases heat, which is absorbed by the second bed or column of heat exchange material, heating the bed to 1000° C. This heat sustains the auto-oxidation process without requiring additional fuel input. Valves and dampers repeatedly reverse the flow of incoming VAM to keep the hot zone in the centre of the oxidizer. Regenerative Catalytic Oxidizers (RCO) operate on the same principal with the addition of catalysts that are intended to allow the reaction to occur at lower temperatures and with reduced pressure drop across the bed of heat exchange material. Some RTO installations allow heat recovery of excess heat (USEPA, 2019b).

Figure 11-3: VAM Regenerative Thermal Oxidizer



Key:

A: Combustion Chamber	H: Dilution Air Valve/Inlet	O: Combustion Air Fan
B: Heat Recovery Chambers	I: Bypass (if equipped)	P: Flame Sight Glass
C: Structural Skid	J: Process Control Dampers	Q: Access Door(s)
D: Inlet Manifold	K: Fuel Gas Train/Regulators	R: Purge Dampers
E: Outlet Manifold	L: Access Ladder	S: Exhaust Stack
F: Process Fan	M: Service Platform	T: Air Tank
G: Process Isolation Valve	N: Burner	U: Heat Recovery Media (inside)

(Gulf Coast Environmental Systems, 2019)

11.3.1 Murray Energy - Marshall County Coal Mine

A VAM mitigation project was commissioned in 2012 by Verdeo at Murray Energy's Marshall County Coal Mine (formerly CONSOL Energy's McElroy Mine) in West Virginia. The project has been successfully destroying methane from this underground mine using RTO technology.

At start-up of the RTO, the ceramic medium bed in the RTO is heated with a propane burner. VAM is then forced through the bed, methane is oxidized, and the released heat is recovered by the ceramic bed medium and the air flow is reversed. The heat recovered from the first cycle heats the incoming VAM and the process repeats.

The methane concentration in the VAM ranges between 0.6-1.5%. Each RTO has a capacity of 25 Nm^3/s for a total plant throughput capacity of 75 Nm^3/s (160,000 scfm), which is 80% of the shaft flow. As of December 31, 2017, the project has registered an estimated 1,045,923 tCO_2 in emission reductions (USEPA, 2019b).

The success in demonstrating both the technical and commercial viability of the project suggests the potential for additional VAM project deployment in coming years.

11.3.2 Advantages and Disadvantages

Some of the advantages of using RTOs as compared to other emission control technologies are as follows (Gulf Coast Environmental Systems, 2019):

- RTOs are particularly reliable, durable systems that carry a low operating cost
- RTOs typically eliminate as much as 99% of volatile organic compounds and have low NOx operation
- RTOs are suitable for continuous operation
- Energy efficiency is around 95% and up to 99%, reducing fuel consumption for heating the exchanger bed
- Several customizable options are available based on specific output and application

The major disadvantages of RTO's are as follows (Gulf Coast Environmental Systems, 2019):

- High upfront investment costs
- Large size and weight
- Ceramic beds may be blocked by dust and condensed particles
- In discontinuous operation, the bed must be re-heated at every startup, using extra fuel

11.3.3 Barriers to Adoption

According to an expert dialogue on VAM organized by CSIRO and supported by the Global Methane Initiative and USEPA, some of the market and economic barriers to VAM deployment include (CSIRO, 2018):

- VAM oxidation projects have high capital requiring many years of operation before payback is achieved.
- Manufacturers of VAM abatement systems have little interest in further R&D to improve designs and reduce costs without the existence of confirmed markets.
- Where possible, it may be more effective to invest in increased gas drainage. This could include drilling additional pre-mining and post-mining boreholes or increasing drainage time.
- A critical need for project success is access to reliable data on VAM emissions including air flow and methane concentrations on a mine-specific and shaft-specific basis. Such data will provide essential information on the resource and the potential for emission reductions and will also support more accurate assessment of marginal abatement costs and project opportunities.

- Unless projects incorporate heat recovery or utilization of VAM, the only revenue stream is from carbon credits or avoidance of carbon taxes/penalties. The high capex and extra opex required by VAM projects combined with exposure to uncertain policy-controlled markets result in considerable risk exposure for project developers. In some cases, project developers, investors and coal mine owners/operators prefer to invest in addressing other GHG sources.

11.4 CMM Abatement

Methane is often found in association with coal deposits. These deposits might be virgin coal seams (coal seam methane / coal bed methane), be in the process of being mined or may be abandoned (Clarke Energy, 2019). Methane emissions can adversely affect both the safety and the productivity of underground coal mines (USEPA, 2019c). Generally, it is economically feasible to handle emissions up to 28 m^3 per tonne coal mined with a well-designed ventilation system; however, at higher emission rates, ventilation alone becomes inadequate and other means are necessary to stay within statutory methane limits (Karacan, 2009).

11.4.1 Drainage Methods

Supplementary methane control measures, such as degasification of the coalbed, are needed prior to or during mining. Figure 11-4 shows a schematic representation in a longwall mining environment and the different types of degasification boreholes commonly used in US mines.

Since ventilation alone may not be enough to control methane levels in a mining operation, gob vent boreholes, horizontal and vertical drainage boreholes, and their combinations are drilled and used as supplementary methane control measures in many mines (Karacan, 2009). The most commonly applied methane control technique, especially in high in-place gas content coalbeds, is drilling drainage boreholes into the panel area prior to longwall mining to reduce the methane content of the coalbed and to reduce face emissions during mining. These boreholes can be vertical boreholes drilled from the surface or in-seam horizontal boreholes drilled from the gate road entries.

Horizontal and Vertical Drainage Boreholes

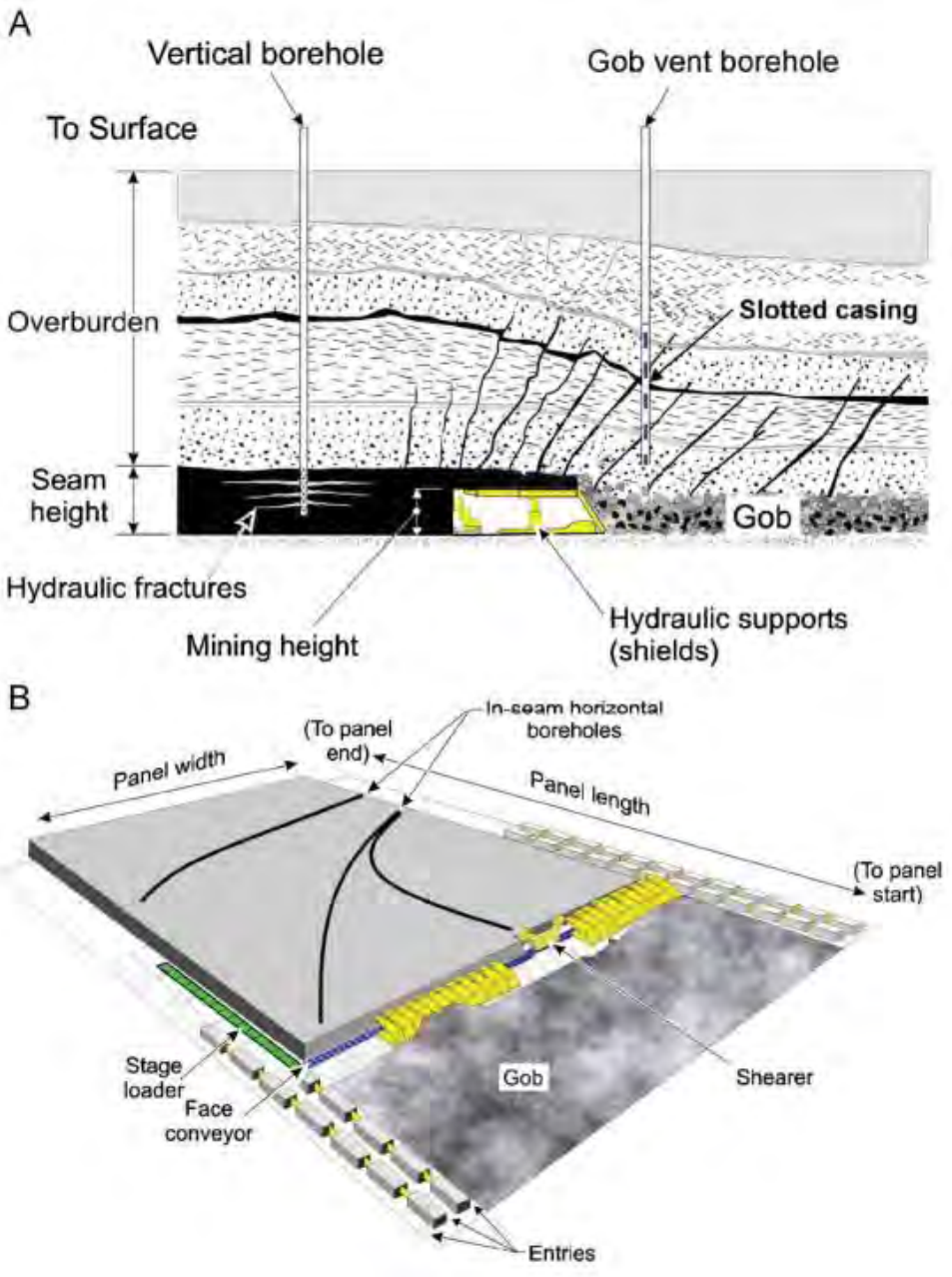
Inseam horizontal methane drainage boreholes are usually completed open-hole and they are logistically difficult to drill due to the limited work space. Vertical methane drainage boreholes on the other hand have the distinct advantage of not being conducted in the restrictive underground environment. They are mostly suited for highly gassy, deep, low-permeability coal seams where it takes a long time prior to mining to adequately degasify the coalbed. However, the drainage area of vertical wells is limited compared to that of horizontal boreholes. Thus, in most circumstances vertical wells need to be stimulated by hydraulic fracturing.

Gob Ventilation Boreholes

Gob ventilation boreholes are applicable to longwall mining only. They are commonly used to control the methane emissions from the fractured zone and are drilled from the surface to a depth that places them above the caved zone so that they do not directly interact with the ventilation system. The bottom section of the pipe is slotted and placed adjacent to the expected gas production zone. These ventholes generally become productive after the mining-induced fractures propagate under the well. They are equipped with exhausters to capture gas from long distances and reduce methane migration from the fractured zone into the mine.

Despite different drainage methods used in most US longwall operations, some operations do not use any degasification if the gas emission levels can be effectively controlled with ventilation. In most cases, a combination of different drainage methods leads to the highest recovery of methane from the coalbed and its overlying strata. The preferred methane recovery method depends on the mining parameters and the gassiness of the coal seam.

Figure 11-4: Longwall Mining Environment and Commonly Used Degasification Borehole Types

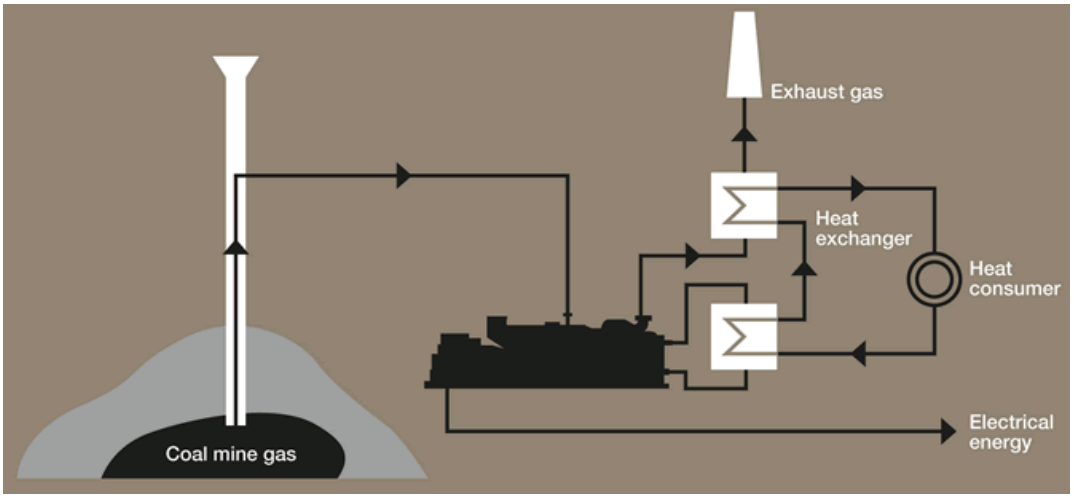


(Karacan, 2009)

11.4.2 Types of Methane

Methane gas from each of the boreholes described above may be suitable for capture and utilization as an energy source. Using coal gas for electricity and/or heat generation helps prevent emissions to atmosphere and provides a useful form of on-site utilization. A schematic of coal mine gas undergoing degasification to generate electricity with waste heat recovery to deliver useful thermal energy is presented in Figure 11-5.

Figure 11-5: Coal Mine Gas Used for Combined Heat and Power Generation



(Clarke Energy, 2019)

The main component of the primary coal seam gas is methane in a concentration of up to 95%. The gas develops during the geochemical conversion of organic substances to coal (carbonization). Coal seam gas is present both as liberated gas in fissures, faults and as adsorbed gas on the inner surface of the coal and neighboring rock. Gases derived from coal come in four key forms described below (Clarke Energy, 2019).

Coal Bed Methane

Coal Bed Methane (CBM) is primary coal seam gas collected from unmined coal beds. These coal seams are drilled down into, releasing the associated gas which is extracted and can be used to generate electricity. CBM consists of over 90% methane and can be harvested independently of coal mining in some locations. The gas composition is normally stable, meaning that the gas can be fed directly into the natural gas network or a gas engine.

Coal Mine Methane

Coal mine methane (CMM) is a type of gas present in active, working mine sites. This gas when extracted from the mine helps improve safety and prevents the uncontrolled release of methane to atmosphere. CMM is a mixture of methane and air released during the process of coal mining. Methane has adverse effects as a GHG with a global warming potential 25 times higher than that of carbon dioxide, therefore its capture and use in gas engines has significant environmental benefits. The methane/air proportion within captured CMM is subject to sudden fluctuations during operation, thus complicating its use in gas engines.

Abandoned Mine Methane

Even after coal mines are shut down, coal mine gas continues to be released. Coal mine gas from abandoned mines typically contains no oxygen, and its composition changes slowly. The methane content ranges from 60-80%. Historically, capping and/or flooding has been used to alleviate post-mining emissions from underground mines. A modern producing mine would be capped at the end of its operating life to prevent this type of release.

11.4.3 Shanxi Coking Coal Group - TengHui Coal Mine

TengHui is an underground coal mine located in China's Shanxi Province along the western border in Xiangning County and owned by the Shanxi Coking Coal Group. There are two mineable seams for coal production at the TengHui Mine, the No. 2 seam and the No. 10 seam. The No. 2 seam is the only seam that is currently being mined. The mine produces 1.2 Mt per year and employs a gas drainage system but does not utilize any of the CMM produced in the mine.

Approximately half of the total mine methane emissions are vented to the atmosphere via the mine's ventilation system. The majority of the balance of the methane gas is captured by a network of in-seam boreholes drilled in advance of development for the purposes of pre-drainage. A small amount of methane gas is captured from cross-measure boreholes and large diameter through-pillar boreholes intended to capture gob gas during mining. The gas from both pre-drainage and gob drainage is liberated upon recovery.

Average total mine methane emissions are 53,280 m^3/d. The approximate specific emissions from the mine are 15.5 m^3/t. The average in-situ gas content of the No. 2 mining seam is reported as 9.2 m^3/t, and the underlying No. 10 seam is reported as 7.7 m^3/t. The No. 2 seam is 4.9-7.5 m thick and requires gas content reduction through drainage to achieve reasonable mine production rates when mined in a single lift. As indicated above, existing drainage activities are solely conducted for the purpose of controlling the methane content in the underground mine environment and meeting safety requirements.

The TengHui Mine officials recognize the opportunity to reduce mine emissions by optimizing CMM recovery and implementing a gas utilization project. A pre-feasibility study was completed for the mine through the USEPA Coalbed Methane Outreach Program (CMOP) in support of the Global Methane Initiative (GMI). The study was part of an integrated best practices training program for the China International Centre of Excellence on Coal Mine Methane (USEPA, 2019d). The USEPA CMOP works closely with the coal mining industry in the United States to reduce CMM emissions and is also actively engaged in promoting the economic recovery and use of CMM in key coal-producing countries. The program conducts the latter under the GMI, an international partnership that focuses on cost-effective, near-term methane recovery and use as a clean energy source.

The pre-feasibility study performed for the TengHui Mine included a review of gas availability and end use options to reduce emissions as a foundation for a more detailed feasibility study that would ultimately lead to a CMM abatement project. Historical data relating to the gas flow and performance of the existing drainage and ventilation systems was used in the study.

Power Generation was deemed the most viable option for utilization of the CMM recovered from the TengHui Mine (USEPA, 2019d). Additionally, the study identified a number of practices that would effectively improve the recovered gas quality, reduce methane drainage costs, and increase the value of the captured gas, including (USEPA, 2019d):

- To improve pre-drainage, replace the short in-seam cross-panel boreholes with long directionally drilled boreholes placed in advance of and flanking mine developments. This reduces the number of wellheads and potential points of air leakage into the gas drainage system.
- To improve gob degasification, use horizontal (directionally drilled) gob boreholes drilled from the mining seam to a derived height above the low-pressure side of the longwall panel near the tailgate entry.

The financial analysis of the study considered all capital and operating costs of a CMM abatement project including the cost of drilling boreholes, the gathering system, and the power plant. Returns for the entire project which includes both the gas drainage program and the surface utilization project are presented in Table 11-2. The high case represents the most optimistic scenario in terms of returns. The base case is the most realistic return scenario given available data used for key inputs in the financial analysis.

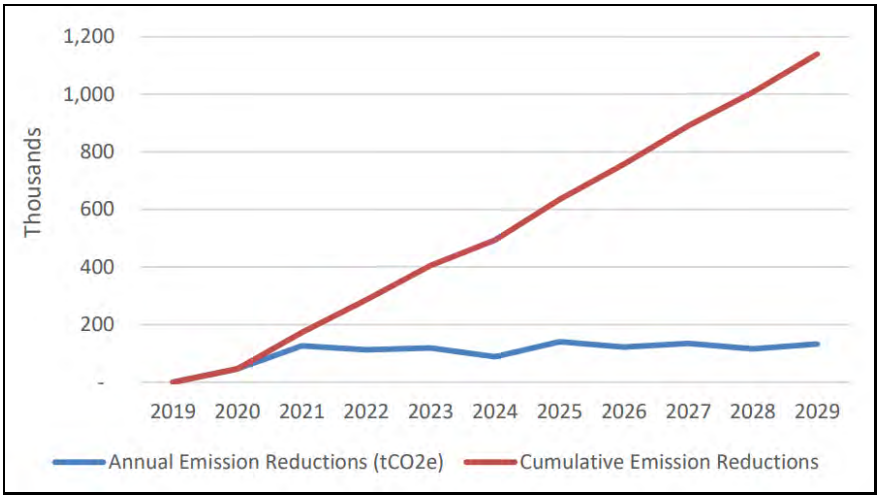
Table 11-2: Summary of Economic Results for TengHui Mine

Case	Max Power Plant Capacity (MW)	NPV ($'000)	IRR	Payback (years)	Net CO_2 Reductions (tCO_2e)
High	5.23	9,491	22.06%	4.90	1,481,616
Base	3.71	1,684	12.23%	6.45	1,139,704
Low	3.47	-943	8.72%	7.24	797,793

(USEPA, 2019d)

The proposed CMM project has optimal net emission reductions potential of 1,481,616 tCO_2e alongside 5.23 MW of power production capacity, which highlights an attractive financial opportunity with benefits of emission reductions and increased energy security. In Figure 11-6, from 2021-2029 the average emission reductions of the project are 121,434 tCO_2e per year. Note that emission reductions occur at a steady rate after gas delivery and use occurs.

Figure 11-6: Projected Emission Reductions at TengHui Mine



(USEPA, 2019d)

11.4.4 Advantages & Disadvantages

Benefits of coal seam methane capture and utilization include (Clarke Energy, 2019):

- Abatement of methane release into the atmosphere
- Alternative disposal of a problem gas whilst simultaneously harnessing it as an energy source
- Increased mining safety when methane is pre-drained at active collieries
- Smooth operation despite fluctuations in gas pressure, methane content and impurities in the gas
- Sound economics with overall efficiency of up to 90% in the case of combined heat and power, and 43% in the case of power generation alone

CBM/CMM is extracted from coal beds through the drilling of wells. However, unlike drilling for natural gas, it is typically necessary to first pump out water from the coalbed to depressurize the area and allow the flow of methane into the well. This can pose a unique challenge since the water typically has a high salinity level and therefore cannot be introduced into local freshwater ecosystems without the potential for adverse effects. As such, the environmental impacts of methane drainage from coal mines must be considered and assessed.

11.4.5 Barriers to Adoption

Several studies have looked at barriers to methane abatement and utilization at a country-by-country level. Barriers can be government policies, ownership issues, technological issues, and financial. These barriers can also be perceived versus real challenges. Following is a summary of potential barriers to the widespread global adoption of CMM abatement strategies (Banks, 2012):

- Lack of clarity regarding legal ownership frameworks such as rights to CMM production and whether these are included with the coal exploration rights for a given deposit
- Lack of inventories and accurate assessments of CMM resources at active and planned mines
- Lack of technology transfer between private companies and access to training and skills for new technology
- Lack of investment capital and low risk tolerance within industry
- Lack of financial incentive mechanisms for CMM production

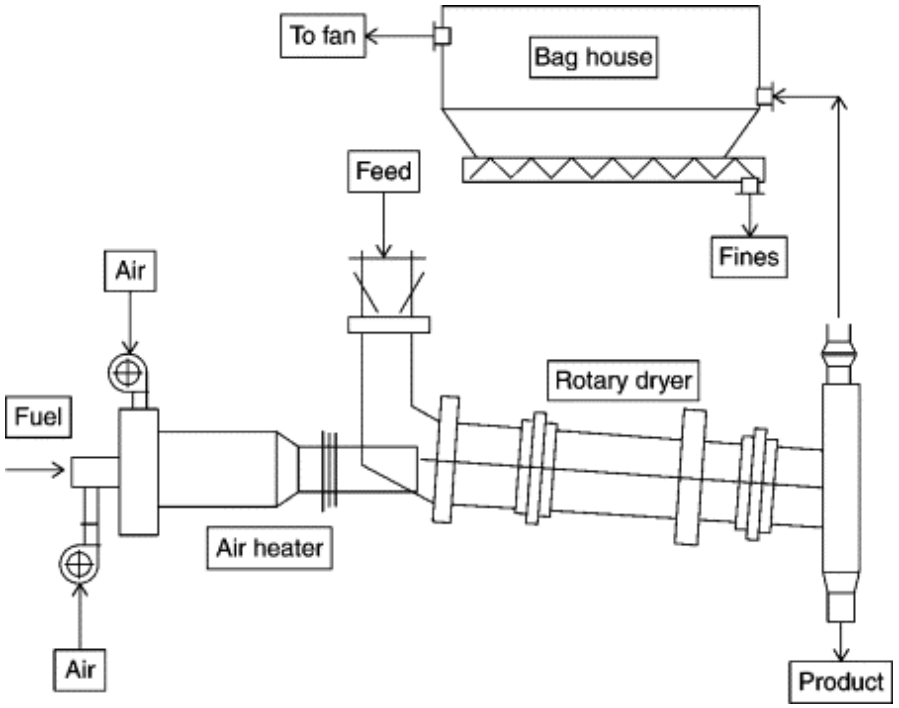
Technology adoption barriers can often be related to policies that have unintended consequences or insufficient impetus for change. An increase in CMM projects could be achieved by introducing policy that better incentivizes and regulates methane abatement in coal mining. Financing these projects will continue to be an issue; however, such hurdles are continually being overcome using innovative financing models and R&D funding related to clean technology (Banks, 2012).

11.5 Coal-to-Gas Conversion

As part of the processing of metallurgical coal, residual moisture post coal sizing and washing must be removed in preparation for shipment. This is normally achieved using industrial thermal dryers that burn fuel to generate heat. In the coal mining industry, thermal drying units are typically coal fired. The hot gasses from combustion are directly applied to the wet coal mass to evaporate the water content (Vince, 2013).

Common industrial dryers include fluid bed, flash tube, and direct contact rotary dryers. A typical direct contact rotary dryer is illustrated in Figure 11-7 consisting of three main sections. Hot air is generated on one end of the unit and is then directed to the rotary drum where the wet coal enters. The dried coal exits from the bottom of the end hood, while the vapor/gas stream passes through air pollution control devices to remove airborne fine particles (Vince, 2013). Rotary dryers are used by many coal producers and are known for their robust build, high throughput, and ability to accept variance in feedstock (Le Capitaine & Carlson, 2017). Industrial dryers are designed for the intended feedstock. In the case of coal drying, special consideration is given in the design and operation of these units to mitigate the risk of fires/explosions given the combustibility of coal.

Figure 11-7: Direct Contact Rotary Dryer



(Vince, 2013)

11.5.1 Teck – BC Steelmaking Coal Mines

Teck is a diversified resource company that is the world's second largest seaborne exporter of steelmaking coal, with six mining operations in Western Canada. As one of their initiatives to reduce GHG emissions, the company has been displacing coal used as fuel in their dryers with natural gas.

Four of Teck's coal operations are designed to use both coal and natural gas in their product drying process. Traditionally, these dryers have predominantly been burning coal. In 2010, the company made the shift to using greater proportion of natural gas at their Elkview Mine (Teck, 2011). Given the impressive results that this project yielded, the company has subsequently increased the use of natural gas at Coal Mountain, Fording River and Greenhills mines (Teck, 2011). Today, Greenhills is the only mine of the four that still uses coal (Teck, 2019). Line Creek's dryer is a gas-only dryer and has never used coal, while Cardinal River has a coal dryer with no gas option due to the absence of a gas line connection to the mine (Teck, 2019).

Figure 11-8 shows the decline in GHG emissions associated with product drying at the four mines that have undergone the change. Between 2010 and 2011, this fuel modification reduced absolute emissions by 90 $ktCO_2e$ and emission intensity by 4.4 tCO_2e/kt product (or $kgCO_2e$ per tonne of clean coal) – a 23% reduction in coal drying emissions (Teck, 2011). Note that while the Teck mines referenced in this case study are surface mines, this GHG abatement strategy applies to both surface and underground operations that include coal processing.

Figure 11-8: Teck Emissions Associated with Product Drying (2006 - 2011)



(Teck, 2011)

11.5.2 Advantages and Disadvantages

While natural gas is a fossil fuel, the global warming emissions from its combustion are the lowest amongst fossil fuels. This is a function of the carbon content of the fuel. Compared to coal, natural gas emits roughly 30% less carbon dioxide per unit of energy.

When it comes to greenfield developments, natural gas is considered the fuel of choice by many operators given increasing pressures by the investment community, governments and the public to demonstrate commitment to climate action. In the case of brownfield mines, coal-to-gas conversion is a cost-effective approach to maintaining capacity while increasing flexibility for total asset management (Brown, 2015). Where dryers are not equipped with dual burners, a retrofit to add a secondary burner allowing for gas firing may be considered. In some instances, switching from coal to natural gas may result in a marginal loss of efficiency which should be evaluated especially if not considered in the original equipment design.

11.5.3 Barriers to Adoption

Although coal-to-gas conversion continues to be a hot topic, there remains to be much confusion in industry about the actual scope, performance, and financial impacts that this solution may provide (Brown, 2015). A major challenge is the question of whether natural gas will remain price competitive in emerging markets. With the increased demand for natural gas, there is uncertainty around how stable gas pricing will be in the short and long term.

12 Emerging Technologies & Practices

This chapter describes GHG-reducing technologies and practices that are in the early stages of development or yet to be adopted at a sector-wide commercial scale. Measures follow the same order presented earlier in Chapter 5. Where a measure applies to both surface and underground mining, the applicable discussions are combined in a common section.

12.1 VAM Utilization as Principal/Ancillary Fuel

This measure applies to underground mining. There is currently growing interest within the global coal mining industry to pursue abatement strategies that not only destroy VAM emissions but convert VAM to a useful form of energy, such as heat or electricity. VAM is an energy resource that may be used as a primary or ancillary fuel to further mitigate GHG emissions associated with coal mining. The strategies described below are among the most prominent in this emerging field. Limited adoption of VAM as a fuel is primarily attributed to the challenging nature of the resource with its large flow rates and dilute methane concentrations.

Addition of Heat Recovery to Thermal Oxidizers

At high methane concentrations, thermal VAM oxidizers generate excess heat energy that is typically lost to the atmosphere. Oxidizers may be combined with a heat recovery system to harness this waste energy for use at the mine or to generate electricity. The first full scale VAM-to-Power project was developed in 2007 by BHP Billiton for one of their major collieries in New South Wales, Australia (USEPA, 2019b). The company received substantial government funding for the development project in which they worked closely with B&W MEGTEC, the oxidizer manufacturer, to integrate the oxidization process into the steam cycle of a power plant (UNECE, 2016). The VAM-fuelled power plant effectively used RTOs as specialized furnaces capable of extracting energy from an extremely dilute form of fuel (UNECE, 2016).

In addition to this demonstration project, recent policy drivers in China have led to the launch of more VAM heat recovery projects in the region. However, the technology lacks widespread implementation in the coal mining industry.

Use of VAM in Lean-Burn Gas Turbines

Various lean-burn gas turbines are being developed to operate strictly on VAM or VAM that has been enhanced with a supplemental fuel. The minimum methane concentration for electricity generation using lean-burn gas technology is typically 1% (USEPA, 2019b). Mines that produce lower quality VAM require the blending of methane from other sources such as drained CMM or natural gas.

Electricity generation using lean-burn gas turbines that operate on VAM as the primary fuel is an emerging technology that is approaching commercialization (USEPA, 2019b). One important example is the CSIRO VAMCAT™ technology which uses a catalytic combustor to allow combustion at low methane concentrations. Through a partnership between the Australian and Chinese governments in 2011, CSIRO built and tested a 25 kW test unit at an underground coal mine in China. The unit validated the technology in a field environment and demonstrated successful operation at a methane concentration of 0.8% (CSIRO, 2019).

Use of VAM as Combustion Air

VAM may be used as an ancillary fuel such as in the form of combustion air in internal combustion engines, gas turbines, and steam boilers for power generation or other industrial/utility purposes. The energy content of VAM displaces a portion of the primary fuel consumed by these processes.

The concept has been demonstrated at various mines in Australia; however, its implementation is limited by siting constraints since the combustion application and associated equipment is required near the mine shafts (USEPA, 2019b). Another limitation is matching equipment size to VAM flow rates such that venting is fully abated (Singh & Mallick, 2015).

VAM Concentrators

Advancements in concentrating or enriching VAM to increase its methane concentration is an emerging field that expands the potential for VAM end-use. For example, if VAM is concentrated to 30% methane or greater, it can be used in conventional gas turbines/engines for power generation.

Multiple research bodies are working on VAM concentrators including CSIRO, which is developing a capture and enrichment unit named VAMCAP™. The technology collects and separates out methane from the ventilation air stream using carbon composite adsorbents. The VAMCAP™ has been prototyped and bench tested with results showing that VAM concentrations can be increased tenfold through one-step adsorption and fortyfold using two-step adsorption (USEPA, 2019b). Further research is required to advance the technology to the field demonstration stage.

12.2 Mobile Fleet Electrification Using Battery Operated Vehicles

This measure applies to surface and underground mining. Electrification through battery electric vehicles (BEV) is a disruptive technology in modern day transportation that is progressively advancing from the light-duty vehicle market into the medium-duty and heavy-duty segments, displacing conventional diesel power trains (RMI, 2019).

In the case of surface mining, battery operated mine haulers are still in the early stages of development and face a significant challenge of scale. The largest battery powered mining truck known to date is the eDumper, a prototype developed by the Swiss company eMining with the support of various research partners (Gleeson, 2019b). The 63-tonne payload truck is a modified Komatsu HD605-7 in which the diesel engine was replaced with an electric motor and a 700 kWh battery pack (Gleeson, 2019b). The eDumper has been operational at a limestone quarry in Switzerland since 2017 and serves as a basis for the development of larger electric mining haulers. Estimates suggest that the eDumper is likely to cost 2.5-3 times more than its diesel equivalent with the battery packs accounting for 30-40% of the difference (Gleeson, 2019b). The upfront capital is offset by the reduced maintenance as a result of eliminating the diesel engine and higher speed resulting in productivity gain.

According to RMI (2019), BEVs for surface mining are projected to achieve commerciality and economic feasibility in 8-15 years. Among the organizations working to accelerate this transition is ICMM which announced a new collaboration last year between 27 leading mining companies and equipment suppliers through the Innovation for Cleaner Safer Vehicles (ICSV) programme. One of the ambitions of ICSV is to introduce GHG-emission-free surface mining vehicles by 2040, BEVs being part of the solution (ICMM, 2018).

In the case of underground mining, battery operated LHD units, personnel carriers, and other mobile equipment are gaining increased momentum with a select few models currently commercialized. The development of this equipment is primarily driven by the metal mining sector where fleet electrification provides value streams beyond GHG reduction. In underground metal mines, diesel consumption has a direct bearing on the ventilation requirements of the mine. Significant savings of capital and operating ventilation costs can be realized through the elimination of diesel exhaust in the underground mine environment. In coal mining however, the ventilation system capacity is determined based on methane emissions and the gassiness of the mine which means that such cost savings may not be possible. Yet, the elimination of particulate matter emissions and reduction in noise, vibration and heat associated with diesel engines contributes to an overall better working environment for miners.

The gold mining company Newmont Goldcorp is one of the early adopters of BEVs with their all-electric Borden mine near Chapleau, Ontario. The mine achieved commercial production in the Fall of 2019 after several years of development. The company teamed up with equipment suppliers Sandvik Mining and MacLean Engineering and received federal and provincial funding towards electrification of the mine fleet which includes a host of battery operated machines (Jamasmie, 2019).

As discussed in Chapter 4, diesel accounts for roughly 40% and 5% of total GHG emissions at a typical surface and underground coal mine respectively. Evidently, the size of the GHG reduction opportunity is much larger for surface mining. The GHG benefit of BEVs ultimately depends on the carbon intensity of the electric grid providing power to the electric vehicles. The greater the share of renewable sources, the greater the GHG reduction potential of going from diesel to electric propulsion. A number of trade-offs are at play in the development and implementation of BEVs in coal mining as an alternative to traditional diesel operation. These are summarized in Table 12-1. Such considerations must be carefully assessed given site specific conditions and requirements as part of the decision-making process for adoption of the technology.

Table 12-1: BEV Trade-offs in Coal Mining

Barriers/Challenges	Advantages/Benefits
▪ Lower energy density sacrificing payload and/or range (energy content per unit mass of diesel more than 50 times higher than the most energy dense lithium ion batteries) ▪ Higher capital cost of equipment (surface haul trucks: +250-300%, underground fleet: +20-30%) ▪ Requirement for charging infrastructure and associated capital ▪ Charging or battery swapping more complex than refueling ▪ Operational changes necessitated by charging ▪ Battery performance drops at below freezing temperatures	▪ Lower carbon footprint and opportunity for renewable energy integration due to electrification ▪ Lower O&M costs due to fewer moving parts and consumables (e.g. oil, filter changes, repairs and rebuilds of diesel engine) ▪ Increase in efficiency (approximately 3 times higher for electric motor compared to diesel engine) ▪ Incorporation of regenerative breaking technology which can capture energy during deceleration and store it in battery ▪ No need for idling at rest or when vehicle is parked ▪ Higher torque at low speeds favourable to operators ▪ Higher haul speeds resulting in shorter cycle times ▪ Elimination of exhaust fumes resulting in improved air quality ▪ Reduction in noise, vibration and heat generation

(RMI, 2019), (GMG, 2018), (Gleeson, 2019b), (Taylor & Lewis, 2018)

12.3 Mobile Fleet Electrification Using Hydrogen Fuel Cell Vehicles

This measure applies to surface and underground mining. The use of hydrogen fuel-cell electric vehicles (FCEV) to decarbonize transportation is an aspiring solution that is gaining increasing momentum in the heavy-duty vehicle segment.

While traditional combustion technologies burn fossil fuels to generate mechanical energy, fuel cells generate electricity via a chemical reaction between hydrogen and oxygen, which in turn is used to power an electric motor. Oxygen is readily available in the atmosphere and hydrogen is supplied to the fuel cell as pressurized gas in a manner comparable to refuelling conventional vehicles. The process produces zero exhaust emissions and the only by-product is water vapour.

The same is not true for the process by which most hydrogen is produced today – an emission intensive process known as steam-methane reformation. However, recent developments in "green hydrogen", hydrogen produced with energy from renewable sources, increases the viability of FCEVs as an alternative to fossil fuelled vehicles. Water electrolysis is the most promising pathway to renewable-energy-based hydrogen production whereby solar or wind electricity is used to separate hydrogen out from water molecules (RMI, 2019).

In addition to the possibility of delivering entirely emission-free power, FCEVs have all the advantages of an electric power train while offering comparable driving ranges to traditional vehicles (Anglo American, 2019a). The global mining community recognizes hydrogen as a future option for powering mobile equipment and is closely monitoring developments in the hydrogen industry. Recent high-power hydrogen applications by companies such as Alstom and Nikola Corp demonstrate the potential of FCEVs in heavy machinery; however, at the present time, hydrogen lacks cost competitiveness and is considered by most mining companies prohibitively expensive for large-scale adoption (Mason & Babbitt, 2019).

In 2017, thirteen leading energy, transport and industry companies, including mining giant Anglo American, launched the Hydrogen Council as a global initiative to accelerate investment in the development and commercialization of hydrogen technologies (Anglo American, 2017). In 2019, Anglo American announced its plans to develop the world's largest hydrogen powered mine haul truck in partnership with energy company Engie, which will be providing the hydrogen generation solution (Anglo American, 2019b). The converted truck is slated for testing in 2020-2021 at Anglo American's Mogalakwena platinum surface mine in South Africa and is seen by the company as an important step towards achieving their sustainability ambitions including operational carbon neutrality (Anglo American, 2019b).

Introducing hydrogen into underground mines faces an added challenge due to the risk of leaking and venting from hydrogen fuel cell systems. Maintaining a safe work environment requires an understanding of how hydrogen behaves in confined spaces and the ventilation requirements necessary to avoid accumulation of hydrogen at flammable concentrations. A team at NRCan's CanmetMINING is presently conducting research to determine just that and to recommend best practices for use of hydrogen in underground mining conditions (Bedard, 2019). Similar efforts are underway at South Africa's North-West University and national Council for Scientific and Industrial Research (Moore, 2019).

12.4 Use of Surface Miners for Material Extraction and Loading

This measure applies to surface mining. A surface miner is a machine that cuts, crushes and loads ore in a single operation offering an alternative to traditional rip-and-stack or drill-and-blast coal mining. The surface miner is equipped with an onboard drum that cuts and crushes material off the ground, as well as a loading conveyor system that dumps the sized material onto the trucks that transport it out of the pit. Refer to Appendix H for illustrations and images of surface miners in operation.

Surface miners are a relatively new solution in the mining industry that is intended to improve mining efficiency and lower costs (Orzechowski, 2018). Commercial models are available through two main German equipment manufacturers, Wirtgen and Tenova TAKRAF; however, adoption is limited compared to conventional methods. It is important to note that the suitability of this technology is highly dependent on ore characteristics and not every deposit can be economically mined with surface miners (Orzechowski, 2018). When considering this technology, the resource must be carefully assessed in terms of compressive strength, abrasivity, rock structure, and other properties to ensure the equipment can reliably and effectively cut and crush the ore (Orzechowski, 2018).

From a GHG perspective, surface miners can reduce emissions primarily by reducing the fuel consumed during the material extraction and loading process. In a study conducted by Wirtgen and RWTH Aachen University, a surface miner was integrated into an ongoing coal operation over a period of four months to measure and compare performance. The miner replaced a conventional mining system comprising of two dozers for ripping and staking overburden and coal, and a front end loader for loading onto mining trucks. While the study report is not published, the company stated average fuel savings of just under 80% at comparable production levels, and overall mining cost savings of 60% per unit weight of coal (Wirtgen, 2018). This suggests that the technology has material GHG reduction potential where applicable to a surface coal deposit and is worthy of further investigation.

Surface miners offer additional benefits including (Orzechowski, 2018):

- Elimination of blasting and associated emissions, dust, noise, and vibration. This saves operators capital and operating costs as well as alleviates permitting challenges especially where mines are located near roads or other infrastructure.

- Allowing selective mining of coal and interburden. With surface miners, operators can cut material with depth accuracy of a few centimetres which reduces ore loss and minimizes ore dilution with waste rock. This is especially advantageous in the case of deposits were coal seams are thin and separated by numerous layers of interburden.

- Reduction in crushing requirements at CPP since ore is reduced in size by the surface miner rolling drum. The size fraction of the extracted ROM will depend on the miner speed, drum speed, cutting depth, and tool spacing among other factors.

- Cost savings on equipment and labour as a result of the various operational efficiencies gained. Note that a surface miner displaces multiple pieces of equipment and generally requires a single operator.

12.5 Use of Mechanical Dewatering instead of Thermal Coal Drying

This measure applies to surface and underground mining. An emerging approach among coal producers is to eliminate the thermal coal drying process and utilize mechanical dewatering techniques instead to strip moisture out of clean coal.

Mechanical dewatering is generally more economical than thermal drying and can be achieved to varying degrees using equipment such as centrifuges at smaller scale and filter presses for large scale applications. The end moisture content of the coal product is an important consideration for coal producers. A lower moisture content increases the value of coal and means that less moisture is being shipped per tonne of product. A higher moisture content however, has the benefit of binding fines together and producing "lumpier" coal which is more desirable in export markets and therefore has the potential to fetch higher sale prices. Dewatering by extrusion is particularly effective in that regard.

According to information obtained from Teck, the company is currently piloting the use of centrifuges as a way to reduce the level of fines and produce coarser clean coal (Teck, 2019). The main driver for Teck behind this pilot and attempts to reduce the use of thermal drying is to improve the marketability of their product; however, the company acknowledges the ensuing GHG benefit (Teck, 2019).

12.6 Small Modular Nuclear Reactor

This measure applies to surface and underground mining. Small Modular Nuclear Reactors (SMNR) have been increasingly discussed as a method for overcoming the historically large capital costs and long development times for nuclear facilities. This allows economies of scale to be developed and to be built within fabrication facilities and mobilized to remote sites. There has been an influx in investment and research in SMNR facilities recently. However, outside of military applications there are currently very few planned SMNR installations globally and none currently in operation. Several SMNR are indicated as being under construction in Russia, while a large number are indicated as being under design development globally.

SMNR are smaller than conventional nuclear and include passive safety features that improve on their expected safety performance, associated certification and permitting time, as well as negative public perception (World Nuclear Association, 2018). There are a wide variety of SMNR under development including simplified versions of current reactor technology and entirely new fission-based technologies. This includes technology families such as fast neutron reactors, molten salt reactors, and high temperature gas cooled among others (IAEA, 2018).

The heat generated by SMNR and captured by the system coolant can be used to produce steam which in turn can be directly utilized or used to produce emission free electricity. SMNR are typically designed to slot into the scale of facilities that conventional power plants occupy, generally 300 MWe or less. This is within the scale of oil sands mining operations yet the economics of SMNR are still considered unfavourable for this application. Refer to ECCC's BAT/BEP study on oil sands extraction facilities for additional information regarding SMNR (Advisian, 2019).

In the case of coal mining, the electrical load is in the order of tens of MW (~30 MW for surface mines, and ~60 MW for underground mines). SMNR will have even more adverse economics at this scale and therefore require further research and development to penetrate the mining market.

13 Conclusion

This study offers an in-depth look at the GHG reduction landscape in the coal mining industry, supported by a techno-economic evaluation comparing a selection of GHG-reducing measures for surface and underground mines. Advancements in reducing the carbon footprint of mining range from incremental improvements to step changes in equipment design and operation. Where sufficient performance and cost data was available, a quantitative assessment was conducted; otherwise a qualitative discussion was presented.

The study suggests that material GHG reduction opportunities exist within coal mining and processing activities. Electrification of material movement and methane emission management are key elements of the solution for surface and underground mines respectively. As Canada strives for net-zero emissions by 2050, the coal mining sector must ramp up the implementation of GHG abatement projects. Future planned mines must abandon conventional mining practices that neglect GHG impacts, and adopt a portfolio of emission reduction strategies that tackle the various emission sources.

The pathway to net-zero is expected to include the following measures:

1. Full electrification of material transport and handling and elimination of mobile combustion sources within mine operations, with connectivity to a low emission intensity grid or on-site renewable energy generation. This may be achieved through increased reliance on conveyor systems and electric vehicles.

2. Incorporation of carbon capture on stationary combustion sources or use of alternate innovative approaches such as mechanical dewatering instead of thermal drying of the clean coal product.

3. Abatement of methane emissions through degasification and destruction or utilization of the captured gas.

4. Repurposing of disturbed land at the end of mine life for use in green projects such as renewable generation and carbon sinks. One example is the BIOSALIX mine reclamation and biomass production project underway at Westmoreland's Paintearth Mine. The project will transform the reclaimed mine land to be used for the production of fast-growing willow wood biomass crops serving as feedstock in clean energy.

5. Offset projects beyond the mine boundary.

As reflected in this report, ECCC is positioned to navigate the GHG reduction potential within current and future coal mining projects and engage with stakeholders and key players in the industry. Advisian recommends that ECCC consider the following areas for future work:

- Engagement and collaboration with producers and industry organisations, such as the International Council on Mining and Minerals and the Global Methane Initiative, to:
  - Form challenge statements related to GHG reduction
  - Continue to identify BAT/BEPs which address these challenges
  - Track the development of those BAT/BEPs
  - Identify root causes of success, failure, or suspension of BAT/BEPs

- Further investigation and understanding of the role that the federal Environmental Impact Assessment processes play in the encouragement or discouragement of BAT/BEP adoption by industry, including:
  - Requirement to provide details of pre-commercial BAT/BEP in impact assessment and permitting, which challenges the full-scale integration of non-conventional technology
  - Technology risk and development cost imposed by the associated requirements
  - Discovery of other enabling factors and drivers of advancement and implementation

Deployment of GHG-reducing BAT/BEPs is seen to be slow-paced within the coal mining sector in Canada and lagging on the global stage. Investment in new and innovative solutions is hampered by a risk-avert industry and economic uncertainty. A thoughtful approach and concerted effort towards encouraging BAT/BEP adoption and allocation of the public and private funding necessary to support market penetration will accelerate the industry towards greater GHG reductions.

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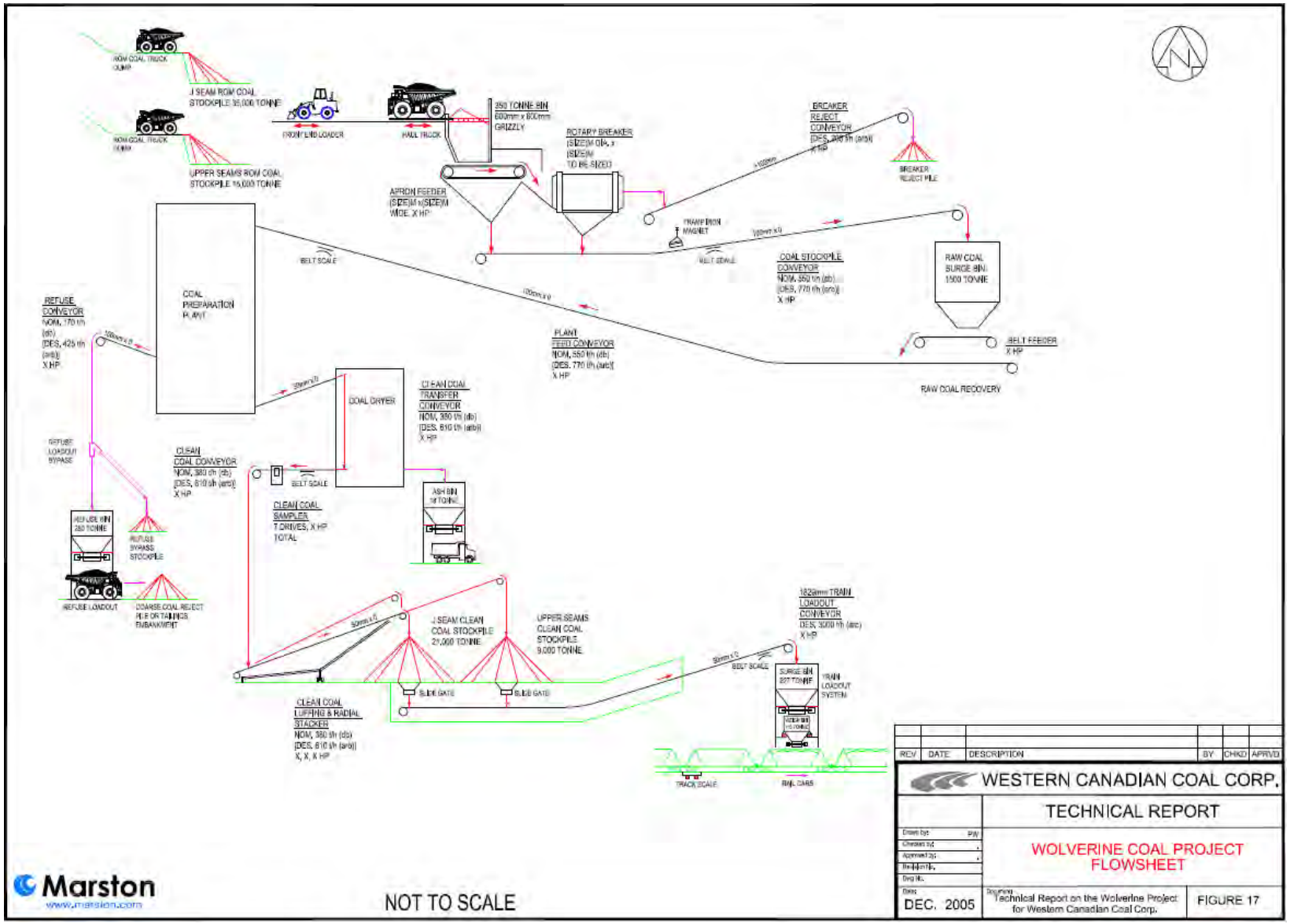
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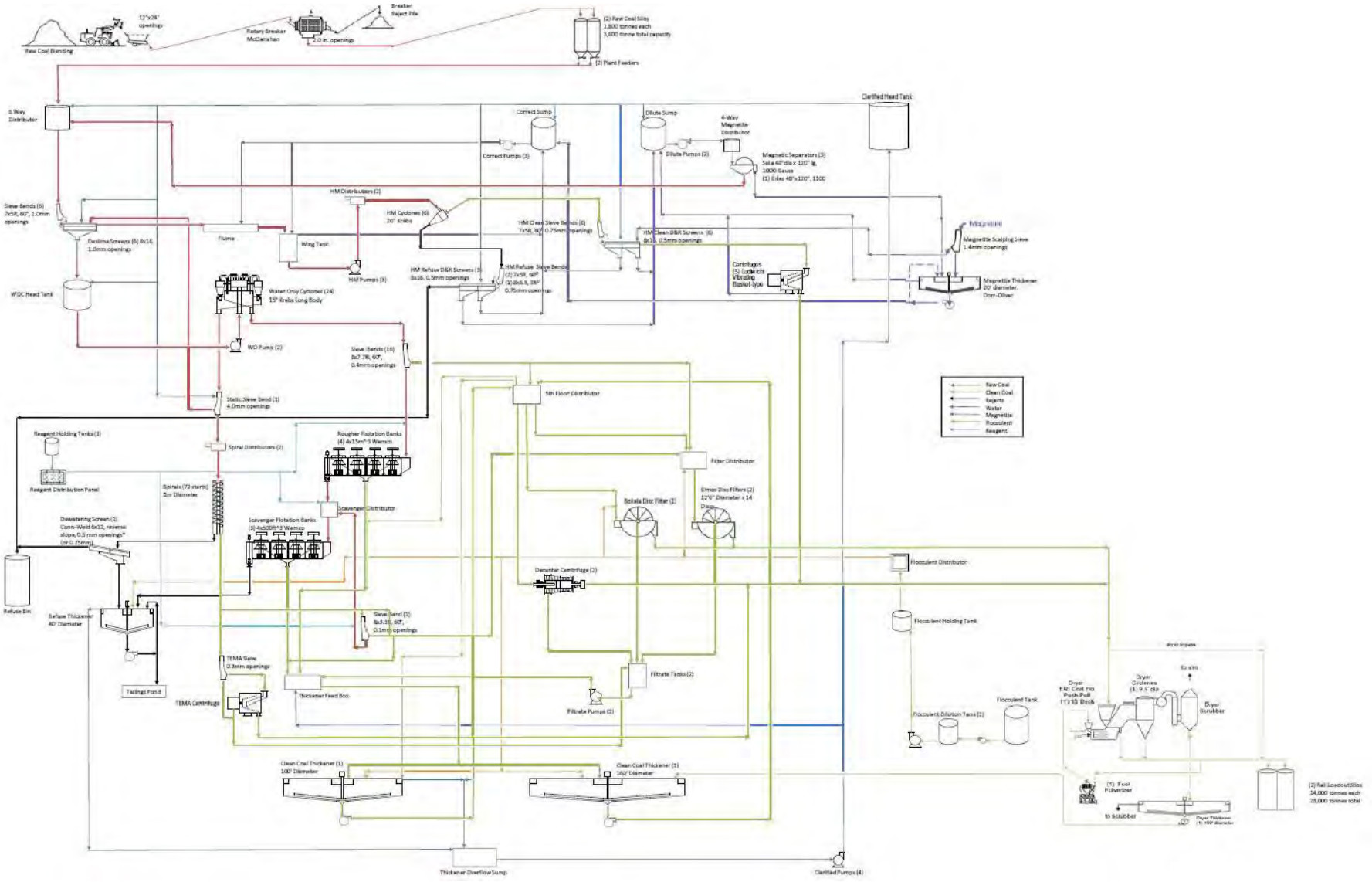
Appendix A
Mine Flowsheets

Figure A-1: Wolverine Mine Flowsheet



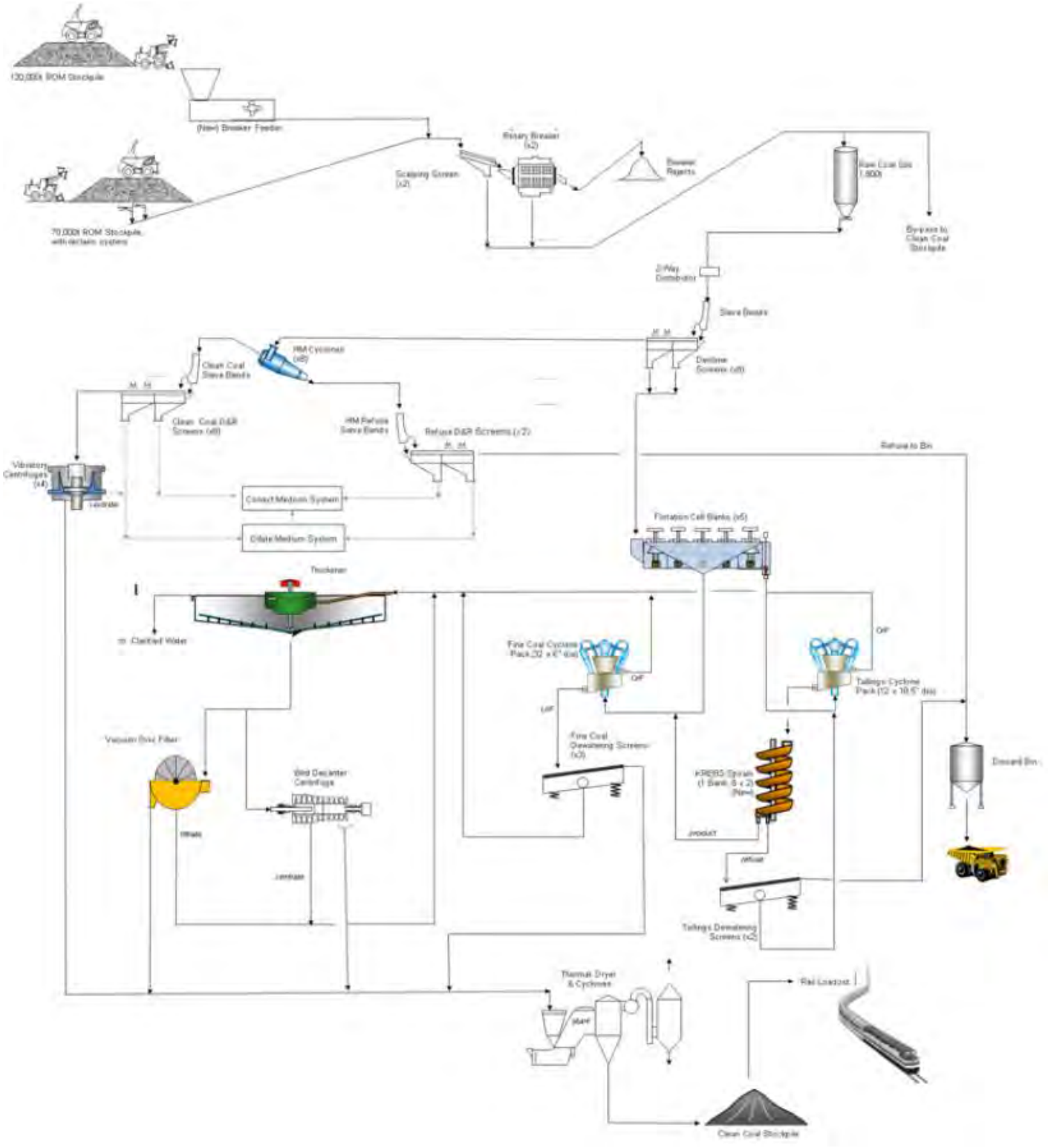
(Marston, 2005)

Figure A-2: Greenhills Mine Flowsheet



(Teck, 2016)

Figure A-3: Grande Cache Mine Flowsheet



(Amec, 2011)

Appendix B
Coal Mines in Canada

Operational Coal Mines

This section provides information on coal mines in Canada that were operational as of the beginning of 2019. This excludes mines that have gone into care and maintenance in recent years due to economic conditions such as Teck's Quintette and Anglo American's Trend surface mines in British Columbia. Mines are organized by ore type and increasing capacity. The last column provides information regarding the coal end use and method of transport.

Table B-1: Canadian Surface Coal Mines in Operation

Ore Type	Capacity (ROM Mt/yr)	Mine Name	Company	Province	Start Year	Processing Plant	End Use & Transport
Lignite	3.5	Poplar River	Westmoreland	SK	1978	No	Thermal coal hauled to rail load-out area then railed 20km to Poplar Power Station
	6.2	Estevan	Westmoreland	SK	1973	No	Thermal coal hauled to Boundary Dam and Shand Power Stations, also feeds on-site Char Plant and Activated Carbon Plant (note that Estevan combines Bienfait and Boundary Dam mines)
Sub-Bituminous	3.0	Paintearth	Westmoreland	AB	1956	No	Thermal coal hauled to Battle River Power Station
	3.6	Sheerness	Westmoreland	AB	1984	No	Thermal coal hauled to Sheerness Power Station
	6.0	Genesee	Westmoreland	AB	1988	No	Thermal coal hauled to Genesee Power Station
	13.0	HighVale	TransAlta	AB	1970	No	Thermal coal hauled to Sundance and Keephills Power Stations
Bituminous	0.5	Stellarton	Pioneer Coal	NS	1996	Y	Thermal coal hauled to processing plant then to Trenton Power Station
	1.2	Willow Creek	Conuma	BC	2004	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export
	2.2	Wolverine	Conuma	BC	2006	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export
	2.3	Coal Valley	Westmoreland	AB	1978	Yes	Thermal coal hauled to processing plant, clean coal railed to some domestic markets as well as port terminal for export
	2.4	Grande Cache	CST Canada	AB	2004	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export
	2.5	Brule/Dillon	Conuma	BC	2006	Crusher Only	Thermal and Metallurgical coal hauled to crusher then hauled to Willow Creek processing plant, clean coal railed to port terminal for export
	2.7	Coal Mountain	Teck	BC	1974	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export
	3.0	Cardinal River	Teck	AB	2003	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export
	4.0	Line Creek	Teck	BC	1981	Yes	Metallurgical coal hauled to crusher/breaker then conveyed to processing plant, clean coal railed to port terminal for export
	5.4	Greenhills	Teck	BC	1982	Yes	Metallurgical coal hauled to crusher/breaker then conveyed to processing plant, clean coal railed to port terminal for export
	7.0	Elkview	Teck	BC	1993	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export
	9.0	Fording River	Teck	BC	1969	Yes	Metallurgical coal hauled to processing plant, clean coal railed to port terminal for export

Table B-2: Canadian Underground Coal Mines in Operation

Ore Type	Capacity (ROM Mt/yr)	Mine Name	Company	Province	Start Year	Processing Plant	End Use & Transport
Bituminous	0.5	Quinsam [1]	Quinsam	BC	1986	Yes	Thermal coal conveyed to surface then fed to processing plant, clean coal hauled to port terminal for export
	2.4	Grande Cache [2]	CST Canada	AB	2004	Yes	Metallurgical conveyed to surface then hauled to processing plant, clean coal railed to port terminal for export
	3.5	Donkin	Kameron Collieries	NS	2017	Yes	Thermal and Metallurgical coal conveyed to surface then fed to processing plant, clean coal hauled to Lingan Power Station as well as port terminal for export

[1] Quinsam Coal filed for bankruptcy in July 2019 at which point the mine ceased operating and was placed in care and maintenance

[2] Grande Cache operations includes both surface and underground mines

Planned Coal Mines

This section provides information on anticipated coal mine developments in Canada that are currently in the permitting/design phase or for which construction has started. Mines are organized by ore type and increasing capacity.

Table B-3: Canadian Coal Mines Planned for Future Development

Ore Type	Mining Method	Capacity (ROM Mt/yr)	Mine Name	Company	Province	Status	Planned Start Year
Sub-Bituminous	Surface	11.0	Vista Project	Bighorn Mining	AB	Construction	2020
Bituminous	Surface	1.0	Tenas Project	Telkwa Coal	BC	Design/Permitting	2021
	Surface	2.3	Marten Wheeler	Teck	BC	Design/Permitting	2021
	Surface	2.6	Grassy Mountain	Riversdale Resources	AB	Design/Permitting	2021
	Surface & Underground	2.6	Sukunka	Glencore Canada	BC	Design/Permitting	2023
	Underground	2.7	Gething	Canadian Kailuan Dehua	BC	Design/Permitting	2021
	Surface & Underground	4.0	Michel Creek	North Coal	BC	Design/Permitting	2020
	Surface	4.1	Crown Mountain	NWP Coal Canada	BC	Design/Permitting	2021
	Surface & Underground	5.0	Bingay Coal	Centermount Coal	BC	Design/Permitting	2021
	Surface & Underground	5.9	Carbon Creek	Cardero Coal	BC	Design/Permitting	2024
	Surface	5.9	Roman Mountain	Peace River Coal	BC	Construction	2020
	Underground	6.0	Murray River	HD Mining International	BC	Design/Permitting	2024
Anthracite	Surface	5.4	Arctos Anthracite	British Columbia Railway	BC	Design/Permitting	2022

Appendix C
Factors & Constants

Table C-1: Emission Factors and Calculation Constants

Parameter	Value	Source
Explosives Emission Factor	0.200 $kgCO_2e/kg$	(Goswami & Brent, 2016)
Explosives Energy Content	3.500 MJ/kg	(Dyno Nobel, 2010)
Diesel Fuel Emission Factor [1]	2.630 $kgCO_2e/L$	(Government of British Columbia, 2017)
Diesel Fuel Energy Content	38.300 MJ/L	(Government of British Columbia, 2017)
Natural Gas Emission Factor	1.937 $kgCO_2e/m^3$	(Government of British Columbia, 2017)
Natural Gas Energy Content	38.850 MJ/m^3	(Government of British Columbia, 2017)
Coal Emission Factor	2.180 $kgCO_2e/kg$	(Environment and Climate Change Canada, 2019)
Coal Energy Content	29.300 MJ/kg	(NRCan, 2018)
BC Grid Emission Factor [2]	11 $kgCO_2e/MWh$	(Government of British Columbia, 2017)
AB Grid Emission Factor [3]	570 $kgCO_2e/MWh$	(Government of Alberta, 2019a)
AB Grid Emission Benchmark [4]	370 $kgCO_2e/MWh$	(Government of Alberta, 2019b)
Density of Methane	0.6570 kg/m^3	At 25°C and atmospheric pressure
Bank Density of Coal	1,346 kg/m^3	Based on raw coal conditions

[1] Based on diesel fuel supplied in British Columbia, B4 (96% petroleum diesel and 4% biodiesel)

[2] Based on BC Hydro grid intensity, assuming no fossil fuel based imports for in-province consumption

[3] Based on displacement of grid electricity with renewable energy at point of use according to the Alberta Emission Offset System

[4] Based on the "good-as-best-gas" benchmark set by Alberta's Technology Innovation and Emissions Reduction Regulation (TIER)

Appendix D
Technology Readiness Level

Table D-1: Technical Readiness Level (TRL) Definition

TRL	Definition
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab (bench-scale testing)
TRL 5	Technology validated in relevant environment (pilot testing)
TRL 6	Technology piloting in operational environment (field pilot)
TRL 7	System demonstration in operational environment (field demonstration)
TRL 8	System complete and qualified (first of a kind commercial system)
TRL 9	Actual system proven in operational environment (commercial application)

(European Commission, 2017)

Appendix E
Commodity Cost Curves

Figure E-1: Commodity Cost Curves – Electricity, Thermal Coal & Metallurgical Coal

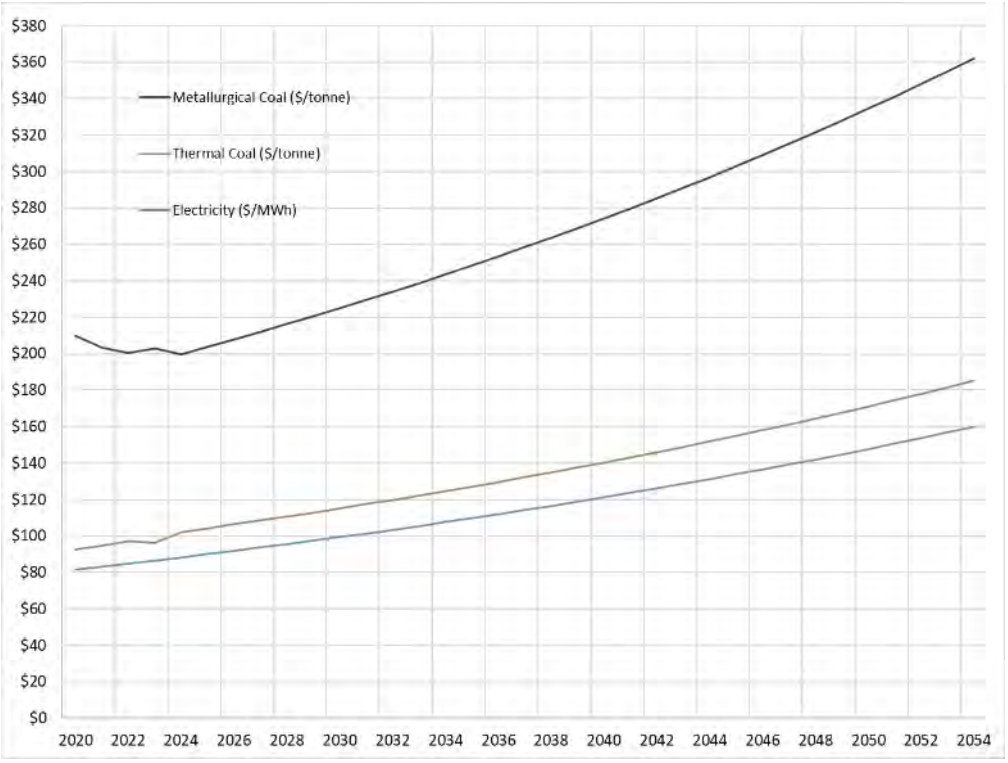
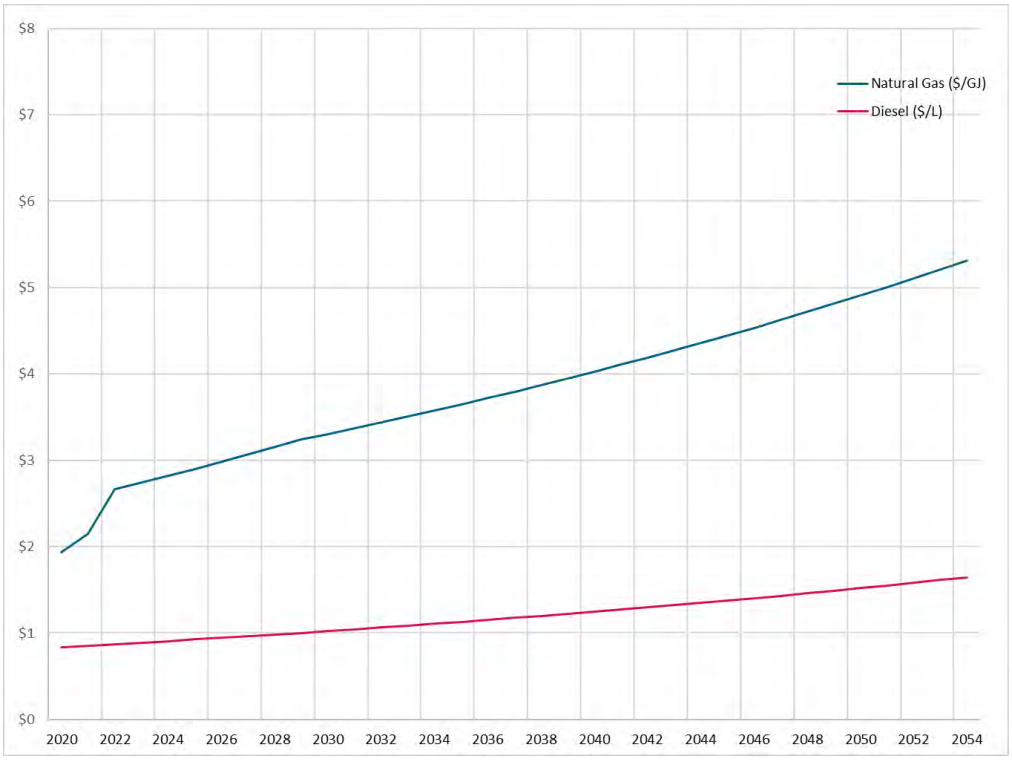
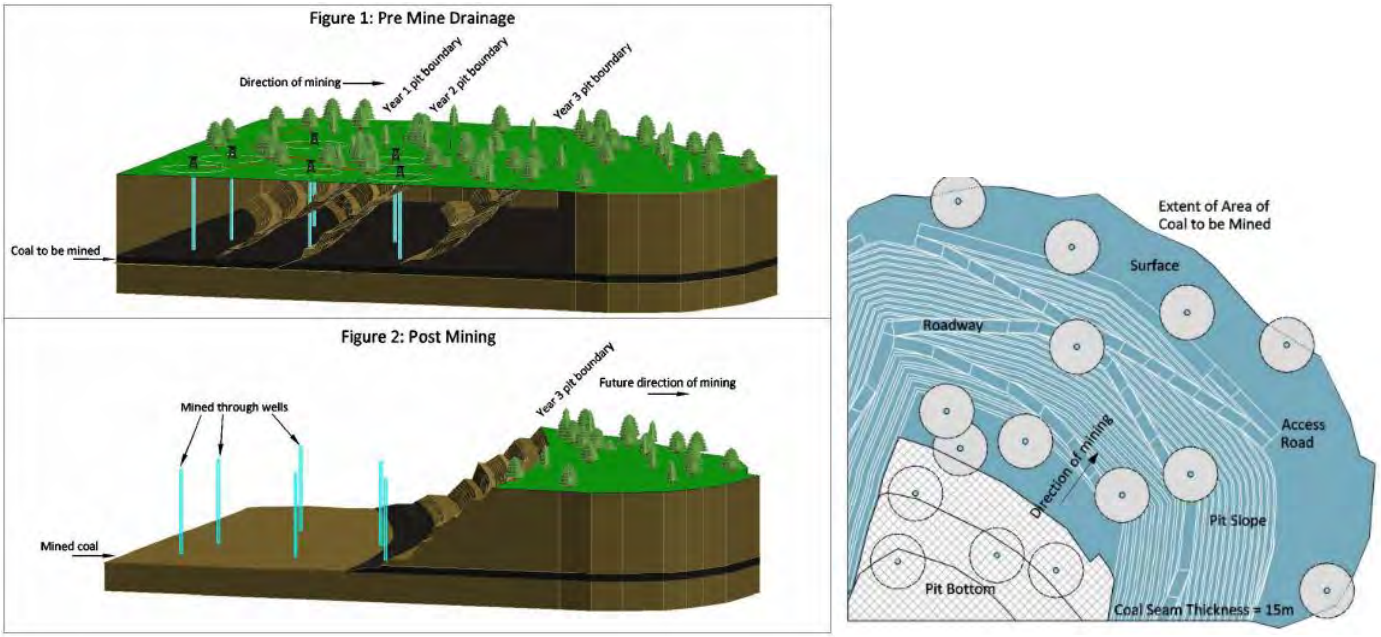


Figure E-2: Commodity Cost Curves – Diesel & Natural Gas



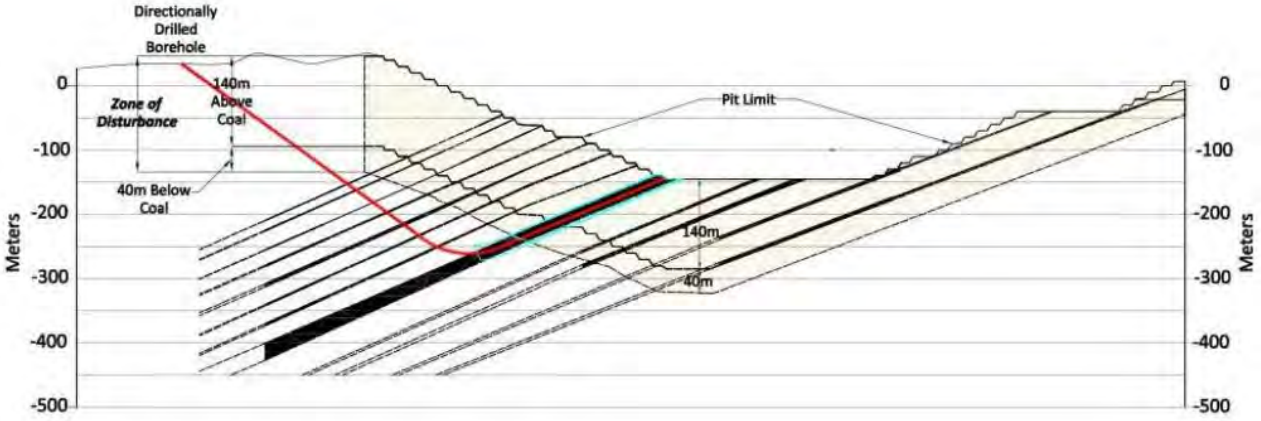
Appendix F
Degasification Illustrations

Figure F-1: Drilling of Vertical Pre-drainage Wells Relative to Planned Mine Expansion at Open Pit Surface Mine



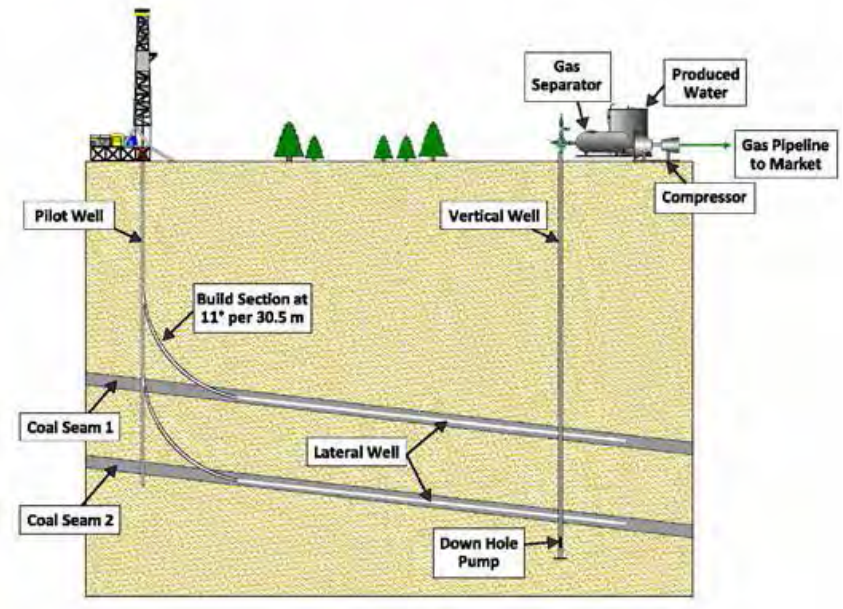
(Marshall, Pilcher, & Boger, 2011)

Figure F-2: Directional Drilling of Pre-drainage Wells from the Surface at Open Pit Surface Mine



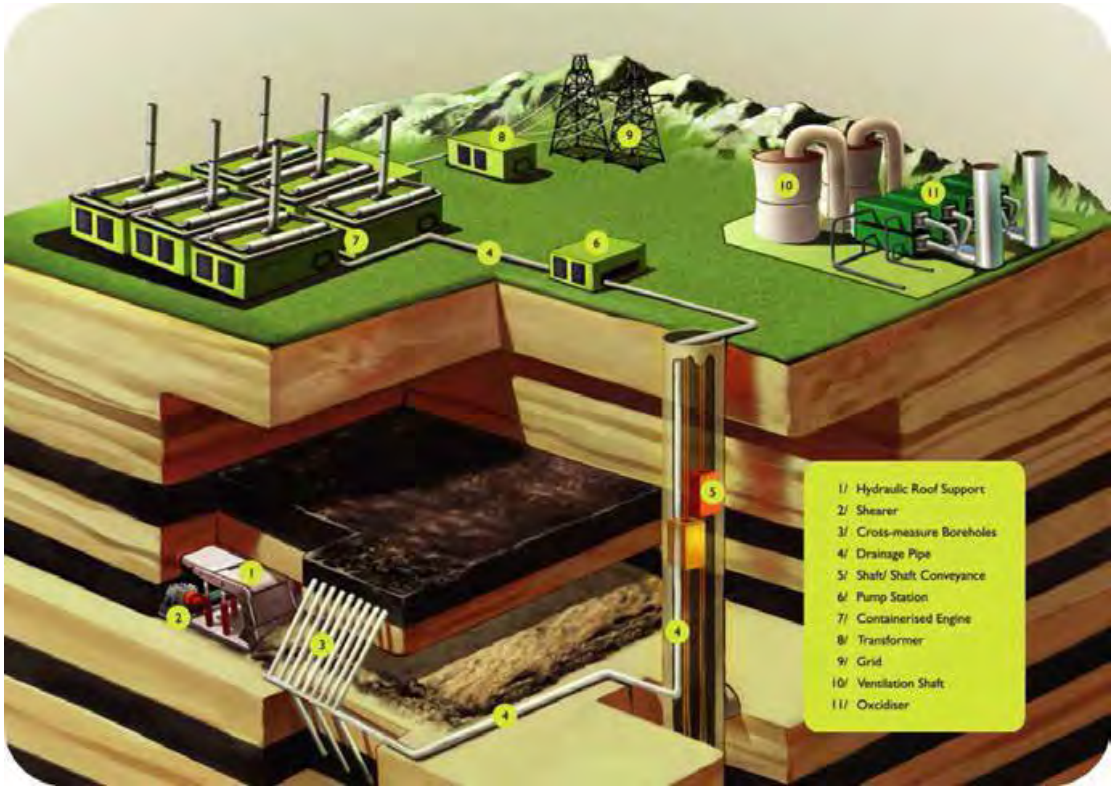
(Marshall, Pilcher, & Boger, 2011)

Figure F-3: Pre-drainage Drilling Configuration Using Vertical and Lateral Wells at Underground Mine



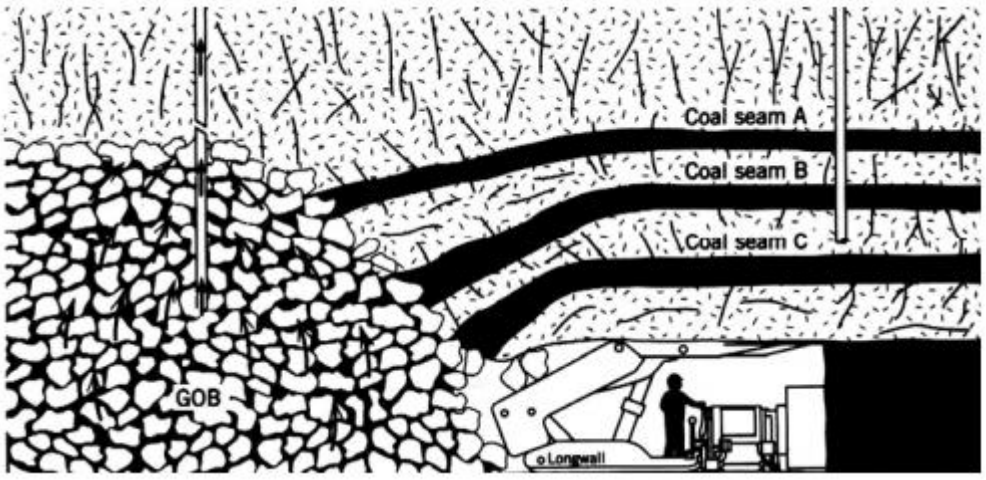
(UNECE, 2016) - (Courtesy of Raven Ridge Resources)

Figure F-4: CMM Power Generation and VAM Oxidizer Systems at Underground Longwall Mine



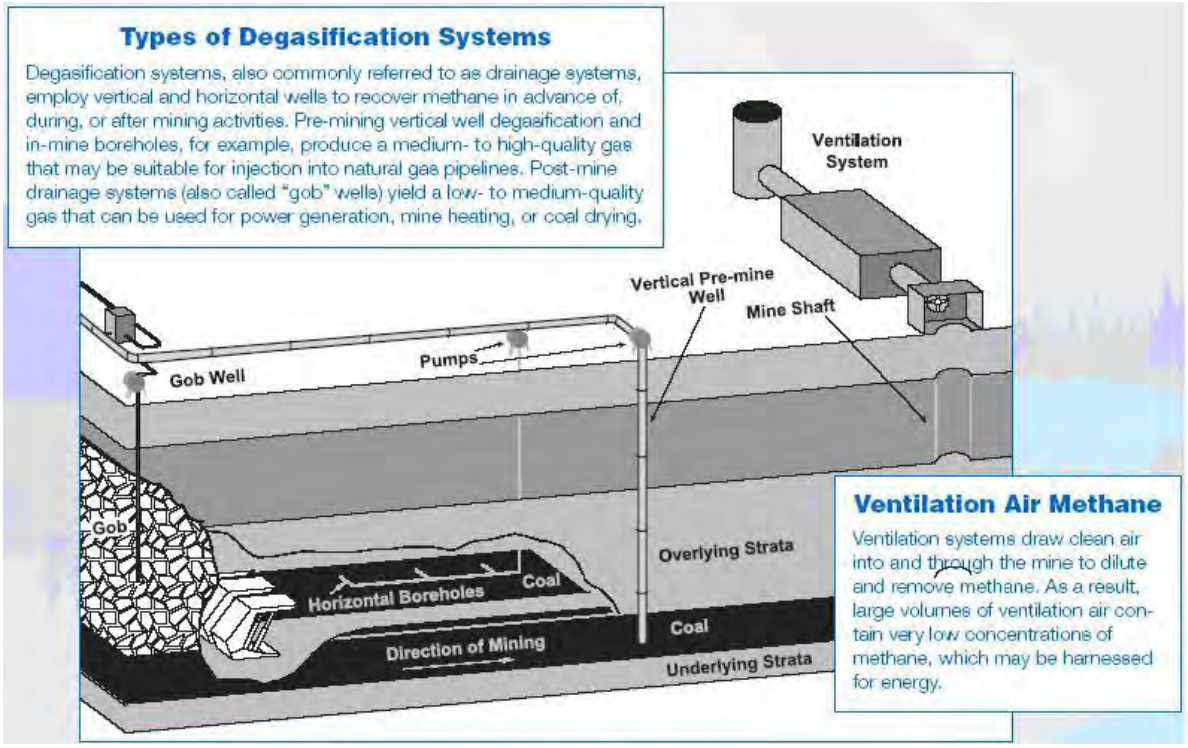
(UNECE, 2016) - (Courtesy of Green Gas International)

Figure F-5: Typical Gob & Pre-Drainage Wells Showing Impact of Overlaying Seams at Underground Longwall Mine



(Harpalani & Prusty, 2009)

Figure F-6: Various Degasification Schemes at Underground Longwall Mine



(Energy Edge, 2007)

Appendix G
VAM Oxidizers

Table G-1: Exemplar VAM Oxidizers from Industry

Commercial Name	Technology Developer / Manufacturer	Project / Installation
VOCSIDIZER™	B&W MEGTEC Systems, United States	West Cliff Colliery Mine, New South Wales, Australia Datong Mine, Chongqing, China
EcoPure®	Dürr Systems, Germany	McElroy Mine, Marshall County, West Virginia, United States Gaohe Mine, Shanxi, China
VAMOX™	Biothermica, Canada	Blue Creek Mine, Brookwood, Alabama, United States
VAMMIT™	CSIRO, Australia	Demonstration project a mine in Australia
COMET™	Johnson Matthey, United Kingdom	Demonstration project at a mine in Australia
CH4MIN™	CANMET, Canada Sindicatum Sustainable Resources, Singapore	Demonstration project at a mine in China

(USEPA, 2019b)

Appendix H
Surface Miners

Figure H-1: Wirtgen Surface Miner Key Components



(Wirtgen, 2019a)

Figure H-2: Wirtgen Surface Miner in Operation at Sub-bituminous Coal Mine in Texas





(Wirtgen, 2019b)

TAB 2

Fisheries and Oceans Canada | Pêches et Océans Canada

SUBMISSION OF FISHERIES AND OCEANS CANADA

TO THE JOINT REVIEW PANEL

FOR BENGA MINING LIMITED

PROPOSED GRASSY MOUNTAIN COAL PROJECT

<Original signed by>

C. Thomas Hoggarth
Regional Director
Aquatic Ecosystems
Ontario and Prairie Region
Fisheries and Oceans Canada

September 21, 2020

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Fisheries and Oceans Canada
Pêches et Océans Canada

1 DFO's Mandate and Responsibilities

The Minister of Fisheries and Oceans Canada (the "Minister") is accountable to Parliament for the administration and enforcement of the *Fisheries Act* and regulations thereunder. On behalf of the Government of Canada, Fisheries and Oceans Canada (DFO) is responsible for developing and implementing policies and programs in support of Canada's scientific, ecological, social and economic interest in relations to oceans, sea, coastal and inland fisheries.

On June 21, 2019, the amended *Fisheries Act* (the Act) received royal assent and became law, while the Fish and Fish Habitat Protection Provisions came into force on August 28, 2019. The modernized Act restores protections lost with the 2012 changes to the Act and incorporates modern safeguards. Key amendments include restoring comprehensive protection for all fish and fish habitat, and a new requirement to make information on project decisions public through an online registry. The Act improves the protection of Canadian fisheries and their ecosystems, and recognizes that decisions can be guided by principles of sustainability, precaution and ecosystem management.

The Act includes a legal framework for regulating impacts associated with any work, undertaking or activity that risk harming fish and fish habitat. This applies to all fish and fish habitat throughout Canada. The Act defines fish habitat as "waters frequented by fish and any other areas upon which fish depend directly or indirectly to carry out their life processes, which includes spawning grounds and nursery, rearing, food supply and migration areas."

The Fish and Fish Habitat Protection Provisions of the Act include prohibitions against the carrying on of a work, undertaking or activity that results in the:

- death of fish by means other than fishing - subsection 34(1); and
- harmful alteration, disruption or destruction of fish habitat in - subsection 35(1).

The *Fish and Fish Habitat Protection Policy Statement* (August 2019), interprets "harmful alteration, disruption or destruction" as any temporary or permanent change to fish habitat that directly or indirectly impairs the habitat's capacity to support one or more life processes of fish.

Proponents are responsible for planning and implementing works, undertakings, or activities in a manner that avoids and mitigates impacts to fish and fish habitat. If residual harm to fish and fish habitat is still anticipated after the application of avoidance and mitigation measures, proponents are required to request authorization under paragraphs 34.4(2)(b) and/or 35(2)(b) of the Act in order to proceed without contravening the Act.

The *Authorizations Concerning Fish and Fish Habitat Protection Regulations* (2019) sets out the information requirements for a proponent when applying for a ministerial authorization and the timelines for processing an application. Applications must include an offsetting plan to counterbalance unavoidable death of fish and/or harmful alteration, disruption or destruction of fish habitat resulting from the proposed project.

Offsetting measures can range from localized improvements to fish habitat to more complex measures to address factors limiting fish production. Following the guidance set out in DFO's *Policy for Applying*

Measures to Offset Adverse Effects on Fish and Fish Habitat under the Fisheries Act (2019), proponents should select measures that meet the following principles:

- Measures to offset should support fisheries management objectives and give priority to the restoration of degraded fish habitat;
- Benefits from measures to offset should balance the project impacts;
- Measures to offset should provide additional benefits to the ecosystem; and
- Measures to offset should generate self-sustaining benefits over the long term.

When preparing an offsetting plan, proponents must characterize the residual effects; select measures to offset; and determine the amount of measures to offset required. Proponents need to consider the following:

- The amount of measures to offset required should provide ecological benefits that are proportional to the residual effects caused by the project. This requires evaluating equivalency when quantifying the residual effects and the offset measures.
- Uncertainty associated with the offset may increase the offsetting required.
- Time lag between the impacts on fish and fish habitat and the full benefit from the offsetting measures may increase the offsetting required.

Additional considerations may be required in specific contexts. For example, the uncertainty associated with project impacts may require increasing the scope and scale of offsetting required.

Monitoring measures are required as part of the offsetting plan to assess the effectiveness of the measures to offset relative to the objectives set, and are included as conditions of the authorization.

Before recommending the issuance of authorizations or permits, the Minister must consider the eight factors set out in subsection 34.1(1) of the Act. These are:

a) the contribution to the productivity of relevant fisheries by the fish or fish habitat that is likely to be affected;
b) fisheries management objectives;
c) whether there are measures and standards to avoid, mitigate or offset the death of fish and/or the harmful alteration, disruption or destruction of fish habitat;
d) the cumulative effects of carrying on the work, undertaking or activity in combination with other works, undertakings or activities that have been or are being carried on, on fish and fish habitat;
e) any fish habitat banks, as defined in section 42.01, that may be affected;
f) whether any measures and standards to offset the harmful alteration, disruption or destruction of fish habitat give priority to the restoration of degraded fish habitat;
   Preference is given to enhancing previously degraded habitat rather than attempting to enhance and potentially disturbing pristine habitat.
g) Indigenous knowledge of the Indigenous peoples of Canada that has been provided to the Minister; and
h) any other factor that the Minister considers relevant.

As per the 2014 *Order Designating the Minister of the Environment as the Minister Responsible for the Administration and Enforcement of Subsections 36(3) to (6) of the Fisheries Act*, The Minister of the Environment is designated as the Minister responsible for the administration and enforcement of subsection 36(3) to (6) of the Act for all purposes and subject-matters, except the following:

> (a) the construction, operation, modification and decommissioning of, and other activity in relation to, an aquaculture facility, and any resulting effects of those activities on the waters frequented by fish; and
>
> (b) the control or eradication of any aquatic invasive species or aquatic species that constitute a pest to the fisheries.

Thus, Environment and Climate Change Canada administers subsection 36(3) to (6) of the Act, which prohibit the deposit of deleterious substances into waters frequented by fish, unless authorized by regulations under the *Fisheries Act* or other federal legislation.

The Species at Risk Act

While the Minister of Environment and Climate Change Canada has primary responsibility for the administration of the *Species at Risk Act* (*SARA*), the Minister of Fisheries and Oceans is the competent minister for aquatic species at risk, other than those individuals that are "in or on federal lands," administered by the Parks Canada Agency (PCA). The Minister responsible for the PCA is responsible for species in national parks, national historic sites or other protected heritage areas as defined in the *Parks Canada Agency Act*.

SARA provides legislated protection for wildlife species at risk and is intended to prevent wildlife species from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species and to manage species of special concern to prevent them from endangered or threatened. If a species is listed as endangered, threatened, or extirpated on Schedule 1 of *SARA,* no person shall:

- kill, harm, harass, capture or take an individual of the species (subsection 32(1))
- possess, collect, buy, sell or trade an individual (or any part or derivative of such an individual) of the species(subsection 32(2))
- damage or destroy the residence of one or more individuals of the species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada (section 33)
- destroy of any part of the critical habitat of the species (subsection 58(1)).

A residence signifies a dwelling place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating. If the species has a residence, it will be described for that species in its Recovery Potential Assessment, Recovery Strategy, or Action Plan. A residence may or may not be in an area designated as critical habitat.

Critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species." The amount and type of critical habitat identified in the recovery strategy or action plan must support the population and distribution objectives for the species. Critical habitat is considered destroyed when part of it is degraded, either permanently or temporarily, such that it would not serve its function when needed by the species.

Permitting provisions are set out in Section 73 of *SARA* and allow for the issuance of a permit authorizing a person to engage in an activity affecting a listed wildlife species, any part of its critical habitat or the residence of its individuals, provided it is an activity set out in Section 73(2)(a) to (c):

- scientific research relating to the conservation of the species and conducted by qualified persons;
- activities that benefits the species or is required to enhance its chance of survival in the wild; or
- activities that affect the species is incidental to the carrying out of the activity.

Prior to issuing a permit to affect aquatic species at risk, the Minister of Fisheries and Oceans Canada must be satisfied that all preconditions in subsection 73(3) have been met, including that:

- all reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted;
- all feasible measures will be taken to minimize the impact of the activity on the species or its critical habitat or the residences of its individuals; and
- the survival or recovery of the species will not be jeopardized.

Offsetting is a measure that can be taken to assist in achieving the precondition that the activity will not jeopardize the survival or recovery of the species. However, it should not be relied on exclusively, as SARA requires all options to avoid and minimize harm are fully utilized. Preservation should be given first priority. There are also circumstances in which offsetting is not appropriate, such as where critical habitat is irreplaceable, there is a high probability of the offset failing or where the impacts from the offset failure could be significant.

DFO's offsetting policy also applies in a species at risk context, but with additional considerations required to account for the sensitivity of the species being impacted. These include but are not limited to: the offset must contribute to the attainment of population and distribution objectives described in the recovery strategy or action plan for the affected species, and offsetting should be implemented and confirmed functioning prior to impacts occurring.

In addition to the issuance of "stand-alone" *SARA* permits, Section 74 of *SARA* allows for a *Fisheries Act* authorization to have the same effect as a *SARA* permit provided that the requirements of *SARA* subsections 73(2) to (7) are met. Consideration of potential effects on aquatic species at risk are incorporated into DFO's review of applications for authorization under subsections 34.4(2)(b) and 35(2)(b) of the *Fisheries Act*. *Fisheries Act* authorizations can be issued for works, undertakings or

activities near water that affect aquatic species at risk if the conditions for issuing a permit under *SARA* are met. Under Section 75 of *SARA*, specific terms and conditions may be added to a *Fisheries Act* authorization in order to protect a listed wildlife species.

Canadian Environmental Assessment Act, 2012

In accordance with *Canadian Environmental Assessment Act 2012* (CEAA), DFO is participating in the Environmental Assessment of the Grassy Mountain Coal Project (the Project), proposed by Benga Mining Limited (the Proponent), as a federal authority providing "specialist or expert information or knowledge" with respect to the Project to the Joint Review Panel (the Panel) in relation to DFO's mandate. DFO must also contribute knowledge to the Panel regarding the potential environmental effects of the Project, as listed in Section 5 of the CEAA 2012, that fall within the Department's expertise and mandate.

Section 7 of CEAA 2012 prohibits DFO from exercising any power or performing any duty or function under the *Fisheries Act* unless the EA decision statement with respect to the Project, issued by the Minister of the Environment, indicates that the Project "is not likely to cause significant adverse environmental effects" or "that the significant adverse environmental effects are justified in the circumstances".

2 Introduction to the Project

Environmental Impact Assessment (EIA) References:

- CIAR #44, 1st Addendum to the EIS
    - Aquatic Ecology Effects Assessment: Consultant Report #6 (CR #6)

This section provides an overview of the works, undertakings or activities (WUAs) related to the Project that have the potential to impact fish and fish habitat. The Project is located in the Crowsnest River watershed within the Oldman River watershed in southwestern Alberta. An aquatic local study area (LSA) is defined by the Proponent, which is based on "the Project footprint, boundaries of local watersheds [Blairmore and Gold Creek watersheds] and the spatial extent of potential immediate direct and indirect effects of the Project on hydrogeology, surface water hydrology, water quality, and fisheries and aquatic resources" (CR #6). The LSA is intended to comprise the downstream limit of potential impacts of the Project on fish and fish habitat. Gold and Blairmore creeks watersheds contain a ≥ 99% genetically pure (pure) subpopulation of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WCT) and a 95%-99% genetically pure (near-pure) subpopulation of WCT, respectively.

The proponent proposes and considers the following approaches measures to avoid impacts to fish and fish habitat CR #6:

- Size of the Project's physical footprint has been minimized through proactive mine design;
- Maintain appropriate riparian reserves and management zones from watercourses, where feasible;

- Project footprint will be minimized to the extent possible through storage of waste rock in existing disturbed locations and making best use of existing facilities, including through backfilling mined-out pits;
- Existing infrastructure, rather than new infrastructure, will be used or upgraded where feasible and sustainable;
- Implement erosion and sediment control based on industry standards.

The Project includes several WUAs that have the potential to impact fish and fish habitat, including within WCT critical habitat and its historical distribution:

- open pit development and resource extraction;
- waste rock placement, reclamation, and closure; and
- surface water management.

These WUAs have the potential to cause the following impacts to fish and fish habitat in Gold and Blairmore creeks and their tributaries, including:

- destruction and/or harmful alteration of tributary and mainstem aquatic and/or riparian habitat;
- change in hydrology resulting from the alteration of aquatic habitat;
- death of fish resulting from blasting activities;
- changes in water temperature;
- changes to food supply;
- changes to sediment supply and transport;
- change in recreational access;
- changes to surface or ground water quality;

Project WUAs are predicted to result in the destruction of 26,947 m^2 of aquatic habitat within the LSA. Of this total, 1,796 m^2 of destruction or harmful alteration is anticipated in fish-frequented aquatic habitat, and 25,251 m^2 of destruction or harmful alteration is anticipated in non-fish-frequented aquatic habitat.

In order to calculate the impact of WUAs within riparian habitat, the Proponent delineated riparian buffers of 50 m on the mainstem of Gold and Blairmore Creeks, 30 m buffers on fish-frequented tributaries, and 20 m buffers on non-fish-frequented tributaries. DFO understands that the calculated footprint of proposed WUA impacts to riparian habitat is within these buffer zones, and is estimated at 584,263 m^2 of destruction or harmful alteration. Of this total, 442,433 m^2 is located in the Blairmore Creek watershed, and 141,830 m^2 is located in the Gold Creek watershed.

3 Westslope Cutthroat Trout

3.1 Summary of Legislative Protection

Westslope Cutthroat Trout, Saskatchewan-Nelson River populations, was assessed as “Threatened” by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in May 2005, re-assessed and confirmed in November 2006, and again in November 2016. On March 7, 2013 WCT was listed as

"Threatened" under Part 3 of Schedule 1 of *SARA*. The species is also listed as "Threatened" under Alberta's *Wildlife Act*. A federal recovery strategy, which adopted the *Alberta Westslope Cutthroat Trout Recovery Plan 2012-2017*, and identified critical habitat for this species, was included on the public registry in March 2014 (DFO 2014). In 2019 the recovery strategy was replaced with *Recovery Strategy and Action Plan for the Westslope Cutthroat Trout (Oncorhynchus clarkii lewisi) Alberta Population (also known as Saskatchewan-Nelson River Populations) in Canada* (DFO 2019) which meets the requirements of both a recovery strategy and an action plan under *SARA*. This document will henceforth be abbreviated as the RS-AP. The RS-AP was based on up-to-date genetic information and includes: updated geospatial extent of critical habitat including a primary riparian zone around water bodies, strategic direction for recovery and implementation schedule (the recovery actions), and a socio-economic analysis on the actions. Identification of critical habitat in the riparian zone was informed by Canadian Science Advisory Secretariat (CSAS) Research Document *Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels* (Caskenette et al. 2020; Appendix 8.2) and CSAS Science Advisory Report *Guidance on the Identification of Critical Habitat in the Riparian Zone for Freshwater Species at Risk* (DFO 2020; Appendix 8.3).

All stream segments where WCT was determined to possess a genetic admixture proportion (or purity) across the population of ≥ 0.99% were considered a genetically pure population (pure), as well as areas upstream of these segments that provide indirect habitat to the pure populations, were designated as critical habitat under *SARA*, as defined in the RS-AP developed by the recovery team. As of 2019, critical habitat now includes all known areas currently occupied by naturally occurring pure populations within the original WCT distribution, including the areas on which WCT depend indirectly (e.g. riparian areas) in order to carry out their life processes. Where critical habitat has been identified, riparian areas on both stream banks for the entire length of the stream segments and all banks of waterbodies identified are included in the designation. Riparian area included in the designation are continuous and extend horizontally from the high water mark to a width of 30 m on both banks of the waterbody for the entire geospatial area. Additionally, critical habitat may include areas where pure populations of the species formerly occurred and have the potential to be reintroduced.

Critical habitat within the LSA includes approximately 14 km of the Gold Creek mainstem, and tributaries of Gold Creek (**Figure 1**). The population of WCT in Blairmore Creek exhibits 95-99% genetic purity (near-pure) and is therefore not afforded protection under SARA and the habitat is not identified as critical. Key differences between the current extent of critical habitat and that which was listed at the time of the Project's environmental impact statement is the protection of riparian and headwater habitat, as well as the potential for areas with high potential for re-establishment to be listed in the future. The Proponent has not updated estimates of impacts to critical habitat or fish and fish habitat since the RS-AP was updated.

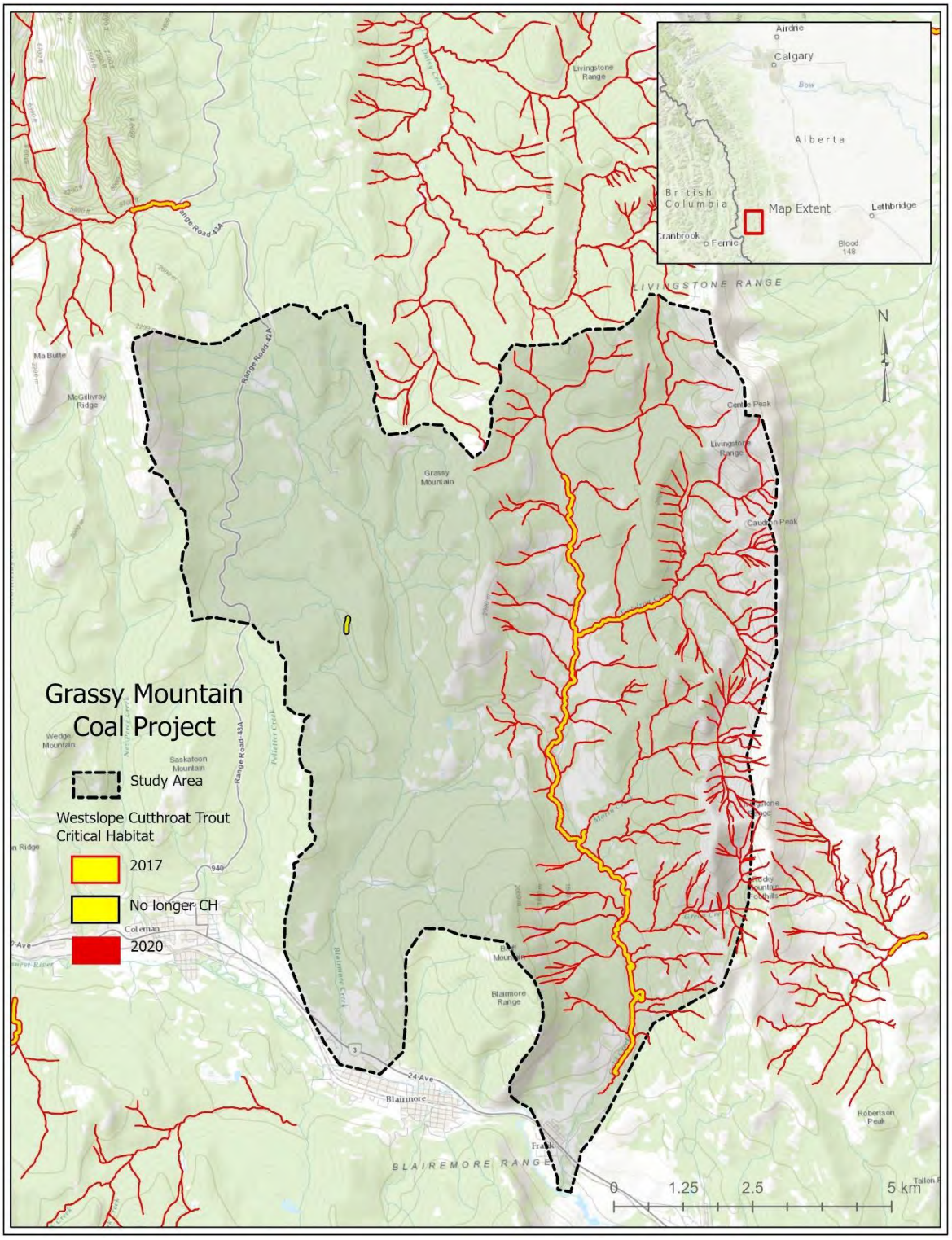


Figure 1: The current geographic extent of critical habitat within and near the local study area, contrasted with the extent of critical habitat that was defined at the time the environmental impact statement for the project was submitted.

3.2 Status and Threats

Cutthroat trout are widely distributed throughout much of western North America; WCT are the only subspecies native to Alberta. Historically, WCT inhabited most cold streams and lakes in southwestern Alberta from alpine to the prairies. The Saskatchewan-Nelson River populations were assessed by COSEWIC because they currently occupy only a small fraction of its original distribution and occurs as small, disconnected populations. Over the last century, it has undergone substantial range contractions, currently covering less than 20% of that observed historically (COSEWIC 2016, DFO 2009). Initially, range contraction was primarily due to overharvest, but more recently a combination of hybridization with rainbow trout and habitat deterioration have also contributed.

“As one of the first salmonids to recolonize western Canada following deglaciation, it is often the only native trout throughout much of the Canadian range. As such, it plays an important role in structuring many north temperate aquatic ecosystems (McPhail and Carveth 1992). Its small size at maturity allows it to exist in smaller streams than most other salmonids, where it contributes to riparian vegetation and forests in terms of nutrient recovery (Willson and Halupka 1995)” (COSEWIC 2016).

Main threats identified for WCT in Alberta include: non-native/invasive species including hybridization with rainbow trout, competition with other species such as brook trout; habitat loss and degradation as a result of land-use activities related to resource extraction; consumptive use/exploitation including incidental mortality from catch and release angling; pathogens and parasites including the myxosporean parasite causing whirling disease; and climate change (COSEWIC 2016, DFO 2009).

The WCT population and distribution objectives are to “protect and maintain the existing distribution of ≥ 0.99 genetically pure populations of WCT, and re-establish genetically pure populations to self-sustaining levels, within the Saskatchewan – Nelson rivers watershed in Alberta.”

As per the RS-AP (2019), the defined critical habitat for WCT is only partial i.e. the extent identified is not capable of supporting the species’ population and distribution objectives. This suggests that any loss of critical habitat would impede the ability to expand or recover the populations in Alberta. There is ongoing work to identify potential recovery watersheds and to develop the methodologies, expertise, and stakeholder support needed to expand the distribution of genetically pure WCT. The goal will be to identify additional critical habitat in future amendments as per work identified in the schedule of studies.

WCT populations in Alberta are inferred to be declining both in number of mature individuals and number of subpopulations. They are observed to be declining in extent of occurrence and area of occupancy. Habitat quality is inferred to be declining, as well. There remain 51 known subpopulations of WCT in Alberta (outside of national parks). More than 50% of habitat patches supporting these are too small to support a viable population in the long term (100 years), and individuals cannot disperse between the habitat patches. Gold Creek is one of ten subpopulations that is estimated to have enough individuals to be considered viable (COSEWIC 2016), although Alberta Environment and Parks (AEP) still

identifies the adult density in the Gold Creek watershed to be "low"[1]. Gold Creek watershed is identified as having a "very high" need for habitat protection[1]. The Alberta Fish Sustainability Index (FSI), a provincial standardized population sustainability assessment tool, overall ranks the Gold Creek population as "high risk". As identified in section 4.1, the mainstem of Gold Creek and all of its tributaries including fishless headwaters are considered critical habitat for WCT.

Although work is ongoing to prioritize areas to re-establish WCT, the Blairmore Creek watershed is considered important in the context of introduction and establishment to support the population and abundance objectives of the RS-AP ; specifically to "identify opportunities to help recover genetically pure and near genetically pure strains of Westslope Cutthroat trout, partly by restoring habitat and eliminating or suppressing populations of non-native fish that are having negative impacts on Westslope Cutthroat Trout." AEP identifies the habitat in the Blairmore Creek watershed as having a "very high" need for habitat protection, and identifies the population has having "very low"[1] density of adult individuals. The FSI overall ranks the Blairmore Creek population as "very high risk". The subpopulation of near-pure WCT resident in the Blairmore Creek watershed may meet the definition of a "conservation population" (The Alberta Westslope Cutthroat Trout Recovery Team 2013), which include key features such as the ability to contribute to the preservation of "unique ecological and behavioural traits," represents "the least introgressed populations within a geographic area," and may represent opportunities to employ "genetic swamping" in an attempt to increase genetic purity level. Collectively, this information is important to inform risk assessments made under the regulatory framework of the *Fisheries Act*.

There are four categories of strategies identified in the RS-AP that are intended to be undertaken to address the identified threats:

- Research
- Monitoring
- Management and regulation
- Education and outreach

Progress on these strategies is expanded upon in the following section. Most applicable to the Project is management and regulation, particularly as it applies to critical habitat and habitat that has the potential to support population and distribution objectives (i.e. Gold Creek, Blairmore Creek, and their tributaries). Based on the threats to habitat that are identified in the RS-AP, the expected outcomes of the proposed project development activities indicate a lack of alignment with the goals of the RS-AP and therefore require a robust and precautionary assessment.

3.3 Initiatives Supporting the Recovery Strategy – Action Plan

The intent of this section is to provide the Panel with an overview of the progress that has been made on the recovery strategies outlined in the RS-AP to help place the potential environmental effects of the

[1] https://open.alberta.ca/dataset/westslope-cutthroat-trout-fish-sustainability-index-maps-2018

Project on the valued component, WCT, into the broader context of efforts aimed at recovering the species.

Federal recovery planning and recovery implementation has been conducted jointly between DFO, PCA and AEP working with multiple stakeholders to support initiatives for the recovery of WCT. Prior to and during the development of the initial Recovery Strategy (DFO 2014), a recovery team was established consisting of multiple stakeholders to develop and review action items for the recovery of the species. DFO's *Report on the Progress of Recovery Strategy Implementation for the Saskatchewan-Nelson Rivers Populations of Westslope Cutthroat Trout in Canada for the Period 2014 -2019*, which outlines the progress of initiatives, is currently in the draft stage of development. It is anticipated to be published in late 2020. In addition, DFO provides funding through the Canada Nature Fund for Aquatic Species at Risk for native trout recovery actions. Some of the initiatives that DFO and our partners have executed to support recovery of WCT are outlined below.

3.3.1 Research

Strategy: Improve Knowledge of Population Genetics

Using standardized sampling techniques and genetic analysis, surveys were conducted to characterize the genetic structure and status of priority WCT populations in the species' original distribution. Particular consideration was applied to areas with no or incomplete information to determine whether additional populations of WCT exist within their original distribution. Extensive genetic sampling has been conducted since 2006 in the Bow and Oldman rivers watersheds to delineate the distribution and genetic status of WCT populations. AEP and PCA have led this research with support from DFO.

A WCT Genetic Delineation Project was conducted by AEP, which maps the genetic status of WCT streams in Alberta from the headwaters downstream to the historical extent of the species on the Bow and Oldman rivers. This information will be used to direct and inform future work in order to fill data gaps and improve certainty, as well as to make informed management decisions towards best practices for recovery of WCT on the landscape. AEP (lead), DFO, and the University of Montana are working together on WCT genetics research using single nucleotide polymorphism markers to provide increased accuracy and precision of estimates of hybridization with non-native trout throughout the range of WCT. It will also distinguish native versus introduced cutthroat trout (*Oncorhynchus clarkii*) populations, identify potential source and target populations for stocking, highlight potential for unique genetic diversity, and local adaptations in certain subpopulations of WCT in Alberta.

Strategy: Conduct Feasibility Studies of Recovering Existing Populations within Historical Range

Classification and prioritization of existing stream and lake populations, according to status of threats, were initiated to determine how threat elimination and mitigation might contribute to an increase in pure populations that are sustainable and resilient. Where desirable, the feasibility of enhancing existing populations by stocking, keeping genetic diversity issues of utmost priority, were examined. AEP, with the support of DFO, completed a population assessment in 2014 in the Picklejar Lakes, which resulted in a change from a daily recreational fishing bag limit to catch-and-release only regulations. AEP developed the FSI and Fisheries Management Objectives for waterbodies that contain WCT. In addition, the East

Slope Riparian Assessment Project conducted by AEP with the support of DFO from 2015-2017 contributed to a better understanding of the riparian conditions and threats associated with land-use activities in the headwaters of the Bow and Oldman rivers' watersheds in Alberta.

3.3.2 Identification of Critical Habitat

The identification of critical habitat is an ongoing initiative as new sampling techniques and technologies advance and wide-scale sampling is conducted to identify new distributions. AEP, with the support of DFO, conducted watershed-scale population assessments on select streams in the Bow and Oldman watersheds. The assessments will help establish distribution, relative abundance, absolute density, and population structure of pure and near-pure WCT. Habitat use and conditions will also be monitored. These data will be used to update the FSI and to update critical habitat. Modelling is underway by AEP to assess cumulative effects (such as habitat quality, climate change, consumptive pressure) on WCT within the Saskatchewan-Nelson rivers watershed in Alberta.

3.3.3 Monitoring

Strategy: Population Monitoring

Ongoing spatial and temporal population monitoring on priority populations are being conducted by AEP and other partners with the support of DFO. Monitoring includes population estimates, relative abundance, distribution, population structure (e.g., size-frequency distribution, life history stage), genetic status, as well as abundance and distribution of non-native species. Frequency of monitoring is dependent on the priority of the population and whether monitoring is related to a restoration or mitigation project. In 2018, the Alberta Conservation Association established 39 sites and took genetic samples of WCT in the Upper Oldman River core area. These sites will form part of an ongoing WCT monitoring program to gauge fish population responses to recent government land management alterations and proposed restoration projects. Summary reports for 2018-19 and 2019-20 on current abundance and distribution of WCT were finalized in February and March 2020.

3.3.4 Management and Regulation

Strategy: Limit the Spread of Non-native Species

A goal was developed to identify priority waterbodies where suppression or removal of non-native species or genetic recovery may be feasible. Based on this list, future pilot projects can be conducted on candidate waterbodies and effectiveness evaluated before proceeding with additional projects. A review of existing literature and consultations with other jurisdictions (i.e. PCA) on similar projects will be conducted when designing methods.

Strategy: Recovery of Populations within the Historical Range

Attempts will be made to recover priority populations, where feasible, to increase population levels and re-establish populations in candidate areas within the species' original distribution, by protecting and/or restoring habitat, managing harvest, reducing hybridization and eliminating or suppressing populations of non-native fish having negative impacts on WCT.

3.3.4 Education and Outreach

Strategy: Improve Awareness of the Species

Target audiences have been identified and efforts have been made to determine how each may contribute to and/or be impacted by recovery plan activities. Based on this information, key messages and outreach options will be defined to target each group. DFO and AEP developed and installed educational signage in various locations in Alberta in 2018. DFO's Conservation and Protection Program and AEP developed and installed signage targeting off-highway vehicle users near waterways, and along Silvester Creek in Alberta. Additional signs were installed along streams in the Livingstone and Porcupine Hills area in 2018. Enforcement advisories have been provided to Alberta Fish and Wildlife officers to assist in directing enforcement efforts to areas of highest concern for WCT protection. AEP is in the progress of developing a Linear Footprint Management Plan and Recreation Plan for the Upper Oldman, Livingstone, and Porcupine Hills area.

3.3.5 Funding

The Canada Nature Fund for Aquatic Species at Risk is a contribution funding program which provided over 4-million dollars to AEP (from 2018-19 to 2022-23) for native trout recovery actions. DFO has also funded several other Habitat Stewardship Program (HSP) projects that target protection and recovery of WCT. Additionally, DFO has supported a multi-year recovery project through the Aboriginal Fund for Species at Risk (AFSAR) program.

3.3.6 Initiative Results

Recovery initiatives have not yet resulted in the re-establishment of pure-strain WCT populations and their habitat. Efforts for recovery continue in the areas of research, monitoring, management and regulation, and education and outreach for this species.

4 Fish and Fish Habitat

Environmental Impact Assessment (EIA) References

- Canadian Impact Assessment Registry (CIAR) #11, EIS Guidelines
- CIAR #42, Updated EIS
    - Section A – Project Introduction
    - Section C – Project Description
    - Section E – Environmental Assessment
    - Consultant Report #3, Hydrogeology (CR #3)
    - Consultant Report #4, Hydrology (CR #4)
    - Appendix 10, Geochemistry Reports
- CIAR #44, 1st Addendum to the EIS
    - Aquatic Ecology Effects Assessment: Consultant Report #6 (CR #6)

- CIAR #69, 5th Addendum to the EIS
- CIAR #70, 6th Addendum to the EIS
- CIAR #89, 8th Addendum to the EIS
- CIAR #251, 10th Addendum to the EIS
- CIAR #313, 11th Addendum to the EIS
- CIAR #352, Panel IR (May 22, 2020)
- CIAR #360, 12th Addendum to the EIS

Components of baseline data collection, effects assessment methodology, and the effects assessments including mitigation measures, residual effects conclusions, and monitoring programs related to each of the pathways of effects that fall within DFO's mandate and area of expertise are discussed in the following subsections. A full summary of each of these topics is not provided. Rather, a discussion on what is viewed as notable uncertainties or shortcomings are offered for each component, as well as additional resources and perspectives that should be considered.

4.1 Baseline Data Collection

Appendix A1 (CR #6) provides detail on the collection of baseline aquatic resources data. The Proponent used appropriate methods and developed an adequate characterization of the existing habitat and biological resources at the time sampling was completed. However, there are concerns with how effectively these data can be used to validate predictions, or to set triggers for adaptive management:

- Data was collected over a limited time period, creating challenges for before-after comparisons, and generating uncertainty in effects predictions.
- The Proponent provides relative abundance estimates of fish or adults per m^2 of stream area, but does not provide confidence intervals. This makes it difficult to determine how readily change in the population could be detected post-impact.
- Results of mark-recapture studies show low recapture rates, and there appears to be high variability in the numbers of fish captured between survey methods (i.e. snorkeling, angling, and electrofishing) and stream reaches. It is unclear which values would be used to define baseline, which is necessary to make post-impact comparisons. This high variability also decreases the confidence that the survey methods are effective in generating useful estimates of relative abundance.
- Invertebrate drift sampling locations failed to align with key locations that would allow for a before-after, control-impact study to determine if effects predications are accurate (e.g. habitat that would be lost downstream of tributaries).

These shortcomings in study design have implications associated with the likelihood that the Aquatic Monitoring Plan (AMP; discussed further in Section 4.5) can be successful in achieving the stated objectives.

4.2 Effects Assessment Methodology

As described in section 3.4 of CR #6, a standard approach for the assessment of impacts to an aquatic environment was taken. This approach aligns with DFO's Pathways of Effects guidance, and contains three main steps:

- Identify potential pathways of effects from the project on specific aquatic environment components;
- Identify whether linkages between the project activity and the environmental component can be broken through the application of mitigation measures; and,
- Identify the residual effect of the project on the aquatic environment.

To meet the needs of the Environmental Assessment, the predicted residual effects are then evaluated based on a number of criteria, and a determination made as to whether a significant adverse environmental effect is an expected outcome of the impact-mitigation-effect pathway.

Pathways of effects have been well defined by the Proponent, however, there remain shortcomings related to mitigation measures and the residual effects conclusions. These are identified and discussed in relation to specific pathways of effect in the following sections.

Additionally, there are shortcomings with the determination of significance framework. The criteria categories outlined in Table 3.6 (CR #6) have not been adjusted to reflect life history processes or the broader population status of the valued component (WCT). For example:

- The duration category "short" covers effects occurring within the development phase. No effort to align the length of any given project phase with life history processes of WCT was made. Therefore, the framework does not reflect that, given the low population levels of WCT, impacts to any given life history process should be considered significant.
- The geographic extent category "local" does not account for the severely fragmented status of WCT populations. A category of "local" represents the full extent of habitat accessible by an entire pure-strain population of WCT, as well as a near-pure population with high recovery potential.
- The reversibility criteria do not reflect the lack of resiliency available to a population of WCT that are confined to a very small habitat extent at the edge of the range within which they historically existed.

These criteria categories may be appropriate for valued components that exist as a part of a broad, connected ecosystem, but they do not reflect the sensitivity of an isolated population of a species at risk nor the importance of preserving existing WCT genetic pools.

Recommendation 1: The Proponent should conduct an effects assessment with associated evaluation criteria for the WCT valued component that is based on life history components of the species, taking into consideration the broader context within which the remaining populations exist, and the potential contribution of the affected populations to re-establish genetically pure populations within their native range, as per the RS-AP.

4.3 Pathways of Effects: Assessment, Mitigation, Residual Effects, Monitoring

4.3.1 Changes in recreational access to fish-frequented stream reaches

The Proponent includes mitigation of this pathway via educating and discouraging their workforce from angling near the Project. However, DFO is of the opinion that concerns remain on this topic that should be taken into consideration.

“WCT harvest regulations have changed from a legal harvest throughout portions of the eastern slopes, to a zero harvest (catch-and-release) regulation from 2009 to 2016 . It is recognized however, that incidental mortality from catch and release angling may be a threat to survival and recovery of populations in some watersheds (COSEWIC 2016), as mortality can occur from the stress of being angled, and physical damage to the fish from hooking or improper handling. In addition, the level of illegal harvest, as a result of misidentification or intentional harvest, is unknown but must be also be considered. Mortality from catch-and-release angling may be a threat to the successful recovery of WCT populations in areas with high angling effort” (DFO 2019).

“Cutthroat trout are the near-perfect reusable fly fishing trout because of their surface-feeding tendencies, willingness to take flies, and durability” (The Alberta Westslope Cutthroat Trout Recovery Team 2013). The desirability of the species suggests that any increase in access is likely to increase angling activity particularly given that Gold Creek represents one of few viable populations of WCT remaining (i.e. angling success is more likely at this location).

The impact of recreational access should not be underestimated as a threat to aquatic ecosystems. Road networks associated with primary resource extraction have encroached upon a multitude of streams containing WCT, causing habitat alterations. Easier road access has also led to an explosion of angling and recreational activities that further degrade sensitive habitats (Alberta Sustainable Resource Development and Alberta Conservation Association 2006, COSEWIC 2016). Increased angler access increases likelihood of introducing whirling disease, and increases the risk of habitat degradation through use of off highway vehicles (OHV) or by manual interference with the creek system. Angling regulations indicate Gold Creek open season June 16 - October 31, and Blairmore Creek June 16 to August 31. However, spawning and egg incubation continue after June 16th, increasing the risk to the species if anglers are not aware of habitat and species sensitivity, or do not endeavour to avoid causing harm.

Mitigating the potential effects of increased access on WCT relies on the Proponent as well as provincial and federal governments to implement broader recovery strategies aligned with their responsibilities for the protection and recovery of the species. A precautionary approach and best practice for mitigating effects to a species at risk should include an access management plan for Indigenous rights holders, the public and employees.

Recommendation 2: The Proponent should develop an access management plan to ensure the public and employees do not have increased access to angling opportunities within the LSA as a result of mine infrastructure and access privileges, unless access is granted for exercising Indigenous rights. The plan should be developed in consultation with the appropriate provincial agencies, and Indigenous

communities to avoid, mitigate, and monitor additional access by recreational users to the extent that is within the Proponent's control, while respecting the exercise of rights of Indigenous communities. The Proponent should align construction, operations, and closure plans with existing and future land use and watershed management plans.

4.3.2 Blasting activities potentially affecting WCT

CR #6 states that the Project requires the use of explosives and that without mitigation there is the potential to cause overpressures greater than 100 kPa and vibrations that may cause damage to incubating fish eggs. The Proponent has identified that they will employ mitigation measures including applying blast delays to ensure they meet guidelines outlined in *Guidelines for the use of explosives in Canadian Fisheries Waters* (Wright & Hopky, 1998). This approach is insufficient to adequately predict and mitigate effects to WCT.

Blasting activities that occur near fish-frequented waterbodies have the potential to impact fish by causing behavioural changes, injury, or death (Wright & Hopky 1998), including potential impacts to fish eggs (Wright 1982). The potential harm caused by blasting "is related to type of explosive, size and pattern of the charge(s), method of detonation, distance from the point of detonation, water depth, and species, size and life stage of fish" (Wright & Hopky 1998). These guidelines outline methods to avoid destruction of fish or potential harmful effects to fish habitat when using explosives (Wright & Hopky 1998). Formulas to calculate recommended set back distances to meet the 100 kPa limit are suggested. The set-back distance provided in the guidelines "closely approximates the theoretical lethal range within which 50% of the fish may be killed or injured" (Wright & Hopky 1998).

Small fish are more likely to experience injury or death than larger fish (Wright 1982), and shallow water with rocky substrates require the largest setback distances, followed by frozen soil and ice (Wright & Hopky 1998). The guideline cited by the Proponent states that methods provided may underestimate the lethal range if the water is shallow or the substrate is rocky (Wright 1982).

It should be noted that these guidelines are not currently accepted as a code of practice by DFO (https://www.dfo-mpo.gc.ca/pnw-ppe/practice-practique-eng.html), and that additional research has occurred since the publication of this document. Setback distances intended to protect fish from the lethal range of explosives do not necessarily fully account for the possibility of non-lethal injury [prohibited under Section 32(1) of *SARA*], or behavioural changes. Further, given the environmental context, the limits proposed by the Proponent do not exclude the possibility of lethal harm. In the context of habitat conditions at the proposed mine site (e.g. rocky substrate), and the presence of fish with small body size, the mitigation measures proposed by the Proponent are not sufficiently protective.

Kolden and Aimone-Martin (2013) summarized several empirical studies that have examined the effect of blasting on salmonids. The authors concluded that limiting peak particle velocity (PPV) to 13 mm/s was sufficiently protective, based on the results of ten studies, in which the lowest PPV to cause mortality was 147 mm/s. With respect to peak overpressure, in four out of ten studies examining effects on juvenile salmonids, peak overpressures at or below 100 kPa caused injury or mortality, and the lowest peak overpressure to cause injury was 69 kPa (in a study examining the effects of blasting near

frozen waterbodies). The authors concluded that overpressures below the limit (100 kPa) provided in the 1998 guideline (Wright & Hopky 1998) could harm fish, and point out that, as a result, the DFO Western Arctic recommended a limit of 50 kPa.

Recommendation 3: A quantitative assessment of the potential effects of blasting on WCT should be undertaken including but not limited to the destruction of habitat, mortality, harm, and behavioral changes. The assessment should be informed by recent research and publications, and include considerations for local habitat conditions (e.g. substrate type, water depth), fish species (particularly WCT) and life stage likely to be affected (e.g. body mass), frequency, timing, and depth and setback distances of proposed blasting activities. The results should be used to develop a site-specific mitigation and monitoring plan to verify the accuracy of predictions and effectiveness of mitigation, and included in the follow up program. The offsetting plan should be updated to account for any predicted residual effects.

4.3.3 Changes in water temperature

Project activities that have the potential to cause changes in water temperature include "the removal of vegetated areas, site preparation and soil salvage" (CR #6). CR #6 indicated that a total of 584,263 m^2 riparian habitat will be impacted within 20, 30, or 50 m buffers from Gold Creek, Blairmore Creek, and their tributaries. Section 4.2.2.1 of CR #6 provides an assessment of the potential changes in water temperature. This assessment employed a model that does "not explicitly consider individual contributions (i.e. from groundwater, interflow, or surface runoff)…" (CIAR #89), but rather focusses on changes in flow as a predictor of temperature changes. It does not appear that the modelling exercise accounts for changes in temperature associated with riparian habitat destruction, riparian habitat harmful alteration, upland vegetation removal, alteration from natural flow regime to sedimentation ponds with large surface areas, or soil salvage activities, despite recognition by the Proponent that these activities have the potential to alter water temperature.

WCT are sensitive to changes in water temperature, and their preference for cooler water appears to make them a superior competitor in higher elevation stream reaches where they are most able to resist invasion by non-native species (COSEWIC 2016). Riparian vegetation maintains low water temperatures by reducing insolation (COSEWIC 2016). A meta-analysis of studies comparing wooded to non-wooded riparian areas suggests that wooded riparian areas contribute to decreased spring and summer stream temperatures, and that lowering of temperatures is more pronounced when considering the maximum stream temperature reached (as opposed to average temperature) (Bowler *et al*. 2012).

It is acknowledged that riparian buffers and vegetation will be protected to the extent possible, however, per the impact assessment there is still a large area of riparian habitat that will be impacted as a result of the project (see item 7 below for additional detail), as well as upland vegetation clearing associated with the project footprint that have unknown impacts on surface runoff water temperature, and therefore stream temperature. The proponent acknowledges that stream temperature can vary on the scale of meters (CR #6) suggesting that complex variables dictate stream temperature within various habitat units. Given the limited habitat available to WCT in Gold and Blairmore creeks, and the species sensitivity to temperature changes, it is important that virtually all available habitat should be protected

from project-related temperature changes that fall outside the natural regime or the species' tolerance range. The predictive mechanism used in this assessment does not include all relevant variables, nor does it appear able to determine potential changes in temperature on the scale of habitat required to fully understand impacts. Due to these limitations, the determination that this pathway of effect linkage has been broken is not in keeping with the precautionary principle.

Monitoring of water temperature has been identified as a water quality parameter to be measured in the AMP (CIAR #313). Mitigation would be required once temperature exceeds a yet-to-be-defined threshold. Uncertainty remains surrounding the ability to apply mitigation measures to achieve the required degree of protection because changes in temperature could be caused by numerous factors that span large spatial scales (e.g. loss or impaired riparian habitat).

Recommendation 4: The Proponent's model to predict changes in water temperature should be updated to include all relevant variables that may affect the temperature of water entering Gold and Blairmore Creeks, and their tributaries. Additional variables may include but not be limited to vegetation loss, increased temperature of water from water management structures, and effects of climate change on air/groundwater temperatures. The offsetting plan should be updated if residual effects are predicted.

Recommendation 5: Prior to construction, the Proponent should identify adaptive management options to be implemented should monitoring indicate that stream temperatures approach trigger values. The Proponent should perform an analysis of their likely effectiveness and the feasibility of implementation considering that stream temperature changes may be caused by multiple activities across the site.

Recommendation 6: The Proponent should update the AMP to define how the temperature monitoring program will verify changes to temperature are within WCT tolerance or natural range throughout the available habitat. The follow up program should include verification of the accuracy of water temperature predictions and effectiveness of mitigation.

4.3.4 Changes in WCT food supply

Changes in WCT food supply is a potential outcome of the following project components, as described in section 4.2.2.2 of CR #6:

- Changes to aquatic and/or riparian habitat of Gold and Blairmore creeks due to Project footprint; and,
- Changes to hydrology causing alteration in aquatic habitat of Gold and Blairmore creeks associated with site water management activities within the LSA.

Invertebrate drift density and biomass were measured at three points in Gold and Blairmore creeks, respectively (Appendix A1 of Appendix A1 of CIAR #44). Results of these site-specific studies indicated that invertebrate drift density and biomass in Blairmore Creek increased with distance downstream, while this trend was not observed in Gold Creek where density and biomass were reported as being more evenly distributed throughout the length of the mainstem.

Notably, considerations related to this pathway of effect overlap with those of "Changes to tributary and mainstem aquatic habitat and/or riparian habitat," as well as "Changes to hydrology in Gold and Blairmore creeks." The Proponent noted that reductions in flow are anticipated to be small enough due to tributary loss that they will cause no change in invertebrate productivity or drift. The Proponent cited a study that indicated that headwaters contribute 12.4% of invertebrate prey to downstream environments in one Alaskan study (Wipfli & Baxter 2010), and that food drift in stream environments generally drifted 1-100 m based on a number of field studies. The Proponent rationalized that since food does not drift very far, the majority of aquatic or riparian habitat upstream of the fish-frequented portion of the system to be lost does not convey food drift to the fish-frequented portions. Based on this information, the Proponent concluded that any loss in food drift would be immeasurable relative to the local invertebrate production, and no effect on WCT is anticipated.

An earlier study concluded that "fishless headwaters are a year round source of invertebrates", and that within the ecological context that source could theoretically support 100-2000 young of the year salmonids per km of stream reach (Wipfli & Gregovich 2002). Another publication concluded that "delivery of invertebrate prey from tributary streams is small relative to local, in-stream production…However, prey from headwater sources may be seasonally important at fishless-fish interfaces, as some fish species may seek out these specific habitats during certain times of the year…and may partly explain the high fish densities often seen at tributary junctions…" (Wipfli & Musslewhite 2004).

While DFO did not perform a full literature review on this topic, the conclusions made in the scientific literature presented by the Proponent and above do not support the effects conclusion that the Proponent has reached. Given that WCT subpopulations are limited to the upper-most extents of their historical range with no ability to migrate seasonally or otherwise to more productive habitat, the loss of food drift contribution in the range of 12% is likely a residual effect. Further, the data collection performed by the proponent lacked the resolution to determine whether these literature values apply to the ecological context found in the project setting. For example, data was not collected at tributary junctions and was not collected in the winter. Indeed, given the isolated nature of the fish to these upper extents of the watershed, and the feeding habits of WCT, headwater invertebrate drift may contribute significantly more to the population than is found in other contexts. Further, the Proponent did not address the inter-connectedness of systems; there is no discussion on whether the removal of tributary habitat and associated riparian area may reduce nutrient and detritus contribution to the downstream local environments where they indicate the majority of the food source would be generated. The assessment and conclusions are not aligned with the current RS-AP that identified headwater tributaries and riparian areas as critical habitat, which is defined as habitat that is critical for the survival of the species.

Recommendation 7: The Proponent should conduct a detailed assessment of locations where food drift may be reduced due to loss or alterations in aquatic or riparian habitat, or changes in flow. The locations should be cross referenced with habitat suitability in those areas. Subsequently, the effects assessment, residual effects conclusion, and offsetting plan should be updated to reflect the results, if required. The

assessment should be based on a detailed project design understanding, a comprehensive literature review, and conservative assumptions to account for lack of site specific data. Residual effects conclusions should take into account the sensitivity and lack of resiliency of the WCT subpopulations affected. Any areas of predicted loss should align with sampling locations defined in the AMP to verify predictions.

4.3.5 Changes to hydrology in Gold and Blairmore Creeks

The Proponent indicated that open pit development, resource extraction, land clearing, haul road construction, water management activities, and potential discharge from the proposed end-pit lake have the potential to cause changes in the hydrology of Gold and Blairmore creeks, and their tributaries (CR #6). Ditching or pumping is proposed to intercept any water (surface runoff, flow from overprinted tributaries, or groundwater) interacting with the mine area for use in mine activities. Water will then be routed to one of six proposed sedimentation ponds, three surge ponds, or the saturated backfill zones for water treatment. Water from the two sedimentation ponds on the east side of the site (East Sediment Pond and Northeast Sediment Pond) will be released into Gold Creek and water from the four ponds on the west side of the site (Plant Site Sediment Pond, Loadout Sediment Pond, West Sediment Pond and South West Surge Pond (initial years only)) will be released to Blairmore Creek.

In section 4.3.2 of CR #6 and CR #4, the Proponent describes the methods by which they characterize baseline flows in the surrounding creeks, assess the predicted changes in flow caused by the Project, and evaluate the resulting impacts to fish habitat as a result of the local hydrologic changes. A summary of their approach is provided below:

- Baseline stream flow was characterized by applying an annual runoff coefficient, sub-divided on a monthly basis for each subwatershed node [CR #4, Appendix 10B of the EIS (CIAR #42)].
- Changes to flow in Gold and Blairmore Creek mainstems were estimated by altering the runoff coefficient values and contributing catchment areas to reflect expected changes due to mining components at each subwatershed node [Appendix 10B of the EIS (CIAR #42)].
    - Although the hydrogeologic (i.e. groundwater) modelling is not used to inform the yield coefficient for either the baseline or the change assessment, the runoff coefficient value was intended to capture any changes related to groundwater contributions to stream flow.
    - Analysis nodes were located exclusively along the main branches of Blairmore and Gold creeks, and therefore changes to tributary flows were not directly estimated.
- The baseline stream flow and predicted change assessments provided the basis for several effects assessments including the following:
    - hydrological impact assessment (discussed below) (CR #4, CR #6);
    - instream flow assessment (IFA; Appendix 3 of CR #6), discussed below; and,
    - changes to fluvial geomorphology (i.e. sediment supply and transport; discussed in section 4.3.6).
- A residual effects analysis was performed (CR #6).

As a result of the hydrological assessment, the Proponent predicted that net losses of total flow are anticipated in all reaches of Gold Creek, reaching a maximum of 4% in the headwaters of Gold Creek above the project, 6-9% above Caudron Creek adjacent to the project footprint, and over 10% at the downstream limit of the project extent above Morin Creek. Blairmore Creek is expected to gain total flow amounting to approximately 15% relative to baseline for most of the year, except in low-flow winter months when increases of up to 33% above baseline are predicted. A detailed summary of these results are found in CR #4.

The Proponent then compared the predicted instream flow changes with the habitat suitability in the areas where they would manifest and estimated that approximately:

- 288 m^2 of adult holding habitat;
- 205 m^2 of juvenile rearing habitat;
- 10 m^2 of overwintering habitat;
- 27 m^2 of spawning habitat; and,
- 96 m^2 of fry habitat would be harmfully altered in Gold Creek as a result of hydrological changes (CR#6).

The Proponent concluded that only those changes that represented a loss of more than 10% of the available habitat component were considered a residual effect to the aquatic ecology valued component, WCT.

It is well recognized that maintenance of natural flow regimes is an important consideration for the conservation of fish and fish habitat, and WCT specifically (COSEWIC 2016, DFO 2013). Numerous variables must be considered in order to fully capture the alteration of the existing flow regime with sufficient detail to assess the potential impacts to fish and fish habitat, including extreme low flows, low flows, small floods and high-flow pulses, large flood (Arthington 2012). Impacts to the critical components of the flow regime that support WCT (functional flows) must be considered.

While the Proponent's model produced coarse estimates of annual and monthly runoff likely suitable for the design of the water management system and testing operational scenarios, the simulation results have a high level of uncertainty on a monthly basis, specifically during low flow conditions. An effort was made to translate the results to enable prediction of impacts on fish and fish habitat, however, the approach taken does not provide appropriate detail or resolution to support the impact assessment that was generated for the valued component, WCT.

The following sections provide technical analysis to support DFO's opinion that the analysis performed by the Proponent is inadequate to characterize potential impacts of changes to hydrology to fish and fish habitat.

Baseline stream flow characterization

An analysis of the current and future hydrologic conditions at the Project site was completed with the GoldSim Water Balance and Load Model introduced in Volume 3, Appendix 10B of the EIS (CIAR #42).

The water quantity forecasts generated by the model have been relied upon throughout the study, critically when evaluating the environmental flow needs in Blairmore and Gold creeks and the potential for flow-related effects on WCT and its habitat [Appendix A of CR #6, p. 180 of Addendum 11 (CIAR #313), p. 30 of Addendum 12 (CIAR #360)]. The Proponent offers the following description of GoldSim in Addendum 8 (p. 108; CIAR #89):

"GoldSim software is a graphical, object-oriented interface for carrying out spreadsheet calculations. The software includes many standard functions that allow for easy implementation of Monte Carlo simulations, vector and matrix operations, for tracking interdependencies of calculations, and unit consistency checks. GoldSim is fundamentally a spreadsheet program; subsequently, it is up to the user to define the level of complexity and physical processes represented in the water balance. Any process that can be described in terms of mathematical functions can be implemented in GoldSim; as such, there are no inherent limitations on the level of complexity that can be incorporated."

GoldSim is inherently not a hydrologic model, rather it is a modelling framework for representing system processes. GoldSim simulations only incorporate processes that are explicitly added by the modeller. The simplistic representation of the site hydrology included in the model produces considerable uncertainty when applying model results that has prevented the Proponent from adequately assessing potential hydrologic impacts to fish and fish habitat, as described in further detail below.

The hydrologic processes explicitly captured within the Water Balance and Load Model primarily relate to runoff. Monthly surface runoff volumes within the model are calculated based on annual precipitation, a monthly runoff distribution and runoff coefficients [p. 17, Volume 3, Appendix 10B of the EIS (CIAR #42), SRK Water and Load Balance Modelling Report]. Runoff coefficients are dimensionless ratios relating runoff (typically recorded at a streamflow gauge) to precipitation. Within the model, specific coefficients were assigned on a subcatchment basis depending on the land use and surface characteristics in the contributing area. A value for the undisturbed portions of the project site was estimated from regional stream gauges with others taken from book values.

Runoff from the Project site is estimated on an annual basis by multiplying the runoff coefficient for a given area by the mean annual precipitation. The annual runoff volume is then distributed on a monthly basis by multiplying the mean annual runoff by an additional coefficient derived for each month. Hydraulic processes related to the water management system such as storage and releases from the surge and sedimentation ponds are simulated on a monthly basis by adding these flows to the appropriate analysis node on Blairmore Creek. No analysis nodes were located on the tributaries to Gold and Blairmore Creeks, preventing the assessment of Project impacts to be assessed on headwater streams.

While the Water Balance and Load Model operates on a monthly basis, the hydrologic processes incorporated in the model are simulated on an annual basis. Mean annual precipitation is the only hydrologic input which is changed during a model simulation. This is confirmed by the Proponent in

Addendum 6 (p. 109; CIAR #70): "The purpose of the Monte Carlo simulation was to examine the range of variability in flow at various nodes based on the expected year-to-year variability in total annual precipitation, which was the only stochastic variable defined in the simulation". With the runoff coefficients and monthly runoff distributions fixed during simulations, the variability in the predicted monthly streamflow is controlled by the variability of the annual precipitation inputs.

The use of annual precipitation inputs to drive the hydrologic simulation calls into question the suitability of the model to represent drought and low-flow conditions. Since the variability in annual precipitation is lower than the variability in monthly streamflow, this results in a narrower range of potential monthly runoff values than might occur naturally. This dampens the simulated monthly runoff response, resulting in unrepresentative higher flows during dry periods and lower flows during wet periods. The Proponent does not demonstrate the correlation between annual precipitation and the monthly streamflow response. Even during a period of precipitation drought, the relative monthly streamflow response is fixed by the use of a constant monthly runoff distribution, this further mitigates the simulated low flow response; by imposing a constant monthly runoff distribution, the model is not capable of simulating the natural monthly variability in streamflow (i.e., flows in an unseasonably dry June versus flows in an unseasonably wet June), and as such has limited its usefulness when considering the impacts to fish and fish habitat. Future modelling should simulate streamflows at a monthly timestep, incorporating more representative natural monthly variability to better simulate both low and high flow periods.

The ability of the model to represent drought and low flow conditions is further questioned when considering the hydrologic processes captured in the GoldSim Water Balance and Load Model. Conceptually, the hydrologic processes incorporated into the model can be presented as follows:

$$P_{year} - R_{year} - L_{year} = 0$$

$$\begin{aligned} where \quad P_{year} &= \quad Annual\ Precipitation \\ R_{year} &= \quad Annual\ Runoff \\ L_{year} &= \quad Lumped\ Processes \\ & \quad (Evapotranspiration, Groundwater\ Flow) \end{aligned}$$

This conceptual model assumes that all precipitation that falls each year either runs off the site or is removed from the surface water system as evapotranspiration or deep groundwater flow. No water is stored in the model on an annual basis, and past hydrologic conditions do not influence future years in the analysis. For example, the influence of a dry year in the analysis does not result in less runoff or lower streamflow conditions in subsequent years. In practice, only the distributed monthly runoff is calculated in the model; losses to evapotranspiration or groundwater flow are not considered further in the analysis. The monthly runoff component of the water balance is fully represented in the model, calculated from annual precipitation as follows on a subwatershed basis:

$$P_{year} \times C_{year} \times D_{month} = R_{month}$$

$$where \quad P_{year} = \quad Annual\ Precipitation$$
$$C_{year} = \quad Annual\ Runoff\ Coefficient$$
$$D_{month} = \quad Monthly\ Runoff\ Distribution$$
$$R_{month} = \quad Monthly\ Runoff$$

The representation above is compared with a simple conceptual water balance for a subwatershed presented below. This conceptual description incorporates the basic components of the hydrologic cycle and forms the basis of many numerical hydrologic and water balance models.

$$P - R - G - E - T = \Delta S \qquad \text{(Bedient \& Huber 2002)}$$

$$where \quad P = \quad Precipitation$$
$$R = \quad Runoff$$
$$G = \quad Groundwater\ Flow$$
$$E = \quad Evaporation$$
$$T = \quad Transpiration$$
$$\Delta S = \quad Change\ in\ Storage\ Over\ the\ Timestep$$

While the Grassy Mountain conceptual model is much simplified by considering primary runoff, the concept of storage (ΔS) is neglected. The storage represents the capture of water within one timestep for release or use within future timesteps, for example the storage of recharge during the spring within the groundwater system for release in the summer as baseflow. Natural hydrologic storage capacity in a catchment is found in snow and glaciers, peat swamps and bogs, the soil column, the groundwater system, and lakes and wetlands (Van Loon 2015). The representation of storage is critical when simulating low flow conditions, as the resilience of aquatic systems is tied to the release of stored water as baseflow. While storage associated with Project elements such as the surge ponds and gravel bed reactors are captured within the Water Balance and Load Model, fluctuations in the natural hydrologic system are not captured within the model. While periods of persistent drought are less common at the annual timescale, storage must be incorporated into the model to accurately capture the streamflow response to dry and extreme dry periods.

This limitation is partially related to the use of runoff coefficient methods within the model. The runoff coefficient method is usually applied to estimate flood flows where variables like groundwater flow, evaporation, and changes in hydrologic storage are less critical. While appropriate at the Project site for design purposes, this approach is limited for assessing the predicted impacts to the hydraulic regime as they relate to fish and fish habitat, as employed by the Proponent. This analysis approach does not differentiate between the separate pathways contributing to runoff (i.e., surface flows, interflow, and groundwater discharge) [“Instream Flow Assessment” (p. 13; Appendix A3 of CIAR #44)], and this limitation makes interpreting the project impacts on fish and fish habitat as they relate to baseflow and low flow maintenance challenging.

Predicted changes to hydrology resulting from the Project

The assessment of the future hydrologic regime was completed within the Water Balance and Load Model by modifying two components:

- the annual runoff coefficient to correspond to future estimated land use and surface characteristics; and,
- the contributing area of the prediction nodes downstream of disturbed areas.

The selection of runoff coefficients to represent future conditions is subjective and subject to uncertainty. The Proponent relied on book values and professional judgement (p. 112; CIAR #70), which makes the prediction of future flows subject to a high degree of uncertainty. The Project could be well into production before sufficient data is collected to verify the accuracy of the chosen runoff coefficients.

As noted above, the Water Balance and Load Model fails to incorporate a representative range of monthly and seasonal streamflow variability, owing to the use of annual precipitation inputs, fixed monthly distribution coefficients and a lack of consideration of natural storage within the hydrologic system. Accordingly, the future hydrologic regime under periods of extended or intense hydrologic drought has not been evaluated.

The proponent indicates that harmful alteration as a result of hydrology changes in Gold Creek will be offset for, and if there are low flow years flow augmentation will be used to prevent changes beyond those predicted (CR #6). However, due to potential water quality issues, there appears to be a lack of confidence that there will be enough water of sufficient quality that this type of mitigation can be guaranteed. Offsets as a mitigation approach is discussed in section 4.4.

Summary of the Assessment Approach

While the model will produce coarse estimates of annual and monthly runoff likely suitable for the design of the water management system and testing operational scenarios, the simulation results have a high level of uncertainty on a monthly basis, specifically during low flow conditions. A single average monthly precipitation distribution is used to translate annual precipitation and annual estimates of runoff to a monthly timestep. This analysis does not incorporate monthly streamflow variability, only annual precipitation variability, which limits the model's ability to accurately predict the impacts of the Project on the monthly flow regime. With no incorporation of storage, the predictive power of the model during hydrologic drought is questionable. The use of runoff coefficients to estimate future hydrologic conditions is subject to high uncertainty. Additionally, the complex relationships identified between the surface and subsurface by the ongoing gauging program (especially on Gold Creek) suggest a more rigorous analysis approach is warranted.

The model represents a limited and insufficient framework for assessing the impacts to fish and fish habitat, and WCT. The simulations of future streamflow are considered highly uncertain and, therefore, conclusions drawn from analyses which relied upon these data should also be considered highly

uncertain. This approach does not have the resolution to capture seasonal variation or to understand what is occurring at the mesohabitat scale, which is the scale at which fish habitat assessments were performed. Additional analysis is required to reduce the uncertainty of the predicted Project impacts to the hydrologic regime of Blairmore and Gold Creeks.

Recommendation 8: The Proponent should update the modelling analysis to assess the impact to the hydrologic regime at a temporal scale suitable to the assessment of fish and fish habitat, in particular WCT. Future modelling should simulate stream flows at a monthly timestep (as a minimum), incorporating monthly variability to better estimate both low and high flow periods. Hydrologic processes and components required to accurately capture the streamflow response to dry and extreme dry periods should be incorporated into the model. Analysis nodes should be included at key tributaries to allow project impacts to be assessed on low order, headwater streams.

Predicted impacts to WCT resulting from predicted changes in hydrology

In order to predict how changes in the hydrological regime could result in impacts to WCT, the Proponent performed an instream flow assessment (IFA; Appendix A3 of CIAR #44):

"The IFA (Appendix A3) conducted for the Project considered potential flow changes on fish habitat associated specifically with WCT during construction, operations, reclamation, and closure phases of the Project. It was performed by comparing model-predicted indices of species-specific habitat availability and suitability in Gold and Blairmore creeks during the different Project phases to these same indices under baseline conditions (i.e. natural, pre-construction flows)" (p. 74 of CR #6).

As described above, the Proponent did not adequately characterize baseline conditions nor predict altered hydrologic conditions. Setting these concerns aside, there are additional concerns related to the approach taken by the Proponent to align hydrologic changes to fish life history processes. The habitat availability is based off the areas the Proponent has described as being suitable for a given life history. While habitat suitability curves (HSC) can be useful tools, they are an inherently coarse and simplistic representation of what occurs in the natural environment. These curves may not represent the full use of the habitat by individuals of the species, e.g., outliers, differing life stages. In the case of a species at risk, individual use becomes the scale at which we must measure. A second way in which these conceptualizations of habitat and their use by fish may be incomplete is the apparent exclusion of the contribution of adjacent, lower quality habitat to the higher quality habitat (see IFA for a description of how the area weighted suitability metric is calculated).

Recommendation 9: DFO recommends that the Proponent define low flow (ecosystem baseflow) thresholds that are required to maintain habitat functionality. The proponent should describe how streamflow reductions below set thresholds will be mitigated, particularly under natural low flow conditions. A reference gauge approach to estimate the required augmentation under low flow conditions should be employed.

Recommendation 10 : The Proponent should include a sampling methodology that will verify the habitat suitability predictions in the Aquatic Monitoring Plan (AMP).

Residual Effects Conclusions

The threshold for "no significant" effect to WCT due to predicted flow changes that the Proponent defined was that at least 90% of total habitat availability remained over the relevant biological stanzas for WCT (CR #6). The Proponent predicts that "288 $m^2$of adult holding, 27 m^2 of spawning, 205 m^2 juvenile rearing, and 10 m^2 of overwintering will be altered during average flow (runoff) conditions" (CR #6).

The Proponent has relied upon the DFO Advisory Report *Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada* (2013) to support an allowable hydrologic alteration of 10% monthly flows or 30% of the mean annual flows. The 10% value suggested in the advisory report refers to alterations in *instantaneous flows*, not monthly averages. Further, this value represents estimated thresholds where the impacts have a lower probability of causing impacts, which is not synonymous with no residual effect. In the context of a subpopulation of WCT that has been confined to the edge of its historical range, in a highly complex and variable hydrologic environment, a threshold of 10% change in instantaneous flows may not be an appropriate metric for a no residual effects determination, especially when uncertainty and limitations outlined here are considered. An assumption that a 10% change in average monthly flows will have no residual effect is even less conservative. This uncertainty is compounded further by the uncertainty in the way the average monthly flow changes were predicted. Further, the Proponent appears to assume that only habitat loss (i.e. habitat that is no longer under water due to hydrologic alterations) should be accounted for. Complete habitat loss (destruction) and reduced functionality of habitat due to changes in the natural flow regime (harmful alteration) are two separate pathways that need to be considered. The Proponent has not accounted for all destruction of habitat not quantified harmful alteration associated with flow alterations. This has likely underestimated the scale of impacts to WCT.

Recommendation 11: The Proponent should update the changes in hydrology effects assessment to incorporate updated hydrologic modelling and instream flow needs. The analysis should be precautionary and conservative, incorporating DFO's Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (2013) and accounting for all habitat destruction and alterations associated with flow alterations. The offsetting, AMP, and Follow-Up Program should be updated, as required.

4.3.6 Changes to sediment supply and transport mechanisms

Potential changes to sediment supply and transport mechanisms were identified as a secondary effect pathway as described in Table 4.2 and Section 4.2.2.2 of CR #6. Specifically, Project activities associated with site preparation, surface water management and active water treatment, open pit and resource extraction, waste rock placement, and reclamation and closure were all identified as elements potentially impacting sediment supply and transport mechanisms.

This pathway can be divided into three different categories, each of which has the potential to result in negative impacts to WCT, critical habitat, and fish habitat:

1) changes to sediment yield due to sediment laden overland flows entering watercourses;

2) changes to sediment supply due to overprinting of sediment sources; and
3) changes to sediment transport dynamics due to alterations in the hydrologic regime.

Changes to sediment yield due to sediment laden overland flows entering watercourses

Changes to sediment yield due to sediment laden overland flows entering watercourses relates to the potential increase in the supply of fine sediment to a receiving watercourse due to factors such as land-use change, construction, or the removal/disruption of vegetation. The introduction of excess fine sediments to a watercourse can impact both water quality (e.g. total suspended solids; TSS) and habitat (e.g. sedimentation on critical spawning areas). These impacts can largely be mitigated through erosion and sediment control (ESC) best practices such as site isolation and runoff management strategies. ESC mitigation measures are discussed in Table 4.2 of CR #6. A detailed ESC management plan for all project stages will be an important component to demonstrate the Proponent's ability to mitigate these potential impacts throughout the life of the Project. DFO acknowledges this plan will be developed at later stages if the Project is approved, and that adequate planning and implementation is likely to mitigate negative impacts associated with this aspect of the pathway.

Changes to sediment supply due to overprinting of sediment sources

Changes to sediment supply associated with the removal of sediment sources have been noted in both Blairmore and Gold creeks as a result of the full or partial overprinting of several tributaries in the two systems, as identified in table 4.3 of CR #6. Appendix A2 of CR #6 provided a comprehensive inventory of the differing morphologies along the main branches of Gold and Blairmore creeks based on field assessments. In addition, potential sediment sources along these creeks were inventoried, and include landslides and input from tributaries. Two tributaries to Blairmore Creek (BCT-07 and BCT-02) and three tributaries to Gold Creek (GCT-11, GCT-10 and GCT-08) that are proposed to be either fully or partially overprinted by the Project were indicated as being potential sediment sources to their respective drainage systems [Section 3.3 of Appendix A2 (CR #6)].

Rivers are dynamic systems that adjust their forms based on their hydrologic and sediment regimes. Alterations to either of these regimes may result in channel adjustments to re-establish a new dynamic equilibrium, which may have implications to existing fish habitat. Changes to sediment supply are important to fish habitat for two reasons. Firstly, reductions in sediment supply are commonly associated with changes to bed morphology (Buffington & Montgomery 1999, Dietrich *et al*. 1989), potentially impacting morphologic units comprising habitat and critical habitat (e.g. riffles that function as spawning habitat). Secondly, downstream reaches must be supplied with preferential spawning sediment; in these high gradient systems, spawning sediment is readily transported which means that without an upstream supply, the downstream segments have the potential to become denuded of these materials. Given that WCT are geographically isolated within these creeks, these impacts need to be assessed in greater detail to determine the Project's effect on WCT.

The incremental effects assessment [Section 4 of Appendix A2 (CR #6)] only considers potential impacts associated with alterations to part of the hydrologic regime and does not assess potential impacts associated with changes in sediment supply. Although sediment sources are inventoried in the existing

conditions assessment, no analyses or discussion are provided assessing the potential impacts of reduced sediment supply to channel morphology or, correspondingly, fish habitat.

Recommendation 12: The Proponent should assess the potential impacts to WCT, fish habitat, and critical habitat as a result of impacts to sediment supply associated with the overprinting of potential sediment sources in Gold and Blairmore creeks. This may include but not be limited to a sediment budget that considers baseline, operational, end of mine, and long-term closure conditions. Subsequently, the WCT effects assessment, mitigation measures, offsetting plan, and significance assessment should be updated, as required. The AMP and Follow-up Program should include monitoring to verify the accuracy of the predictions and effectiveness of mitigation.

Changes to sediment transport dynamics due to alterations in the hydrologic regime

Section 4 of Appendix A2 (CR #6) presented an incremental effects assessment to assess potential changes in peak flows on sediment stability. The assessment used peak flows derived from a unit area approach, with the assumption that only the natural watershed contributes to flood flows. Runoff from the mine was not considered in the assessment, as it was assumed that all runoff within the mine footprint would be retained in the sedimentation ponds before releasing into the watercourses. A sediment stability analysis was conducted for median and maximum sediment sizes measured in the field assessment, using the predicted peak flow alterations for the 2-year flood (a frequent flood event) and the 100-year flood (an infrequent flood event) throughout the Project's life. The assessment concluded the following:

- Due to the reductions in peak flows, channel beds will become more stable over time.
- Stream channels are formed during high flows, thus the increase in low flows due to the release of water from the sedimentation ponds are not expected to alter the morphology of the stream channels.
- Based on the above points, the physical habitat is not expected to change due to water management throughout the mine life.

The sediment stability assessment completed by the Proponent only considers one component of potential flow regime alterations that can impact sediment transport dynamics, and correspondingly, stream morphology. The future alteration of these peak return flows was determined by removing the planned project from the Mean Annual Flood contributing area (SRK Memo, "Grassy Mountain Peak Discharge Changes" dated Nov 28, 2016, Appendix F of Appendix A2 of CR #6). This approach overestimates the relative change in peak flows by assuming all runoff within the Project footprint is captured by the engineered sedimentation ponds. The assumption in this assessment methodology is that storm runoff is limited to the immediate sheet flow runoff response within the natural catchment, and that contact water within the mine footprint will be subject to retention and settlement prior to discharge to the environment. The impacts of water management operations on peak flow and high-flow pulses has not been assessed by the Proponent; high flow events are assumed to be stored in their entirety. This does not directly tie the water management operations to the analysis of future peak flows. The impacts on storage pond management to attenuate (or augment) peak event flows is not addressed. Thus, the hydrologic alterations of the Project are not fully considered in this assessment.

Additionally, the approach only considers changes to peak flows, and not how those changes in peak flows are redistributed throughout the flow regime. Changes to the flow regime that alter the magnitude, frequency, and duration of flow events can result in a corresponding alteration to the sediment transport dynamics of a system. As rivers adjust to develop a dynamic equilibrium to the altered flow and sediment regimes, changes to one or both can result in channel adjustment and potential negative impacts on aquatic habitat (e.g. excess channel erosion or sedimentation). The magnitude, frequency, and duration of flow events capable of transporting sediment are all important factors in assessing sediment transport impacts, and thus potential impacts to bed morphology. Moreover, the assessment was only completed for the median and largest particles present at each assessment location. Research on mountainous streams in British Columbia has identified that geomorphically significant flows are dependent on a complex relationship between flow regime and the range of sediment sizes present on the channel bed (Hassan *et al*. 2014). This is particularly important for sediment size ranges that are preferential for WCT spawning. These sizes are typically smaller than the median particle size measured at the assessment sections, and thus their transport dynamics are more sensitive to subtle changes to the flow regime. Changes to the transport dynamics of these smaller particle classes (relative to the entire bed mixture) may not result in macro-scale morphologic change (e.g. changes to cross-sectional area, incision, widening), however, they could result in negative impacts to identified habitat units important to WCT.

The Proponent attempted to address this by performing an intra-annual assessment using the predicted changes in monthly flows [DFO-R2-6 (CIAR #89)]. Their conclusion combined the initial peak flow reduction work, which did not incorporate the influence of the water management plan (WMP), with predicted changes to sediment mobility using mean monthly flows. The Proponent concluded that negative impacts are not expected because the reduction in peak flows is greater than the increase in mean monthly flows. These two analyses still do not consider the entire flow regime, nor the complete consideration of the flow regime alterations associated with the sedimentation ponds. Investigating flow regime changes using monthly averaged flows does not consider changes to moderate flow events (larger than the mean monthly flows) that may change transport dynamics of spawning sediment. For example, the release rates of the sedimentation ponds may still exceed the threshold required to transport spawning gravel, thus altering the duration at which these sediments are transported relative to baseline conditions. Investigating flow regime changes using only peak flows that does not consider influences of the sedimentation ponds, how the moderate flow regime is impacted by the Project, and whether those potential changes impact the transport dynamics of sediment classes important to WCT. Geomorphic thresholds related to preferential habitat areas should be compared with the full flow regime for baseline, operational, end of mine, and long-term closure conditions to assess potential impacts of the project to WCT, critical habitat, and fish habitat. The effects assessment also does not consider potential impacts after mine closure when the water management plan is no longer implemented, but the sedimentation ponds and end pit lake will continue to alter hydrologic conditions relative to baseline conditions. Thus, long-term geomorphic and sediment transport impacts have not been addressed.

Sediment Supply and Transport Conclusions

In summary, the morphology of a stream is influenced by its flow and sediment regimes. Alterations to these regimes can result in channel adjustments, potentially having negative consequences to aquatic habitat. The Proponent identified these changes as a potential effects pathway, however, the assessment did not consider potential changes to sediment supply associated with the overprinting of tributaries, even though several were documented to supply sediment to the main branches of both creeks. Additionally, the assessment did not adequately evaluate how potential changes to the flow regime will impact sediment types that have been documented to be preferential habitat, and a key attribute of critical habitat, for WCT. No post-closure impact assessment related to geomorphology or sediment transport was conducted. Given that WCT are geographically isolated within these systems, these impacts need to be assessed in greater detail to determine the Project's potential environmental effects.

Recommendation 13: The Proponent should incorporate hydrologic changes from the WMP into the sediment transport analysis and evaluate potential impacts to the magnitude and frequency of sediment transport for the entire flow regime using daily flow data. The analysis should be used to assess potential impacts to channel-maintenance flows and the magnitude, frequency, and duration of spawning gravel transport, and to assess potential impacts to channel morphology and sediment transport for post-closure conditions. The WCT effects assessment, mitigation measures, offsetting, and significance assessment should be updated, as required.

4.3.7 Direct loss of aquatic and riparian habitat

In section 4.2.3.1 of CR #6, the Proponent identifies that the following Project components have the potential to cause changes to aquatic and riparian habitat:

- Waste rock placement;
- Water management pond placement; and,
- Pit excavation.

To quantify these impacts, the Proponent overlaid proposed project design on environmental features, including watercourses and riparian habitat. Riparian habitat was defined by the Proponent as areas extending 50 m perpendicular to Gold and Blairmore creeks mainstems, 30 m perpendicular from fish-frequented tributaries, and 20 m perpendicular from non-fish-frequented tributaries. Riparian habitat is rated as low, medium, or high quality. No detail is provided on precisely how the Project will interact with these habitat components, so it was assumed that complete loss via overprinting is predicted for the following areas:

- In the Gold Creek watershed, an estimated 758 m^2 fish-frequented aquatic habitat, 5,221 m^2 of non-fish-frequented aquatic habitat, and 141,830 m^2 of riparian habitat would be destroyed as a result of the construction of Project components.
- In the Blairmore Creek watershed, an estimated 1,038 m^2 fish-frequented aquatic habitat, 19,929 m^2 of non-fish-frequented aquatic habitat, 442,433 m^2 of riparian habitat would be destroyed as a result of the construction of Project components.

In section 4.3.1 of CR#6, the Proponent identified mitigation measures, and provides a residual effects assessment resulting from these potential losses. Mitigation measures proposed to reduce the harm resulting from associated project activities include performing a fish rescue, implementing ESC measures, and avoiding (to the extent possible) working in sensitive timing windows related to fish life history processes. Additionally, revegetation of areas is proposed to occur in a progressive manner as sites become available. No assessment is provided as to how revegetation efforts align temporally with fish life history processes.

In an effort to determine residual effects that could occur from the loss of riparian habitat, the Proponent rates the areas based on quality (CR #6):

- Low riparian habitat value: Site within the riparian buffer zone of a non-fish bearing stream which has been previously impacted. Forest within this zone is classified as young.
- Medium riparian habitat value: Site within the riparian buffer zone of a non-fish bearing stream where the forest is classified as mature. Or, alternatively, a site within the riparian buffer zone of a fish-bearing stream where the forest is classified as young or previously impacted.
- High riparian habitat value: Site within the riparian buffer zone classified as a wetland or old growth, or a fish-bearing stream with mature forest.

The residual effects analysis indicated that only impacts to some medium and high quality riparian are considered residual effects for a total of 19, 270 m^2 riparian lost between both watersheds. This conclusion appears to be based on the Proponent's statements that "riparian habitat quality can vary widely within a single stream reach…" and "more mature, structurally complex habitat provides the most valuable fish habitat" (CR #6). No description of which specific areas of riparian habitat loss are excluded from the residual effects conclusion is provided. For aquatic habitat, the Proponent concludes that the loss of 758 m^2 of fish-frequented aquatic habitat in the Gold Creek watershed represents residual harm. The loss of non-fish-frequented aquatic habitat was not considered residual harm. As another type of mitigation, the losses concluded as causing residual effects are accounted for in the "Detailed Offsetting Plan" [Appendix B1 (CIAR #89)]. Offsetting is discussed in further detail in section 4.4.

The Proponent proposed to utilize the AEMP to monitor for changes that are not aligned with these residual effects conclusions. Specifically, a before-after, control-impact study design was proposed. Issues identified with the AEMP are expanded on in section 4.5.

At the time of the assessment, the Project design successfully avoided the overprinting of critical habitat, although as of 2019 critical habitat has been expanded (see section 3.2). As such, a full accounting of loss of critical habitat is not reflected in the residual effect quantification.

There are myriad ways in which intact riparian and headwater tributaries contribute indirectly to habitat that WCT utilize to carry out their life processes. Impacts associated with the loss of this habitat type were assessed separately by the Proponent and have already been discussed in other sections: changes in food supply (section 4.3.4), changes in water temperature (section 4.3.3), changes associated with altered flow regimes (section 4.3.5), and changes in sediment supply and transport (section 4.3.6). One

contribution of these habitat features that has not been discussed is the recruitment of large woody debris (LWD). LWD contributes to habitat complexity by generating log jams that provide cover, and provide pools that may be utilized for holding/feeding or may catch and retain spawning gravels (COSEWIC 2016).

Other than effects related to losses of flow in Gold Creek, which the Proponent considers minor, the Proponent has concluded that none of these pathways are likely to have a residual effect on WCT in Gold or Blairmore creeks. DFO critiques each of these analyses in turn in their respective section, and provides additional evidence below that collectively, changes resulting from riparian and headwater habitat destruction and alteration are expected to result in residual effects to WCT.

The recently updated RS-AP highlights the importance of riparian and headwater tributary contribution to the survival and recovery of WCT. However, the concepts that riparian setbacks and the maintenance of natural flow regimes are important for fish conservation are not new:

“A number of studies suggest that WCT is highly susceptible to habitat perturbation, particularly factors affecting water quality, temperature, or the amount of in-stream structure (Liknes and Graham 1988; Reeves et al. 1997; Porter et al. 2000). Several long-term studies also demonstrate that the loss of riparian buffer integrity leads to a decline in trout biomass, and populations remain depressed for 5-20 years as the riparian zone regenerates (Hartman et al. 1996; Reeves et al. 1997). These perturbations involve complex changes disrupting growth within subpopulations and causing increased mortality of certain age classes (Hartman et al. 1996). As a result, habitat partitioning is disrupted leading to increased competition for resources. WCT may be particularly sensitive to changes in natural flow regimes (Brown and MacKay 1995; Downs et al. 1997). In agricultural or urbanized areas where water has been appropriated for irrigation or domestic use, WCT subpopulations suffer dramatic declines as all life history stages are affected” (COSEWIC 2016).

The Proponent’s conclusions that removal of large areas of these habitat components will not yield a residual effect is not precautionary, is not aligned with post-impact findings throughout the literature, and was not based on an appropriate technical assessment.

The Proponent’s classification system of low, medium, and high quality riparian uses young and impacted areas as rationale for the low and medium categories, and subsequently concludes that loss of large areas of this type of habitat will not have a residual effect. This approach does not account for the timescale of the Project and the potential for these areas to mature, or be rehabilitated in the absence of the Project; this type of rehabilitation aligns with the RS-AP. There is also the potential for watercourses to migrate laterally within their meander belt, potentially implicating currently unconsidered upland vegetation as future riparian vegetation. The conclusion that is based on this rating system does not acknowledge the ecological context and sensitivity. WCT currently inhabit the edges of their range, generally at high elevations. The subpopulations are isolated, and therefore do not have the ability to migrate to areas of higher quality habitat to carry out their life processes. The species and the habitat are both highly sensitive, and have limited resilience to change. This is highlighted by the following statement, written for the 2016 COSEWIC assessment: “it is apparent that subpopulations have very strict habitat requirements during various life history stages and generally do well only in

unaltered lotic environments with cold clean water and varied forms of cover (i.e. undercut banks, pool-riffle habitat, and riparian vegetation) to maintain their numbers." In this setting, even "low" relative contributions of riparian habitat should be recognized as enabling WCT to carry out life processes, and their losses considered a residual effect.

The RS-AP defines riparian critical habitat as "continuous and extend(ing) horizontally from the high water mark to a width of 30 metres on both banks of the waterbody for the entire geospatial area." However, it is also acknowledged that "the width of the riparian area required to protect the attributes of critical habitat for WCT has not been quantified, however the riparian area must be sufficient to maintain clean, cold water, sediment and silt free substrates, and provide inputs of food (invertebrates) and woody debris into the aquatic environment." Additional buffers may be required depending on the site and impacts.

Recommendation 14: The Proponent should undertake a detailed analysis of the ability of the riparian areas in the vicinity of Gold Creek to support the features, functions, and attributes of critical habitat defined in the WCT RS-AP. A similar analysis should be applied to Blairmore Creek given the potential to support recovery objectives in the RS-AP. This analysis should consider the timescale of the Project such that potential future ability of riparian to support features, functions, and attributes is accounted for, including the potential for maturation of riparian areas, and the lateral migration of watercourses that may expand the range of vegetation that has the potential to contribute. Guidance on how to identify riparian habitat capable of supporting life history processes can be found in this recent publication: "Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels" (Caskenette *et al.* 2020).

4.4 Offsetting

Quantification of residual effect to WCT habitat

The Proponent has provided a "Detailed Offsetting Plan" [Appendix B1 (CIAR #89)] , which is intended to provide offsetting concepts to counter-balance the impact of the following residual effects to the aquatic ecology valued component WCT:

Table 5.1 Summary of quantified residual effects on fish habitat for the Project from Hatfield 2017c.

Valued Component	Watercourse	Issue	Residual Effect	Quantity (m^2)
Westslope Cutthroat Trout	Gold Creek	Permanent change to Fish Habitat in the LSA due to Project Footprint	Aquatic Habitat	-758
			Riparian Habitat	-18,868
		Changes to hydrology causing alterations to Critical Habitat	Spawning/Incubation	-27
			Adult Holding	-288
			Juvenile Rearing	-205
			Fry Rearing	+96
			Overwintering	-10

Westslope Cutthroat Trout (Cont'd.)	Blairmore Creek	Permanent change to Fish Habitat in the LSA due to Project Footprint	Aquatic Habitat	0
			Riparian Habitat	-402
		Changes to hydrology causing alterations to aquatic habitat	Spawning/Incubation	+18
			Adult Holding	+192
			Juvenile Rearing	+155
			Fry Rearing	+121
			Overwintering	+12

As discussed in section 4.3, several of the pathways of effects had "no residual effects" conclusions that DFO disagrees with, and therefore the quantification presented here does not represent what would be required to offset for residual impacts to WCT in Gold and Blairmore creeks, and their tributaries. For most potential impacts, additional quantification of residual effects is dependent on results of further assessment, as identified in the associated recommendations. DFO notes that quantification of residual effects will need to reflect the expanded critical habitat definition in the 2019 RS-AP that includes 30 m from the high water mark on both banks of fish-frequented and non-fish-frequented waters in Gold Creek. DFO will also apply this same standard to Blairmore Creek given its near-pure status and potential to support recovery objectives. As noted in section 4.3.7, inclusion of additional width beyond the 30 m may be required based on site-specific conditions, such as what width of riparian habitat provides or has the ability to support the features, functions, and attributes of critical habitat identified in the RS-AP over the timescale of the Project.

Proposed offset measures

A brief summary of the proposed offsetting concepts is below. Contingency measures are not considered in the assessment provided for this submission.

- Habitat gains associated with increased flows due to mine water management plan in Blairmore Creek;
- Alteration within existing aquatic habitat to provide additional overwintering pools;
- Alteration within existing aquatic habitat (Gold Creek) to create a single channel where currently a braided channel exists, with the intent to provide increases fish passage and habitat connectivity;
- Scientific research programme relating to genetic diversity within isolated subpopulations of WCT; and,
- Riparian enhancement.

DFO's current offsetting policy[2] states under guiding principle three that "the coincidental positive benefits of the works, undertakings and activities being authorized should not be considered as measures to offset." Therefore, any additional habitat gained in Blairmore Creek due to water management for the mine would not be eligible for offsetting.

[2] https://www.dfo-mpo.gc.ca/pnw-ppe/reviews-revues/forms-formes/apply-policy-politique-applique-eng.pdf

Overwintering pools, and pool habitat in general, can be limiting factors in WCT productivity, supporting the concept proposed in the offsetting plan. However, the Proponent does not provide a geomorphic analysis of the feasibility of creating deeper overwintering pools, which leads to uncertainty as to whether they will be naturally maintained after initial establishment. Offsetting measures should be ecologically self-sustaining in the long term, and they should balance project impacts both spatially and temporally. Further, there is no analysis or discussion as to whether this type of in-stream manipulation could have up- or downstream impacts on stream morphology that may result in negative impacts to the habitat's capacity to support life history processes of WCT.

The Proponent has suggested that a section of channel braiding that periodically experiences an absence of surface flow could be re-structured to increase habitat connectivity thereby increasing access to habitat and improving gene flow within the Gold Creek subpopulation of WCT. Channel braiding results from high inputs of sediments, which are deposited when the channel slope decreases. If the conditions which are creating the braiding continue to persist after the realignment works are completed, it is likely the channel will revert back to a braided channel. The Proponent has not provided an assessment of why the channel is braiding, nor the sediment transport characteristics of the braiding channel. This leads to uncertainty as to whether constructing a single-channel in place of a naturally braided channel is likely to be self-sustaining in the long term. Further, the Proponent has not provided adequate baseline habitat data to indicate that this feature represents a barrier frequently enough that there would be genetic isolation implications for WCT, nor have they provided genetic data demonstrating this to be an existing issue. Therefore, DFO is uncertain if this habitat enhancement proposal will have the added benefits that are suggested by the Proponent.

The proposed complementary measure may in part meet the needs of the validation exercise for removing braiding in Gold Creek, and as such, that portion of the study would not be considered offsetting. As stated in DFO's current offsetting policy, complementary measures "may be considered where there are limited opportunities for on-the-ground measures to offset fish and fish habitat residual effects…". The Proponent has not provided rationale that indicates there is a lack of on-the-ground measures. Given the restricted habitat availability, it is expected that ample physical offsetting measures likely exist within the range of WCT.

Riparian habitat enhancement has the potential to be a valid offsetting measure, assuming appropriate scale and development of success criteria. An assessment of the potential features, functions, and attributes of critical habitat (see section 4.3.7) gained by the enhancement of riparian habitat are required to determine whether the quantification of benefits is appropriate.

The Proponent provides a Draft Offsetting Effectiveness Monitoring Plan [Appendix B2 of Appendix B1 (CIAR #89)]. This plan should be updated to reflect success criteria that mirror the technical assessments of the value of riparian habitat, as well as the feasibility assessments that support the proposed in-stream alterations.

Other offsetting considerations

Although DFO recognizes that the Panel defines habitat offsetting as a type of mitigation for consideration throughout the environmental assessment process, an offsetting plan is also a regulatory requirement under the *Fisheries Act* and *SARA*, and there are regulatory requirements that may be pertinent to consider at this stage.

Different regulatory considerations apply to each Gold and Blairmore Creeks. Although under the *Fisheries Act*, fish in both systems are considered highly sensitive with low resilience to harm, Gold Creek fish and habitat are further protected in specific ways under *SARA*. As such, it is necessary for the Proponent to differentiate between the impacts to each system, and clearly define how impacts to Gold Creek fish and fish habitat are being offset, and whether the final outcome of that offset aligns with the goals identified in the RS-AP.

Offsetting concepts are proposed to occur within the zone of influence of the project, which means that if any of the assumptions that led to "no residual effect" conclusions are inaccurate, the Project has the potential to impact the offsetting. It is a typical condition of a *Fisheries Act* Authorization that the proponent cannot cause the harmful alteration, disruption or destruction to the established offset. For these reasons, the proposed offsetting creates regulatory uncertainty.

The Proponent indicates "that a period of time of approximately 10 years between the losses occurring and the offsetting measures becoming fully functional will likely occur" [Appendix B1 (CIAR #89)]. Because of the low resilience of the species potentially impacted by the Project, it would likely be considered necessary for offsetting measures to be implemented and confirmed as functioning before the impacts occurred in order to meet the pre-conditions of Section 73 of *SARA*, as well as to provide confidence in ministerial decision making under the "factors to consider" outlined in Section 34.1(1) of the *Fisheries Act*.

Offsetting measures are proposed in existing critical habitat, and therefore have the potential to cause harm to WCT protected under *SARA*. Although the ultimate outcome of the measures, if implemented effectively, may have benefits for some life stages of the population, other life stages may be negatively affected by either the undertaking of the work, or the outcome. For example, juvenile WCT are predicted to be particularly sensitive to perturbations in their environment. An assessment of whether the measures are expected to yield a net positive outcome will need to be conducted to determine how appropriate they are.

A detailed spatial layout of where habitat components will be affected due to overprinting by project components is not provided, but will be required. This includes but is not limited to precise areas of riparian habitat loss, areas impacted by installation of culverts, bridges, roads, and water discharge structures.

Based on the Project information provided to date, which includes large-scale habitat destruction including critical habitat, a high degree of uncertainty in multiple effects pathways predictions, and the conceptual nature of the proposed offsetting measures, DFO's opinion is that counterbalancing residual

effects with the goal of conservation and protection of fish and fish habitat, particularly WCT, will not be achieved. Further quantifying impacts based on the analysis presented here will require the Proponent to substantially increase the scale and scope of offsetting. The offsetting concepts currently proposed require substantial additional analysis in order to satisfy the offsetting policy and ensure their viability. Alternatively, the Proponent could reconsider Project design to reduce impacts on fish and fish habitat, which could reduce risk and uncertainty associated with the decision the Minister would be required to make when considering the issuance of an authorization under the *Fisheries Act* and *SARA*.

Recommendation 15: The Proponent should update the offsetting plan to appropriately characterize residual effects to WCT and counter-balance these impacts. The offsetting plan should be developed in consultation with relevant provincial agencies, potentially affected Indigenous communities, and DFO. The Proponent should address the following in the final plan:

1. Updated quantification of habitat impacts to reflect all riparian and aquatic habitat impacted by the Project.
2. Separate accounting for Gold and Blairmore creeks with clear alignment to offsetting proposed for each, and how those align with the RS-AP.
3. Appropriate assessments to ensure the benefits, feasibility, and sustainability of any offsetting measure. With respect to those currently proposed, the Proponent should:
    a. Undertake detailed geomorphic assessments at each proposed overwintering pool creation site to ensure the proper conditions are present to allow for the development and maintenance of deep pools without creating perturbations which could cause the destabilization of the channel either up or downstream of the constructed deep pools.
    b. Correlate proposed deep pool overwintering habitat locations to the predicted groundwater flux models to help determine the likelihood of success of the overwintering pools.
    c. Conduct field studies to determine with certainty that the braided section of channel acts as a fish passage barrier in a manner that limits the productivity or genetic connectivity of the Gold Creek WCT subpopulation.
    d. Complete a geomorphic assessment of the braided channels to determine the cause of the braiding and whether the conditions will continue to persist in the future, or if the conditions can be addressed to ensure that a single thread channel can be successfully established and will provided self-sustaining benefits in the long term.
    e. Undertake an assessment of the negative and positive impacts of each measure on each life stage of WCT, to determine whether a net positive outcome is expected.
    f. Complete an analysis of the features, functions, attributes of critical habitat gained by enhancement of riparian habitat that is additional to those that currently exist or that would develop without implementation of the measures.
4. Offsetting measures should be implemented and verified as functional before any impact occurs to pure WCT subpopulations.

5. The risk of locating offsetting measures within the zone of influence of the Project should be assessed given the potential for the Project to impact the offsetting if environmental effects predictions are exceeded.

4.5 Aquatic Monitoring Plan

The Proponent provides an AMP [Appendix 6.23-1 of Addendum 11 (CIAR #313)] that includes endpoints related to DFO's mandate including WCT population, WCT bioenergetics, calcite, hydrology, and ground-water surface water monitoring. The purpose of the AMP is to validate predictions related to residual effects and verify that mitigation measures are functioning. Missing from the purpose and framework is an intent to validate the HSCs used to predict impacts due to alterations in hydrology (section 4.3.5). This document outlines an appropriate adaptive management framework for various endpoints that reflect health of the aquatic ecosystem. Critically, however, not all endpoints have a specific trigger value that would initiate adaptive management, and it lacks detailed mitigation options and an assessment of their feasibility should these triggers be exceeded (identified previously by DFO in CIAR # 283 and 347). Pre-defined trigger values are fundamental to the functionality of an adaptive management plan, and given the lack of resilience to change expected from the aquatic ecology valued component, WCT, careful consideration of trigger values is required before an adaptive management plan can be considered complete.

Necessary for the process of defining thresholds is baseline data that captures natural variability. It is not clear from the information provided in the EIS that adequate baseline data has been collected to capture the natural variability of biotic or abiotic endpoints (section 4). Further, baseline data should be collected in a manner that allows before-after impact comparisons. It is not clear from the baseline study that adequate information has been collected to allow the Proponent to determine, at an appropriate scale, changes that occur as a result of the Project. Another study design feature that enables the detection of change are comparisons between impact and control sites. In the case of WCT, however, use of reference populations becomes challenging because of their sensitivity to perturbations (i.e. may be difficult to find a reference site that has similar factors affecting it), and their sensitivity to the sampling itself.

There are outstanding concerns that for many of the potential pathways of effects the impact to the population of WCT in either Gold or Blairmore creeks may be irreversible by the time changes in endpoints are discernable. For example, the Proponent mentions that their survey methods are likely to underestimate the actual abundance of fish per m^2 of habitat (section 4.1), but they do not discuss how this may impede their ability to detect change. Since the population estimates are low relative to actual, it is possible that impacts will occur to the actual number without becoming detectable within the range of their estimates, or that the amount of change will appear smaller than actual. Further, a high degree of variability between fish survey methods and stream reaches reduces the confidence that the methodology can provide an early enough detection of population level impacts to WCT. Due to the highly variable nature of biological data, similar concerns exists for endpoints related to food supply and fish condition (bioenergetics monitoring).

If the monitoring program were to indicate a change in an endpoint, it remains unclear whether there are technically feasible adaptive management options available that could be implemented before those changes caused an irreversible impact on WCT. Table 7.5-1 of the AMP details adaptive management options, but without enough detail to provide confidence that irreversible changes can be avoided. For example, the effects assessment for temperature did not include all relevant variables, and the monitoring program can only determine the endpoint of temperature change; it cannot determine which variable may be responsible for the change. The mitigation measure identified is additional riparian planting. However, if multiple, global variables (e.g. loss of upland vegetation, loss of riparian vegetation, and increased temperature due to altered hydrologic regime) all contribute to temperature changes in the aquatic environment, it is unlikely that riparian planting could be implemented at an adequate spatial and temporal scale to counteract these variables in a timely manner. Note that offsetting is not an appropriate adaptive management technique because factors considered when determining the adequacy of an offsetting plan, and whether it is appropriate to issue an Authorization under Section 35 of the *Fisheries Act* with *SARA* conditions, take into account the magnitude of impacts and how they may affect the local population. In the case of pure and near-pure WCT, additional offsetting would be considered a last resort, and would require a full re-assessment of the risk associated with authorizing additional harm.

Sampling to support monitoring of population endpoints, aquatic effects monitoring endpoints, and bioenergetics endpoints may require sampling that contravenes *SARA*, including but not limited to handling and tissue sampling. Testing and validating predictions, along with long-term monitoring on WCT populations represents a risk in itself to the population due to its limited size.

Recommendation 15: The Proponent should update and finalize the AMP and be reflected in the Follow-up Program requirements. The AMP should include verification of predictions and effectiveness of mitigation, including offsetting. The updated AMP should include but not be limited to the following:

- A framework for validating the WCT habitat suitability curves.
- An appropriate adaptive management framework that defines trigger thresholds for each endpoint identified in the AMP
- A description of the limitations of the baseline data used to define triggers, and what conservative approaches will be used to overcome them.
- Further assessment of adaptive management options, including a full discussion on the scenarios in which a given mitigation measure could prevent irreversible harm to WCT.
- Assessment of the cumulative risk over the timescale of the Project of all monitoring components that have the potential to impact WCT. Subsequently, the monitoring plan should be optimized and employ all avoidance and mitigation measures to reduce impacts to WCT to the greatest extent possible, and ensure survival and recovery of WCT are not jeopardized due to the Project's monitoring activities.

4.6 Closure and Reclamation

General

The Proponent has developed conceptual conservation and reclamation, and closure plans. The conceptual nature of the plan can provide flexibility for refinement, but also leaves a level of uncertainty as to the likelihood of success of the aquatic closure landscape.

The development of a stewardship program to address existing and on-going effects on water quality and fisheries in Gold Creek would be beneficial. However, a Gold Creek Stewardship Program will only be viable if impacts to WCT from the Project are better defined, as outlined in this submission, and avoided or mitigated using effective, tested and proven methods.

This submission has also outlined various uncertainties and limitations associated with the prediction of effects to fish and fish habitat including those that intersect with other disciplines such as hydrology, hydrogeology, and surface water quality. These uncertainties and limitations carry into the reclamation and closure plans. A successfully reclaimed closure landscape depends on robust modelling that has been validated and refined based on the lifespan of monitoring collected on-site, which is then used to inform aspects such as water management plans. A high degree of uncertainty remains with the closure landscape and the Proponent's ability to effectively avoid further impacts to WCT due to the uncertainty with the characterization and prediction of effects detailed in this submission. Of note to DFO is the long-term management of the surge ponds post-closure to mitigate selenium effects, potential changes in groundwater discharge to Gold Creek (discussed further below), the end pit lake and any potential changes in flow to Blairmore and Gold Creeks, and recreational access.

If the Project is approved, robust monitoring and adaptive management of the site through to post-closure will be required to ensure the survival and recovery of WCT is not jeopardized.

Recommendation 16: The Proponent should update the conservation and reclamation, and closure plans with refined modelling and predictions related to the aquatic closure landscape to ensure the management and monitoring requirements are well-defined. The closure landscape should be designed to avoid and mitigate impacts to WCT, and align with the RS-AP for WCT. An adaptive management plan should be developed that defines thresholds and triggers for further action. The Proponent should consult with all applicable regulators, including DFO, throughout planning, operations, and closure to design, implement and monitor the closure landscape. Indigenous groups should be consulted with respect to the closure landscape and their exercise of rights.

Impacts to baseflow

The Proponent has shown that the groundwater system will be permanently altered during mining, which will in turn result in a permanent alteration of the baseflow discharge to the surrounding creeks – particularly Blairmore Creek. Baseflow within the creeks plays a critical role in both the winter and summer months to support WCT populations. During mine operations, discharges from the sedimentation ponds are used for offsetting these baseflow reductions; however, the closure plan

indicates these ponds will be decommissioned at the end of mine (EOM) life, leaving the outflow from the saturated fill zones (SFZ) as the sole long-term baseflow mitigation measure after closure. Since the portions of Blairmore Creek that are expected to be the most severely impacted by baseflow reductions are located upstream of the SFZ outfall point, these impacted reaches do not appear to receive any mitigation beyond the EOM life, despite the permanent and irreversible alteration anticipated after closure.

The Proponent has indicated that the excavation and dewatering of the pit will result in a drawdown of the hydraulic head in the surrounding subsurface geologic materials, the effects of which will spread outward as the cone of depression increases with the pit depth and with time [5.3.1 (CR #3)]. Based on the numerical model predictions, the EOM drawdowns are expected to range between 30 m and 430 m, extending below some of the tributaries of Blairmore and Gold Creeks [5.3.2.2 and Figure 5.3-1 (CR #3)]. Predicted drawdowns for the long-term closure are "similar in magnitude as for the EOM with the maximum drawdown predicted at 388 m and the drawdown cone similar in extent" [5.3.2.2 and Figure 5.3-5 (CR #3)]. Notably, the groundwater drawdowns are considered to be irreversible and persist in-perpetuity following closure of the Project as "part of the natural system will be physically removed during mining" [EIA Section A.10.3 (CIAR #42)] – an outcome that would seem to contradict the benefits claimed by the Proponent to develop the Project in a manner "that allows the full rehabilitation of the Grassy Mountain area at the conclusions of the project in a fashion that is much more sustainable long term than prior mining in the area has currently left it" [EIA Section A.2.7 (CIAR #42)].

The persistence of a permanent groundwater drawdown cone after closure raises concerns with the corresponding persisting effects to the surrounding streams because of the permanent alteration of groundwater discharge (baseflow). Notably, groundwater discharge plays an important role in supporting the surrounding creeks, their tributaries and a number of small springs and groundwater discharge points within the LSA [EIA Section E.3.2.5 (CIAR #42)]. The permanent effect to groundwater discharge to the streams is indicated by the Proponent through their groundwater modelling analysis [5.3.2.2.3 (CR #3)]. CR#3 quantifies the changes in groundwater discharge to the streams (baseflow) at select locations along the main stems of Blairmore Creek (5 locations) and Gold Creek (5 locations), with predicted EOM reductions in baseflow as high as 30% and 19% in Blairmore and Gold Creek, respectively, dropping down to 11% and 18% for the two streams under long-term closure (LTC). These locations are downstream of the project, and represent attenuated changes to baseflow, whereas mapping of predicted reductions in baseflow along all of the stream reaches shows that average baseflow reductions in the tributaries of both Blairmore and Gold Creeks are indicated as exceeding 50% in both the EOM [Figure DFO-R2-20-5 (CIAR #89)] and LTC scenarios [DFO-R2-20-6 (CIAR #89)]. The above establishes that not only will the Project have a permanent and irreversible impact on the groundwater flow system within the LSA, but the alteration of the groundwater flow system will have a corresponding permanent impact on the baseflow regime of the adjacent Blairmore and Gold Creeks.

Groundwater influx is critical to maintaining WCT in Blairmore and Gold Creeks as it not only provides the physical medium that fish need to live, it also provides important thermal regulation during summer and winter. The importance of providing thermal refuge during summer is well documented (section

4.3.3) and has been identified as critical to the survival of fish throughout the winter. Overwintering habitat has been identified as limiting habitat in Gold and Blairmore Creeks [Offsetting Plan (CIAR #89)], therefore elevating their importance. Groundwater flux is an important component in maintaining overwintering habitat free from anchor and frazil ice, which is recognized in CR #6, Aquatic Ecological Effects Assessment, which states: "Stream temperatures during overwintering already reach near-freezing temperatures. A further decrease in temperature could be problematic in Gold Creek given flows are projected to decrease, which could accentuate the freeze-up of overwintering habitat. Frozen conditions can further exacerbate already stressful conditions with the potential of frazil ice, which can damage gill tissues, and the availability of invertebrate food sources could be compromised (Bradford and Heinonen 2008). The potential effects to overwintering will ultimately be manipulated by the contribution(s) of groundwater influx during mine operations once water management features are implemented on site as the ongoing maintenance of WCT overwintering habitat may be largely determined by this factor (Brown and MacKay 1995). Therefore any reduction in groundwater influx during the winter could have a profound impact on the survival of WCT, particularly when large number of fish maybe congregating in a few individual pools."

To mitigate these impacts during the operation of the mine, the Proponent proposes to offset the reductions in baseflow (groundwater discharge) in Blairmore and Gold Creeks through the management and release of water from the five peripheral sedimentation ponds [5.3.2.2.3 (CR #3)]. Discharge locations from the sedimentation ponds are shown on Figure C.5.3-1 through Figure C.5.3-5 of the EIA Section C (CIAR #42). DFO notes that multiple reviewers and information requests have questioned the validity of such an approach, raising concerns over the availability and quality of sedimentation pond water [e.g. AER-6 and AER-19 (CIAR #89), 5.25 (CIAR #251), 6.13 and 6.17 (CIAR #313), 7.3 (CIAR #360)] and the adequacy of using sediment pond water discharge as a substitute for baseflow, particularly with respect to the role of temperature in aquatic health [e.g. 5.20, 5.21, 5.22, and 5.24 (CIAR #251), 6.15 (CIAR #313)].

Notwithstanding the above concerns with the baseflow mitigation strategy during the operation of the mine, it is DFO's understanding that the Closure Plan involves the eventual decommissioning of the sedimentation ponds and the discontinuation of managed flow augmentation (i.e. storage and, when necessary, diversion of water of suitable quality to sedimentation ponds for discharge as required to meet instream flow needs). While passive discharge of water from the site to Blairmore and Gold Creeks will persist from the SFZ and, eventually, the flooded end-of-mine pit lake, respectively, the Proponent has not addressed how these flows have sufficiently offset/mitigated the long term/permanent impacts to baseflows within the two systems; specifically with respect to streamflow volumes, timing and thermal regimes.

In the case of Blairmore Creek, it is DFO's understanding that the water routed through the proposed SFZs will be discharged to Blairmore Creek via an outlet point corresponding to that of Plant Site Sedimentation Pond (SSPP) [Figure C.5.3-5 of the EIA (CIAR #42)]. This will include the water intercepted by the water management infrastructure around the north rock disposal stockpile (Northwest Surge Pond and ditching), which will remain in place after closure until such a time as water quality

parameters allow for its eventual decommissioning [EIA Section C.5.4 (CIAR #42)]. Notably, the SFZ discharge location near the SSPP is situated downstream of the reaches where baseflow reduction impacts on Blairmore Creek are predicted to persist after site closure [DFO-R2-20-6 (CIAR #89)], leaving approximately 3 km of the main stem of Blairmore Creek (not including tributaries) where alteration of the baseflow regime will be permanent and without mitigation.

The southwest surge pond and west sedimentation pond will be decommissioned by EOM; the latter of which provides supplemental flows to Blairmore Creek upstream of the SSPP during the life of mine. While the removal of this pond after closure allows the reclaimed hillslopes to contribute directly to Blairmore Creek [EIA Section C.5.4 (CIAR #42)], these discharges would be expected to contribute more variable and more periodic runoff flows as opposed to the sustained baseflows provided by groundwater discharge – particularly important during low flow periods in the fall and winter when groundwater discharge is expected to make up a significant portion of the stream flow. It is also noted that any "tributaries" running off the reclaimed mine site that form subsequent to the mine closure would likely fall partially or wholly within the future groundwater drawdown cone of the LTC site, and therefore also be subject to the same groundwater impacts afflicting other natural stream reaches adjacent to the Project.

We recognize that predictions of post-closure flows off the site towards Blairmore Creek were assessed in CR #4 using the Water and Load Balance Model [Appendix 10B of the EIS (CIAR #42)]; however, it is noted that the groundwater impacts to baseflows predicted in the groundwater modelling (CR #3) are not directly considered in this analysis, based on the description of the groundwater component of the water balance model provided in Appendix 10b, Section 2.4 (CIAR #42) and the responses provided in Addendum 8, B.14 (CIAR #89). Instead, the water balance model relies upon runoff yield coefficients which have no way of accounting for the non-linear and seasonal sensitivities of the groundwater discharge regimes to the residual drawdown influences predicted for the post-closure pit (evaluated in CR #3).

As such, the proposed closure plan does not appear to account for the need to provide long-term mitigation of the persisting and irreversible baseflow reductions caused by the Project, particularly with respect to the predicted impacts on Blairmore Creek where lasting reductions in groundwater discharge are predicted along the main stem of the creek which supports a population of near-pure WCT, as discussed in section 3.2.

Recommendation 17: The Proponent should address how the permanent reduction in baseflow due to the alteration of groundwater discharge regimes in Blairmore and Gold Creeks will be accounted for in the Closure Plan and residual effects assessment to WCT. A detailed assessment should be undertaken to demonstrate the validity of the closure plan with respect to the proposed mitigation strategy for post-closure baseflow impacts that directly accounts for the effects of the persisting groundwater drawdown cone on discharge to the streams and ultimately on fish and fish habitat. Contingency provisions should be developed to consider the long-term operation of the surge ponds and re-direction of intercepted surface flows from the stockpiles to the SFZs for an extended period after closure before

water quality testing indicates they can be decommissioned (e.g., a conservative assumption could be to evaluate the impacts of keeping these systems online permanently).

5 Cumulative Effects and Other Factors

This section provides DFO's analysis of the Proponent's cumulative effects assessment, and expands on other relevant factors that have the potential to affect WCT specific to the Project and the region.

5.1 Cumulative Effects

As per the EIS Guidelines (CIAR #11), the Proponent prepared a cumulative effects assessment, which was subsequently updated in Addendum 8 (CIAR #89) based on federal guidelines and requests from the Agency. WCT was identified as a valued component (VC) that a cumulative effects assessment should be conducted on.

The Proponent summarizes their effects assessment provided in updated CR #6 (CIAR #44) as rationale for the residual effects that would be considered as part of the assessment. Section 5.3 in this submission provides an analysis of the residual effects assessment of the use of no, secondary, and primary linkage pathways. Specifically, the assessment of residual effects of some of the secondary linkages has uncertainties, assumptions, and data gaps that likely underestimate the effects on WCT, resulting in their removal from the final determination of residual effects of the Project on WCT. This assessment of residual effects is the basis for the cumulative effects assessment, thus introducing and compounding uncertainty in the cumulative effects assessment.

The Proponent considered the analysis in the context of the six primary threat categories to WCT in the RS-AP, which is required as per Section 6.6.3 of the EIS guidelines (CIAR #11). Invasive species are considered a primary threat and includes non-native species like rainbow trout and brook trout that hybridize and/or compete with WCT, as well as pathogens like whirling disease. While the Proponent included an analysis of non-native fish species, whirling disease was overlooked as a potential threat that could interact with the Project. Whirling disease was a potential threat identified in the recovery plan, and was confirmed an additional threat to the species in the COSEWIC 2016 assessment after whirling disease was detected in Alberta. Whirling disease has now been detected in four major watersheds in central and southern Alberta, including watersheds occupied by WCT. Cutthroat trout are particularly susceptible to whirling disease (COSEWIC 2016). Evidence from the province of Alberta in 2019 suggests a decline in rainbow trout populations in the Crowsnest River. High levels of the whirling disease parasite were found in the Crownsest, as well as clinical signs and elevated mortality in young-of-year rainbow trout. Blairmore and Gold Creeks subpopulations are directly adjacent and connected to the Crowsnest, which puts them at higher risk. While there are barriers that may limit the spread, angling is popular in the area. This increases the risk of transmission if anglers are not properly cleaning and drying their equipment (see Section 5.3.1 for additional comments on recreational access). There are other factors that would be required for establishment of the intermediate host like the appropriate substrate. This may limit its transmission in these high elevation streams, but whirling disease has the

potential to become an obstacle for WCT recovery if restoration of mainstem fluvial populations is considered. This would further isolate populations in headwater reaches (COSEWIC 2016).

The potential effects that whirling disease is having, or may have, on WCT populations in Alberta is an important factor to consider in the cumulative effects facing the species (COSEWIC 2016). Whirling disease may further restrict recovery actions to headwater reaches, while the Project impacts are concentrated in these headwater reaches that may become increasingly important. The Proponent appears to have overlooked that the two may act in concert with one another.

Climate change is also identified as one of the six primary threats to WCT. The challenges climate change poses to WCT were briefly discussed, but the extent of analysis was limited to a summary of existing information. The Proponent did not consider climate change explicitly having the potential to interact with Project impacts in their cumulative effects assessment. The RS-AP and RPA for WCT (DFO 2009) provides a summary of the climate change threat to WCT, concluding that climate change poses a significant threat to long-term survival and recovery of pure WCT. The potential impacts of climate change on WCT (which include changes in water temperature, stream morphology, and hydrology) overlap significantly with effects of the Project on WCT. This source of uncertainty and risk is significant given the potential undefined additive effect to WCT during the life of the Project and into post-closure.

The base case includes activities associated with historic mining, timber operations, recreational use, the existing dam on Gold Creek, and ranching activities as affecting the current VC condition, concluding that this accounts for any cumulative changes to the WCT VC measurement indicators (habitat quantity and suitability, survival and reproduction, and relative abundance and distribution of WCT).

This characterization of the base case acknowledges the contribution of these factors but seems to ignore their cumulative outcome that resulted in the federal listing decision under *SARA* in 2013. The base case does not reflect the cumulative effect on the species that has already occurred.

The Proponent provides rationale for including only timber harvest as a future activity with the potential to cumulatively interact with the Project. Because it will continue with or without the Project, the Proponent determined that cumulative effects are expected to be similar in either scenario and therefore did not carry it forward in the assessment. This is not a well-supported rationale as the continuation of other activities on the landscape at any rate is the fundamental basis for cumulative effects assessment.

Similar to timber harvest, recreational use and grazing will continue on the landscape in the future. Despite this, the Proponent excluded these activities from future conditions without rationale. The Proponent notes that recreational use is prevalent throughout the Blairmore and Gold Creek watersheds with multiple locations of off-highway vehicle (OHV) fording on both Gold and Blairmore creeks (CIAR #89). Photo evidence is provided in Section F of the EIS (CIAR #42). This is prevalent throughout the range of WCT; there are designated trail systems, but recreational users are using an expanse of undesignated trails especially in peak recreation periods (COSEWIC 2016). OHV registration increased in the province from 2004 to 2016, but while this trend is important, it likely underestimates OHV use based on failure to license being a large portion of OHV regulation violations (Farr *et al*. 2017).

In 2017, vehicles being operated and parked on the bed, shore and/or in the water of streams, rivers, lakes and wetlands; and random trails that are well established and used by many vehicles causing significant environmental damage were cited as chronic challenges on Alberta's public lands (Alberta Government 2018).

Both grazing and recreational use, particularly OHV use, increases stream bank erosion and sedimentation with consequences for water quality and fish (Alberta Government 2018, COSEWIC 2016, Ouren *et al*. 2007). Short, frequent, intense pulses of sedimentation are often the hallmarks of chronic cattle access and OHV use. Fording locations may have significant pulses numerous times throughout the year, potentially at key bioperiods. This in combination with even a few mine-associated exceedances related to accidents and malfunctions, and other physical activities on the landscape have the potential to result in chronic and uncertain effects on WCT. Given the certainty of the continuation of these activities, the Proponent should have included them in future conditions.

The Proponent concludes that past activities have contributed to ongoing adverse effects to WCT, but that opportunities to mitigate or counterbalance these cumulative interactions are afforded through the development of the Project. Some reclamation of historic mining seems reasonable, while to be able control, mitigate, and/or counterbalance effects to WCT from timber operations, recreational use, ranching, and climate change is unrealistic.

The Proponent provides an overview of the mitigation approach including project design, mitigation and offsetting, and incorporation of stakeholder feedback. It appears that the Proponent is confident in the complete effectiveness of the proposed mitigation measures, and cites improvements in water quality in the Local Study Area (LSA) that will occur as a result of the capture and treatment mitigation. According to the Proponent, residual effects to fish will be balanced and WCT condition improved as a result of the implementation of the Fisheries Offset Plan. This submission details numerous assumptions, gaps and uncertainties in the mitigation strategies that decrease confidence in the predicted effectiveness of the mitigation.

For example, the Proponent reports that TSS levels in both Blairmore and Gold Creeks are below detection limits in all seasons except summer (CR #5). The Proponent concludes that considering the low concentration of TSS in both creeks coupled with effective mitigation, TSS is not expected to interact cumulatively with the Project [IR 5.31 (CIAR #251)]. The rationale is based on standard guidelines for the protection of aquatic life and completely effective mitigation, but does not consider the "clean water" and "sediment/silt free gravel substrate" attributes of WCT critical habitat required and common across all life stages. Accidents and malfunctions, particularly related to erosion and sediment control, are not uncommon and are not likely to be completely avoided over the 27 year operation period of the mine and through to closure. While the Proponent has confidence in their ability to effectively mitigate, the assumptions, gaps and uncertainties in the mitigation strategies detailed in our submission do not provide sufficient confidence in the effectiveness of mitigation in general. In this particular case, the degree of confidence required is high because of the sensitivity of WCT.

The Proponent concludes that the residual effects from the Project in combination with historic/legacy and present stressors are not predicted to be significant enough to affect WCT populations. In addition,

the Proponent predicts that irreversible changes are not expected at the population level nor will resilience of WCT decrease. A precautionary approach would have included a quantitative analysis of how past, existing and future activities may interact with the Project. Without this type of analysis, there is no scientifically defensible basis for this conclusion or thresholds defined to identify what would be considered significant.

The robustness of the Detailed Offsetting Plan [Appendix B1 (CIAR #89)] is anticipated to support these conclusions and to address limiting factors of these WCT subpopulations. Section 4.4 identifies the limitations and gaps DFO has identified with the Detailed Offsetting Plan. DFO cautions against relying on the Detailed Offsetting Plan as it must be finalized, constructed and proven effective before a conclusion could be made that the offsetting can fully counterbalance and exceed the impacts, and meet Section 73 preconditions of *SARA*.

Overall, the cumulative effects assessment does not have a quantitative basis and carries forward and compounds assumptions, gaps and uncertainties that DFO has identified in related effects analyses of the Project. The sensitivity of WCT and the risk to WCT associated with erroneous analyses necessitates a precautionary approach. Due to these fundamental gaps and the other limitations detailed here, the characterization of the potential cumulative effects on WCT are likely inaccurate and the effects underestimated.

Recommendation 18: The Proponent should undertake a quantitative cumulative effects assessment. It should include consideration for the status of WCT; refined residual effects of the Project; appropriate consideration for other potential stressors including but not limited to whirling disease, timber operations, recreational use, grazing, and climate change; and reasonable predictions for the ability of the Proponent to effectively mitigate impacts in combination with other stressors.

5.2 Coal Development Policy for Alberta

A Coal Development Policy for Alberta (Coal Policy) established in 1976 was rescinded effective June 1, 2020. This lifts restrictions on exploration and development in former categories 2 and 3 lands, which encompass a portion of Alberta's east slopes and the range of WCT, bull trout, and Athabasca rainbow trout. A recent assessment of threats to at-risk salmonids concluded that WCT has the lowest ongoing and future threat levels related to habitat loss and alteration, relative to the other at-risk salmonids in the Rockies, due to their location in headwater streams where future development is either not likely or not permitted (Sinnatamby *et al*. 2020). While this may have been valid at the time of publication, the rescinding of the Coal Policy may encourage additional development proposals in the range of WCT that have the potential to increase ongoing and future threat levels.

5.3 Water Quality

As per the 2014 Order Designating the Minister of the Environment as the Minister Responsible for the Administration and Enforcement of Subsections 36(3) to (6) of the *Fisheries Act*, Environment and Climate Change Canada administers Subsections 36(3) to (6) of the *Fisheries Act*, which prohibit deposit of deleterious substances into waters frequented by fish, unless authorized by regulations under the

Fisheries Act or other federal legislation. As such, DFO relies on ECCC for its expertise in this respect. However, where a species at risk is identified, DFO must also must consider that the deposit of a deleterious substance, in this case selenium and the precipitation of calcite, may result in impacts to species at risk and survival and recovery of a species. While we do not possess expertise in selenium or calcite precipitation, the potential effects of both on WCT overlap with the mandates of both ECCC and DFO in this respect. This compels DFO to comment within the context of uncertainty of potential effects to WCT that may affect survival and recovery, while relying on ECCC's expertise.

Calcite

The potential for calcite precipitation was identified as a secondary effect pathway. The Proponent completed a qualitative assessment of calcite precipitation [Appendix A of Appendix 10b of Appendix 10 (CIAR #44)]. The proponent concludes that the potential for calcite precipitation is low because the presence of calcite precipitate was not observed in baseline conditions of both Gold and Blairmore creeks. This conclusion is not well-supported as neither creek currently receives water significantly affected by waste rock. In addition, the Proponent notes that the natural waters appear to have no capacity to prevent calcite precipitation by dilution so active calcite monitoring, mitigation, and adaptive management is required (CR #6). The Proponent commits to including calcite precipitation in the site-wide water quality monitoring program and provides a general explanation of the mitigation strategy prior to release (CIAR #89). Treatment options including active treatment, measures to remove alkalinity, a passive cascade system, and anti-scalants are mentioned in the qualitative assessment but evidence of their feasibility and effectiveness is not provided. The potential effects on fish and fish habitat of implementing these mitigation options were not assessed.

The potential effects of calcite precipitation on WCT habitat are highly uncertain and potentially not insignificant given the isolated nature of the populations and the potential extent of downstream effects. Preliminary work completed in the Elk River watershed in BC downstream of Teck Coal Limited coal mines, indicates that there may be a negative relationship between calcite and egg incubation conditions and redd density (Hocking *et al*. 2019, Wright *et al*. 2017). The work is preliminary and conclusions cannot be drawn from it due to data limitations and other variables that may be contributing. However, it provides further support for the need to exercise the precautionary principle, in combination with the sensitivity of WCT and requirement to understand the effects of the Project on WCT, their survival and recovery.

The qualitative assessment the Proponent completed is insufficient to understand the potential effects of the Project on WCT. The conceptual level of the assessment of effects and mitigation leaves a level of uncertainty that is inappropriate in the case of impacts to WCT. The level of assessment the Proponent performed may be appropriate if the potential for effects due to site-specific factors was low, resulting in low overall risk. This is not the case. DFO supports the inclusion of calcite precipitation in the AMP and Follow-up Program. A comprehensive assessment of the potential effects and mitigation, including testing and validation, is foundational to the development of a monitoring program. Without it, monitoring will only confirm that unaccounted for and potentially irreversible impacts to WCT have

occurred. A significant length of time may pass before effects are evident given the natural variability in populations and challenges in estimating population level effects.

Recommendation 19: A quantitative assessment of the potential for calcite precipitation and its effects on WCT habitat should be completed. Based on the results of the analysis, a robust mitigation strategy should be developed, tested and proven effective prior to implementation. Any residual effects should be accounted for in the final assessment of impacts to WCT and offsetting required, and described in combination with other residual effects in the context of overall potential effects on WCT survival and recovery. A comprehensive monitoring and adaptive management program should be developed and in included in the AMP and Follow-up Program to define thresholds and triggers for action to prevent effects beyond those predicted.

Effects of water quality on food supply

Section 6.3.1 of the EIS Guidelines (CIAR #11) required the Proponent to identify effects on primary and secondary productivity of waterbodies, including a discussion of sensitive species in benthic invertebrate communities and how mine-related effects may affect fish food sources.

The Proponent concludes that there will be no residual effects from changes in water quality or food sources, including selenium, to WCT. The "Third National Assessment of Environmental Effects Monitoring Information from Metal Mines Subject to the Metal Mining Effluent Regulations" (ECCC 2015) identified that effluent from metal mines included in the assessment is causing effects to fish and fish habitat (benthic invertebrate community structure). The assessment is specific to metal mines but does share common effluent constituents with the Project including selenium and sulphate, both of which were included in the list of primary and possible causes of effects in the assessment. The assessment of impacts to food sources does not appear to account for changes in water quality due to effluent discharge. DFO notes that there are differences in the effluent constituents between metal and coal mines. Given the results of the above referenced assessment and the overlap with potential effects to WCT food sources, DFO notes the uncertainty regarding the predicted impacts to food sources should be acknowledged and recommends that the final offsetting plan include an updated analysis of residual effects to food sources that accounts for potential long-term changes due to water quality specific to feeding habits and diet of WCT.

Recommendation 20: DFO recommends that the final offsetting plan include an updated analysis of residual effects to food sources that accounts for potential long-term changes due to water quality specific to feeding habits and diet of WCT. The amount of offsetting required should then be updated to account for this, if required.

Recommendation 21: DFO recommends that the follow-up monitoring program be designed to verify the predictions related to benthic invertebrate communities and any consequential impacts on WCT food sources.

6 Conclusion and Summary of Recommendations

The proposed Grassy Mountain Coal Project will result in the destruction or alteration of large amounts of aquatic and riparian habitat in Blairmore and Gold Creeks. Habitat impacted in Gold Creek is designated critical habitat required for the survival and recovery of threatened WCT, while the habitat in Blairmore Creek supports a near-pure population of WCT. The recovery of near-pure populations of WCT supports the population and distribution objectives identified in the RS-AP required to recover the species. While the Proponent has provided an analysis of the effects to fish and fish habitat from blasting activities, changes in water temperature, change in food supply, changes in hydrology, changes to sediment supply and transport, and direct loss of aquatic and riparian habitat, DFO has identified significant limitations, gaps, and uncertainties with the assumptions and modelling used to derive the predictions and consequently, the identification of residual effects to WCT. Additionally, the approach to the assessment of effects was not in line with the precautionary principle and did not reflect the sensitivity of the species at risk. Given these factors, the Proponent has likely significantly underestimated the impacts to WCT.

The Project will result in impacts to fish and fish habitat that cannot be mitigated. The Proponent has developed an offsetting plan as the primary means to counterbalance the residual effects identified. Based on the offsetting plan's conceptual nature, technical gaps, and misalignment with DFO's policies, DFO's opinion is that counterbalancing residual effects with the goal of conservation and protection of fish and fish habitat, particularly WCT, will not be achieved. Appropriately quantifying impacts will require the Proponent to substantially increase the scale and scope of offsetting. The offsetting concepts currently proposed contain a high degree of uncertainty due to the specialized adaptations of the species and the complexity of their habitat. The offsetting concepts require substantial additional analysis in order to satisfy the offsetting policy and ensure their viability. In addition, the Proponent would be required to demonstrate functional habitat that protects the valuable genetics of the populations prior to impacts. The Proponent's current proposal does not include offsetting that is proven fully functional prior to impacts.

The monitoring proposed and required to verify predictions and effectiveness of mitigation, including offsetting, is itself a risk to WCT due to the limited population size. This prevents robust monitoring and contingency from ameliorating uncertainties because the monitoring itself may have an impact to the population. Further, it is unlikely that the population can withstand the changes that would occur before contingencies could be implemented.

The Project will require the issuance of a *Fisheries Act* Authorization with *SARA* conditions for impacts to WCT and critical habitat. Prior to issuing a permit, *SARA* requires that the Minister be of the opinion that subsection 73(3) preconditions be met including that the activity will not jeopardize the survival or recovery of WCT. The Proponent has made an attempt to assess direct and indirect effects on the survival and recovery of WCT, and DFO has identified several limitations, gaps, and concerns as set out in the submission. The Proponent has also attempted to assess the direct and indirect impacts to the RS-AP and how the population and distribution objectives would be affected. DFO disagrees with the

assessment that it will have a positive effect on WCT, supporting recovery and persistence beyond the current baseline.

Currently, insufficient critical habitat has been identified in the RS-AP to fully achieve the population and distribution objectives for WCT. The isolated nature of the pure-strain populations of WCT means that risk to a given population equates to risk to the population as a whole. This is due to the requirement of drawing on existing populations to re-establish WCT in other areas of the range. While important progress on recovery initiatives has been made, they have not yet resulted in the re-establishment of genetically pure populations of WCT. In addition, WCT continue to face many threats to their survival, including habitat degradation, climate change, and lack of available habitat due to risk of introgression with non-native species.

Based on these factors and the information available to date, it is unlikely that the subsection 73(3) preconditions can be met for the Project. In addition, DFO is of the opinion that the Project has the potential to result in significant adverse effects to the aquatic ecology valued component, WCT.

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8 Appendices

8.1 Summary of Recommendations

Recommendation 1: The Proponent should conduct an effects assessment with associated evaluation criteria for the WCT valued component that is based on life history components of the species, taking into consideration the broader context within which the remaining populations exist, and the potential contribution of the affected populations to re-establish genetically pure populations within their native range, as per the RS-AP.

Recommendation 2: The Proponent should develop an access management plan to ensure the public and employees do not have increased access to angling opportunities within the LSA as a result of mine infrastructure and access privileges, unless access is granted for exercising Indigenous rights. The plan should be developed in consultation with the appropriate provincial agencies, and Indigenous communities to avoid, mitigate, and monitor additional access by recreational users to the extent that is within the Proponent's control, while respecting the exercise of rights of Indigenous communities. The Proponent should align construction, operations, and closure plans with existing and future land use and watershed management plans.

Recommendation 3: A quantitative assessment of the potential effects of blasting on WCT should be undertaken including but not limited to the destruction of habitat, mortality, harm, and behavioral changes. The assessment should be informed by recent research and publications, and include considerations for local habitat conditions (e.g. substrate type, water depth), fish species (particularly WCT) and life stage likely to be affected (e.g. body mass), frequency, timing, and depth and setback distances of proposed blasting activities. The results should be used to develop a site-specific mitigation

and monitoring plan to verify the accuracy of predictions and effectiveness of mitigation, and included in the follow up program. The offsetting plan should be updated to account for any predicted residual effects.

Recommendation 4: The Proponent's model to predict changes in water temperature should be updated to include all relevant variables that may affect the temperature of water entering Gold and Blairmore Creeks, and their tributaries. Additional variables may include but not be limited to vegetation loss, increased temperature of water from water management structures, and effects of climate change on air/groundwater temperatures. The offsetting plan should be updated if residual effects are predicted.

Recommendation 5: Prior to construction, the Proponent should identify adaptive management options to be implemented should monitoring indicate that stream temperatures approach trigger values. The Proponent should perform an analysis of their likely effectiveness and the feasibility of implementation considering that stream temperature changes may be caused by multiple activities across the site.

Recommendation 6: The Proponent should update the AMP to define how the temperature monitoring program will verify changes to temperature are within WCT tolerance or natural range throughout the available habitat. The follow up program should include verification of the accuracy of water temperature predictions and effectiveness of mitigation.

Recommendation 7: The Proponent should conduct a detailed assessment of locations where food drift may be reduced due to loss or alterations in aquatic or riparian habitat, or changes in flow. The locations should be cross referenced with habitat suitability in those areas. Subsequently, the effects assessment, residual effects conclusion, and offsetting plan should be updated to reflect the results, if required. The assessment should be based on a detailed project design understanding, a comprehensive literature review, and conservative assumptions to account for lack of site specific data. Residual effects conclusions should take into account the sensitivity and lack of resiliency of the WCT subpopulations affected. Any areas of predicted loss should align with sampling locations defined in the AMP to verify predictions.

Recommendation 8: The Proponent should update the modelling analysis to assess the impact to the hydrologic regime at a temporal scale suitable to the assessment of fish and fish habitat, in particular WCT. Future modelling should simulate stream flows at a monthly timestep (as a minimum), incorporating monthly variability to better estimate both low and high flow periods. Hydrologic processes and components required to accurately capture the streamflow response to dry and extreme dry periods should be incorporated into the model. Analysis nodes should be included at key tributaries to allow project impacts to be assessed on low order, headwater streams.

Recommendation 9: DFO recommends that the Proponent define low flow (ecosystem baseflow) thresholds that are required to maintain habitat functionality. The proponent should describe how streamflow reductions below set thresholds will be mitigated, particularly under natural low flow conditions. A reference gauge approach to estimate the required augmentation under low flow conditions should be employed.

Recommendation 10 : The Proponent should include a sampling methodology that will verify the habitat suitability predictions in the Aquatic Monitoring Plan (AMP).

Recommendation 11: The Proponent should update the changes in hydrology effects assessment to incorporate updated hydrologic modelling and instream flow needs. The analysis should be precautionary and conservative, incorporating DFO's Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada (2013) and accounting for all habitat destruction and alterations associated with flow alterations. The offsetting, AMP, and Follow-Up Program should be updated, as required.

Recommendation 12: The Proponent should assess the potential impacts to WCT, fish habitat, and critical habitat as a result of impacts to sediment supply associated with the overprinting of potential sediment sources in Gold and Blairmore creeks. This may include but not be limited to a sediment budget that considers baseline, operational, end of mine, and long-term closure conditions. Subsequently, the WCT effects assessment, mitigation measures, offsetting plan, and significance assessment should be updated, as required. The AMP and Follow-up Program should include monitoring to verify the accuracy of the predictions and effectiveness of mitigation.

Recommendation 13: The Proponent should incorporate hydrologic changes from the WMP into the sediment transport analysis and evaluate potential impacts to the magnitude and frequency of sediment transport for the entire flow regime using daily flow data. The analysis should be used to assess potential impacts to channel-maintenance flows and the magnitude, frequency, and duration of spawning gravel transport, and to assess potential impacts to channel morphology and sediment transport for post-closure conditions. The WCT effects assessment, mitigation measures, offsetting, and significance assessment should be updated, as required.

Recommendation 14: The Proponent should undertake a detailed analysis of the ability of the riparian areas in the vicinity of Gold Creek to support the features, functions, and attributes of critical habitat defined in the WCT RS-AP. A similar analysis should be applied to Blairmore Creek given the potential to support recovery objectives in the RS-AP. This analysis should consider the timescale of the Project such that potential future ability of riparian to support features, functions, and attributes is accounted for, including the potential for maturation of riparian areas, and the lateral migration of watercourses that may expand the range of vegetation that has the potential to contribute. Guidance on how to identify riparian habitat capable of supporting life history processes can be found in this recent publication: "Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels" (Caskenette *et al.* 2020).

Recommendation 15: The Proponent should update the offsetting plan to appropriately characterize residual effects to WCT and counter-balance these impacts. The offsetting plan should be developed in consultation with relevant provincial agencies, potentially affected Indigenous communities, and DFO. The Proponent should address the following in the final plan:

3. Updated quantification of habitat impacts to reflect all riparian and aquatic habitat impacted by the Project.

4. Separate accounting for Gold and Blairmore creeks with clear alignment to offsetting proposed for each, and how those align with the RS-AP.
6. Appropriate assessments to ensure the benefits, feasibility, and sustainability of any offsetting measure. With respect to those currently proposed, the Proponent should:
    a. Undertake detailed geomorphic assessments at each proposed overwintering pool creation site to ensure the proper conditions are present to allow for the development and maintenance of deep pools without creating perturbations which could cause the destabilization of the channel either up or downstream of the constructed deep pools.
    b. Correlate proposed deep pool overwintering habitat locations to the predicted groundwater flux models to help determine the likelihood of success of the overwintering pools.
    c. Conduct field studies to determine with certainty that the braided section of channel acts as a fish passage barrier in a manner that limits the productivity or genetic connectivity of the Gold Creek WCT subpopulation.
    d. Complete a geomorphic assessment of the braided channels to determine the cause of the braiding and whether the conditions will continue to persist in the future, or if the conditions can be addressed to ensure that a single thread channel can be successfully established and will provided self-sustaining benefits in the long term.
    e. Undertake an assessment of the negative and positive impacts of each measure on each life stage of WCT, to determine whether a net positive outcome is expected.
    f. Complete an analysis of the features, functions, attributes of critical habitat gained by enhancement of riparian habitat that is additional to those that currently exist or that would develop without implementation of the measures.
7. Offsetting measures should be implemented and verified as functional before any impact occurs to pure WCT subpopulations.
8. The risk of locating offsetting measures within the zone of influence of the Project should be assessed given the potential for the Project to impact the offsetting if environmental effects predictions are exceeded.

Recommendation 15: The Proponent should update and finalize the AMP and be reflected in the Follow-up Program requirements. The AMP should include verification of predictions and effectiveness of mitigation, including offsetting. The updated AMP should include but not be limited to the following:

- A framework for validating the WCT habitat suitability curves.
- An appropriate adaptive management framework that defines trigger thresholds for each endpoint identified in the AMP
- A description of the limitations of the baseline data used to define triggers, and what conservative approaches will be used to overcome them.
- Further assessment of adaptive management options, including a full discussion on the scenarios in which a given mitigation measure could prevent irreversible harm to WCT.
- Assessment of the cumulative risk over the timescale of the Project of all monitoring components that have the potential to impact WCT. Subsequently, the monitoring plan should

be optimized and employ all avoidance and mitigation measures to reduce impacts to WCT to the greatest extent possible, and ensure survival and recovery of WCT are not jeopardized due to the Project's monitoring activities.

Recommendation 16: The Proponent should update the conservation and reclamation, and closure plans with refined modelling and predictions related to the aquatic closure landscape to ensure the management and monitoring requirements are well-defined. The closure landscape should be designed to avoid and mitigate impacts to WCT, and align with the RS-AP for WCT. An adaptive management plan should be developed that defines thresholds and triggers for further action. The Proponent should consult with all applicable regulators, including DFO, throughout planning, operations, and closure to design, implement and monitor the closure landscape. Indigenous groups should be consulted with respect to the closure landscape and their exercise of rights.

Recommendation 17: The Proponent should address how the permanent reduction in baseflow due to the alteration of groundwater discharge regimes in Blairmore and Gold Creeks will be accounted for in the Closure Plan and residual effects assessment to WCT. A detailed assessment should be undertaken to demonstrate the validity of the closure plan with respect to the proposed mitigation strategy for post-closure baseflow impacts that directly accounts for the effects of the persisting groundwater drawdown cone on discharge to the streams and ultimately on fish and fish habitat. Contingency provisions should be developed to consider the long-term operation of the surge ponds and re-direction of intercepted surface flows from the stockpiles to the SFZs for an extended period after closure before water quality testing indicates they can be decommissioned (e.g., a conservative assumption could be to evaluate the impacts of keeping these systems online permanently).

Recommendation 18: The Proponent should undertake a quantitative cumulative effects assessment. It should include consideration for the status of WCT; refined residual effects of the Project; appropriate consideration for other potential stressors including but not limited to whirling disease, timber operations, recreational use, grazing, and climate change; and reasonable predictions for the ability of the Proponent to effectively mitigate impacts in combination with other stressors.

Recommendation 19: A quantitative assessment of the potential for calcite precipitation and its effects on WCT habitat should be completed. Based on the results of the analysis, a robust mitigation strategy should be developed, tested and proven effective prior to implementation. Any residual effects should be accounted for in the final assessment of impacts to WCT and offsetting required, and described in combination with other residual effects in the context of overall potential effects on WCT survival and recovery. A comprehensive monitoring and adaptive management program should be developed and in included in the AMP and Follow-up Program to define thresholds and triggers for action to prevent effects beyond those predicted.

Recommendation 20: DFO recommends that the final offsetting plan include an updated analysis of residual effects to food sources that accounts for potential long-term changes due to water quality specific to feeding habits and diet of WCT. The amount of offsetting required should then be updated to account for this, if required.

Recommendation 21: DFO recommends that the follow-up monitoring program be designed to verify the predictions related to benthic invertebrate communities and any consequential impacts on WCT food sources.

8.2 Guidance on the Identification of Critical Habitat in the Riparian Zone for Freshwater Species at Risk

Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

National Capital Region

Canadian Science Advisory Secretariat
Science Advisory Report 2020/040

GUIDANCE ON THE IDENTIFICATION OF CRITICAL HABITAT IN THE RIPARIAN ZONE FOR FRESHWATER SPECIES AT RISK

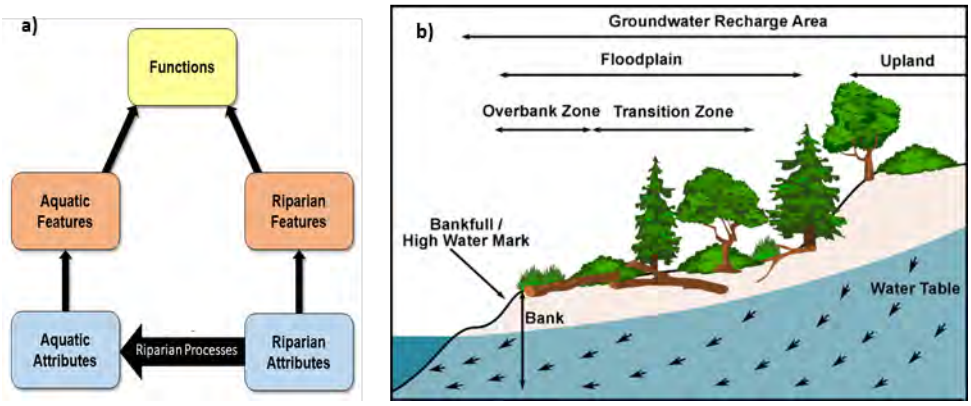


Figure 1. a) Riparian features can constitute Critical Habitat through their indirect effects of riparian processes on aquatic features considered Critical Habitat or through direct effects on a species' life cycle functions. b) Schematic of riparian features.

Context:

Fisheries and Oceans Canada (DFO) is responsible for identifying the Critical Habitat for aquatic species at risk listed under the Species at Risk Act (SARA). According to SARA, Critical Habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species". For aquatic species, the Critical Habitat may include areas in the riparian zone that need to be protected under a Critical Habitat Order (Figure 1). In the 2015 DFO "Guidelines for the identification of Critical Habitat for aquatic species at risk", riparian zones are defined as features outside the aquatic ecosystem, which support the establishment and maintenance of deep and shallow pool features, supply food for migrating and juvenile fish of many species, and influence water temperature (e.g., tree shade). However, as the current riparian zone definition is based on the requirements of only a few fish species, it may not represent the features that support most freshwater fishes and mussels' life cycle process taking place in Critical Habitat (i.e., life cycle functions). Guidance is required that builds upon and complements the Department's existing approaches to identify riparian Critical Habitat, in order to make scientifically-defensible decisions about the identification of Critical Habitat in the freshwater riparian zone.

As specified in SARA (s. 41(1)(c) and 49(1)(a)), every Recovery Strategy and Action Plan developed for a species listed in Schedule 1 of the Act as Threatened, Endangered or Extirpated[1] must identify that species' Critical Habitat, to the extent possible. Currently, there is no national guidance on the identification of Critical Habitat in the riparian zone for aquatic species at risk. Consequently, DFO's

[1] Species listed as Extirpated under SARA may not require the identification of Critical Habitat unless a program of re-introduction is proposed.

Species at Risk Program has requested that DFO Science develop a national scientific guide for the identification of riparian Critical Habitat for listed freshwater species.

This Science Advisory Report summarizes the discussions of the Fisheries and Oceans Canada, Canadian Advisory Secretariat (CSAS) national science advisory meeting of March 3–4, 2020 entitled "Guidance on the identification of Critical Habitat in the riparian zone for freshwater species at risk". Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A science-based guidance document on the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels that builds upon and complements DFO's existing approach to identify Critical Habitat was reviewed.
- A review of Recovery Potential Assessments (RPA) and Recovery Strategies of currently listed freshwater fishes and mussels identified inconsistencies in the assessment of riparian habitat.
- A systematic approach to identify processes that affect listed freshwater fishes and mussels, such as the example in the Appendix 1, would provide a consistent way of identifying the role of riparian habitat on survival and recovery of these species.
- The proposed guidance suggests that riparian features should be considered as Critical Habitat when they 1) are necessary to maintain aquatic features and/or water quality attributes of aquatic features identified as Critical Habitat; and/or 2) support life cycle functions necessary for the survival or recovery of listed freshwater fishes and mussels species or their host species.
- For the purpose of the guidance, riparian zone was defined as the area located between a waterbody's high water mark and the upland area. However, other features such as groundwater recharge areas that may extend further than the riparian zone but still affect aquatic and/or riparian features may also be considered.
- The influence of riparian features on aquatic features and/or water quality can be represented by seven main processes: erosion, filtration, infiltration, isolation, meandering, shading, and subsidization. The importance of each process will be dependent on specific freshwater fish and mussel life history requirements.
- Literature regarding the widths of riparian habitat required for the processes was reviewed and showed that increasing width protected a greater number of processes. However, in this guidance specific widths of riparian zone for the different processes were not recommended due to species-specific habitat requirements and regional differences in underlying factors such as geomorphology, slopes, land use practices, and site potential vegetation height. When determining riparian Critical Habitat width, reference should be made to regional and species-specific guidance as appropriate.
- Riparian Critical Habitat may be located adjacent to aquatic Critical Habitat, but strong longitudinal connectivity in streams means that riparian Critical Habitat can also be identified upstream of the aquatic Critical Habitat if it is necessary for the survival and recovery of freshwater fishes and mussels.

- Processes that allow for the survival and recovery of an aquatic species have a range of natural variation. In the description of the extent of riparian Critical Habitat, the natural variation in the processes should be considered on a species- and site-specific basis, and be robust to environmental and climate change with the goal of maintaining or restoring the natural function of the riparian zone.
- There is a broad scientific consensus that riparian zones are essential habitat for natural aquatic ecosystem structure and biophysical functioning and are therefore important for all aquatic species.

BACKGROUND

Fisheries and Oceans Canada's (DFO) Species at Risk Program is responsible for carrying out the Department's mandate under the *Species at Risk Act* (SARA) to protect, recover, and conserve all listed aquatic species at risk in Canada. When a freshwater fish or mussel species is listed on Schedule 1 of SARA as threatened, endangered or extirpated, DFO is required to identify and protect the habitat that is necessary for the survival and recovery of the species (i.e., Critical Habitat), which is linked to the population and distribution objectives established in the Recovery Strategy.

The identification of a species' Critical Habitat is based on the best available scientific information. To determine Critical Habitat, a biophysical description is used. The biophysical elements of Critical Habitat are broken down into: life cycle functions, features, and attributes (Figure 2). Functions describe a species' life cycle processes, which are directly linked with feature(s) of the Critical Habitat. Features are defined by the attributes of an habitat that are key in supporting a species' life cycle function necessary to achieve the species' population and distribution objectives. Some features designated as Critical Habitat may support functions indirectly by supporting or reinforcing other features. These features may be outside of the aquatic ecosystem, i.e., in the riparian zones. Every feature is defined by a set of measurable attributes, which are the characteristics that enable the feature to support the species' functions. Attributes provide the greatest level of information about a feature, the quality of the feature, and the mechanism by which the feature is able to support particular life cycle requirements of a species and provide explicit targets for habitat management or restoration.

Although riparian habitat has been defined in the 2015 DFO "Guidelines for the identification of Critical Habitat for aquatic species at risk" as features outside the aquatic ecosystem, which support the establishment and maintenance of deep and shallow pool features, supply food for migrating and juvenile fish of many species, and influence water temperature, this definition was based on the requirements of only a few fish species, and it may thus not be representative of all of the features that support most freshwater fishes and mussels' life cycle process (i.e., functions) that take place in Critical Habitat. For aquatic species, Critical Habitat may include areas in the riparian zone. There is a desire that Critical Habitat identification guidelines be more representative of all features found in the riparian habitat that support freshwater fish and mussels' life cycle processes.

DFO's Species at Risk Program requested advice to ensure a more rigorous and systematic approach to identify Critical Habitat in the riparian zone. The purpose of this science advisory process is to provide guidance on the identification of Critical Habitat in the riparian zone for freshwater species at risk, while building on and complementing the Department's existing approaches to identify Critical Habitat. More specifically, the objectives of this process are to provide DFO's Species at Risk Program with guidance on: (1) How to determine when riparian

features constitute Critical Habitat; and (2) how to determine the extent of the riparian zone that is important for features that constitute Critical Habitat.

The riparian zone is defined as the area located between a waterbody's high water mark and the upland area. However, other factors such as groundwater recharge areas that may extend further than the riparian zone but still affect aquatic and/or riparian features may also be considered as Critical Habitat features.

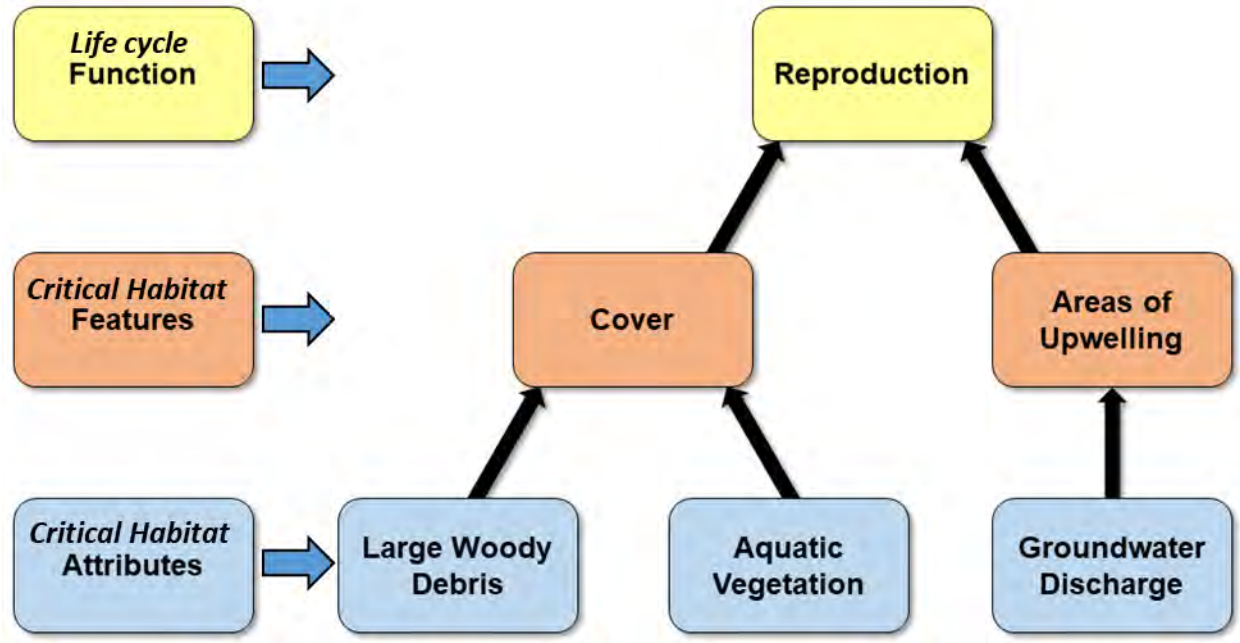


Figure 2. Flow chart representing examples of life cycle functions, Critical Habitat features, and Critical Habitat attributes.

ASSESSMENT

Identification of Riparian Critical Habitat

A review of the publicly available Recovery Potential Assessments (RPA) for freshwater fish and mussels showed a lack of inclusion of riparian zones as candidate Critical Habitat. As highlighted in several of the RPAs, this can be explained by a scarcity of data and/or a lack of understanding on how to define candidate Critical Habitat in the riparian zone for a given species.

Publicly available Recovery Strategies for freshwater fish and mussel species listed as Threatened or Endangered were also reviewed, and only a small proportion included riparian Critical Habitat as part of the species' Critical Habitat. Among those Recovery Strategies, there were inconsistencies in how the riparian Critical Habitat was described and its contributions to the aquatic habitat. Nevertheless, most of the Recovery Strategies reviewed, including the ones that did not include riparian zones as Critical Habitat, incorporated the loss, damage or reduction of riparian zones as a threat to the species, and included protection or recovery of riparian zones in the recovery planning sections. The inconsistencies that have been identified by this review underlines the need for guidance on how to determine when riparian features constitute Critical Habitat.

Richardson et al. (2010) suggested that riparian habitat should be considered as Critical Habitat if its impairment affects aquatic habitat or water quality in a way that negatively impacts the survival or recovery of a species at risk. Riparian habitat is considered impaired when the riparian features (Figure 1) are not able to support the life cycle functions of fishes and mussels. Therefore, riparian features should be considered as Critical Habitat if they are necessary to maintain aquatic habitat or water quality attributes required for the survival or recovery of freshwater fishes and mussels (Figure 1a). If a riparian feature affects aquatic habitat features identified as Critical Habitat, that is a clear path forward for identifying the riparian feature as Critical Habitat (Richardson et al. 2010).

Current SARA guidelines on determining Critical Habitat do not provide guidance on how to include water quality as Critical Habitat (DFO 2015) since water quality is not listed a feature in the current guidelines but rather a set of attributes common to most aquatic features. In this sense, any riparian feature that affects water quality in turn affects any aquatic features that would be impaired by poor water quality. However, riparian features located upstream of aquatic Critical Habitat features may influence water flow and quality attributes of aquatic Critical Habitat, and should also be considered when defining riparian Critical Habitat.

The boundary between terrestrial and aquatic habitats is not necessarily a barrier for freshwater fishes and mussels. Due to changes in water level (i.e., flooding), the ability to tolerate desiccation or life cycle process requirements, riparian features may also directly support functions of some freshwater fishes or mussels. Riparian features that directly support functions required for the survival or recovery of freshwater fishes and mussels should also be included as Critical Habitat (Figure 3b).

Consequently, riparian features should be considered as Critical Habitat when they:

1. are necessary to maintain aquatic features identified as Critical Habitat,
2. are necessary to maintain water flow and water quality upstream of Critical Habitat, and/or
3. support functions necessary for the survival or recovery of a listed wildlife species.

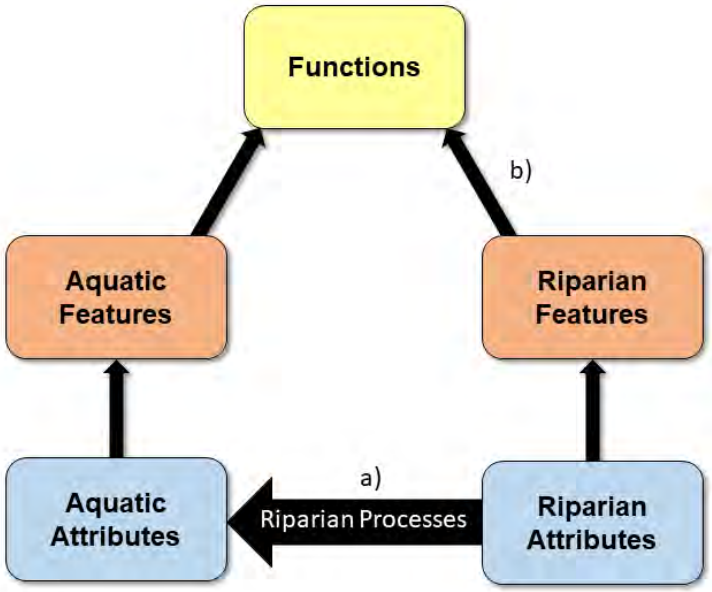


Figure 3. Riparian features can constitute Critical Habitat through a) their indirect effects of riparian processes on aquatic features considered critical habitat or b) through direct effects on a species' functions.

Riparian features that affect aquatic habitat features and water quality attributes

The riparian zone is defined as the area located between a waterbody's high water mark and the upland area. The ecosystem in the riparian zone has unique physical, geomorphological, and chemical properties. The riparian zone acts as an interface between aquatic and terrestrial habitats, and is sensitive to environmental change. Activities that occur in the riparian zone may have direct implications for the aquatic habitat due to the strong connections between aquatic and riparian features.

A literature review was undertaken to identify current scientific evidence regarding the effect of riparian features on aquatic habitat features. Seven main processes that occur in the riparian zone that help maintain aquatic features were identified (Table 1; Figure 4).

Table 1: Main processes occurring in the riparian zone that support aquatic features and their description. These processes are dynamic and occur within a range of natural of variation that needs to be considered when defining riparian areas as Critical Habitat.

Process	Description
Erosion	The wearing of soil from terrestrial sources by wind, water or gravity. When erosion is occurring within a natural range of variation, it controls sedimentation and siltation; supporting aquatic attributes such as aquatic vegetation and interstitial spaces.
Filtration	Removal of matter, light or sound from air or water. Filtration prevents contaminants and excess nutrients in surface and subsurface water in the riparian zone from entering a waterbody.
Infiltration	Entry of surface water into soil. Riparian vegetation provides shading and structure that prevents evaporation, runoff, and allows surface water in the riparian zone to infiltrate into the water table.

Process	Description
Isolation	Spatial distancing of a place or thing from a disturbance. The intensity of noise and light decreases the farther away from the source. Therefore, the riparian zone isolates the water body from noise and light pollution that can affect the acoustic and photic environment, as well as other forms of human disturbance.
Meandering	Back and forth movement of a stream or river, changing shape as it flows across a floodplain or valley eroding and depositing sediments on alternating banks. Natural levels of meandering by a river or stream creates habitat features such as cover, backwater, and shoals.
Shading	Regulation of the amount of light admitted onto a surface. Shading in the aquatic habitat by vegetation, large woody debris (LWD), and undercut banks provides cover and maintains the photic environment. Shading by riparian vegetation maintains natural variation in temperature of water in the aquatic habitat.
Subsidization	Transfer of energy, food, and structural components from the terrestrial zone to the aquatic habitat. Riparian features provide food for mussels (e.g., organic matter) and fishes (e.g., terrestrial insects, nutrients and organic matter that support aquatic invertebrates). Coarse sediment, such as gravel and boulders from banks and beaches, in the riparian zone is transferred into waterbodies as a result of erosion processes and meandering. The subsidization of wood, also termed wood recruitment, is the addition of wood into waterbodies from the associated riparian trees as a result of the mortality of individual trees, disturbances affecting multiple trees or meandering of a river or stream.

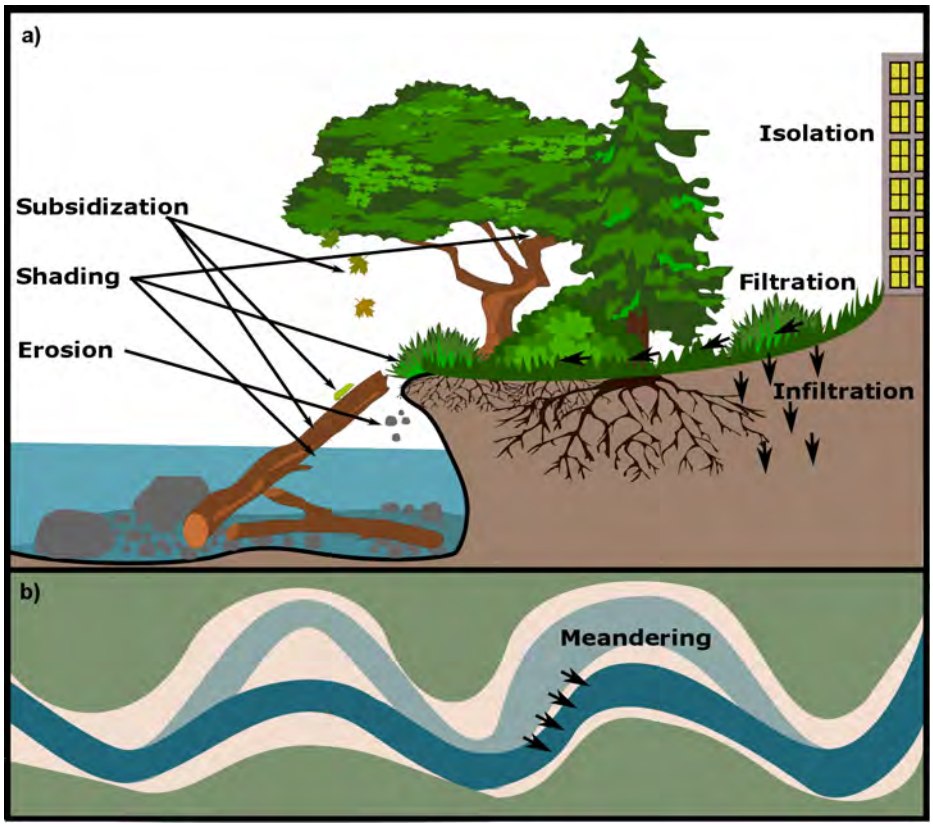


Figure 4. The seven main processes by which features in the riparian zone maintain aquatic features from two different perspectives, cross-sectional (a) and aerial (b).

To determine which riparian features may be considered Critical Habitat through their impact on aquatic Critical Habitat features (Figure 3), their associated processes were outlined for each aquatic feature (Table 2).These processes are dynamic and occur within a range of natural variation. In the description of the extent of riparian Critical Habitat, the natural variation in the processes should be considered on a species- and site-specific basis. The natural state of the riparian habitat will have a considerable impact on its capability to provide the functional processes. For example, an altered riparian vegetation community, such as a lawn or cultivated field, may not provide key functional processes like provision of large woody debris (LWD) inputs or solar shading. It is therefore implicit in the description of riparian Critical Habitat that a native vegetation community be present or if absent, that it be actively or passively restored to a native vegetation community. Riparian Critical Habitat identification should also be robust to environmental change with the goal of maintaining or restoring the natural function of the riparian zone.

*Table 2: The features in the riparian zone that have an effect on aquatic features, and the processes by which these riparian features impact them. The details pertaining to water quality attributes (marked with an *) are found in a separate table (Table 3) to reduce redundancies.*

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Acoustic environment	sound intensity	filtration, isolation	Riparian features filter out and isolate waterbodies from anthropogenic noise (e.g., road/bridge traffic, urbanization) that can interfere with acoustic signal-to-noise ratios, mask signals or alter organismal behavior.	beach, floodplain	(Mickle and Higgs 2018; Reid et al. 2019)
Areas of upwelling	groundwater discharge	infiltration	Upwelling in the freshwater habitat is caused by groundwater discharge that is recharged in the groundwater recharge area.	floodplain, groundwater recharge area	(Ouellet et al. 2017)
Areas of upwelling	water quality*	-	-	-	-
Backwater	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation can reduce flow to create backwater and is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Cheng and Yong-ming 2008; Jones et al. 2012)
Backwater	-	meandering	Channel migration in the meander belt creates backwater.	meander belt	(Biron et al. 2018)
Backwater	-	erosion	Riparian vegetation maintain banks from eroding and separating backwater from the waterbody.	bank, beach, floodplain	(Mondal and Patel 2018)
Backwater	large woody debris (LWD)	subsidization	Backwater is created by LWD being recruited from the floodplain.	floodplain	(Lehane et al. 2002; Seo et al. 2010)
Backwater	water quality*	-	-	-	-
Cover	groundwater discharge	infiltration	Upwelling groundwater is recharged in the groundwater recharge area.	floodplain, groundwater recharge area	(Malcolm et al. 2005)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Cover	interstitial spaces	erosion	Vegetation in the floodplain controls erosion, which prevents sedimentation that fills interstitial spaces.	bank, beach, floodplain	(Wohl 2015)
Cover	-	shading, erosion, meandering	Undercut banks are maintained through erosion control in the floodplain and created by meandering in the meander belt.	bank, beach, floodplain, meander belt	(Florsheim et al. 2008; Vargas-Luna et al. 2018)
Cover	LWD	subsidization, shading	LWD in the floodplain provides shading. LWD that falls into the aquatic habitat from the floodplain creates complex habitat and cover.	floodplain	(Crook and Robertson 1999)
Cover	small woody debris	subsidization	Small woody debris that falls into the aquatic habitat from the floodplain creates shelter for juveniles and small-bodied fishes.	floodplain	(Enefalk and Bergman 2016)
Cover	-	shading	Overhanging riparian vegetation in the overbank zone provides cover.	bank, floodplain	(Raines and Miranda 2016)
Cover	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the availability of refugia and cover.	floodplain, meander belt	(National Research Council 2002; Logez et al. 2016)
Cover	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation provides cover and is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Jones et al. 2012; Massicotte et al. 2015)
Eddies	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation causes swirling and is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Nepf 2012; Jones et al. 2012)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Eddies	LWD	subsidization	LWD that falls into the aquatic habitat from the terrestrial habitat creates obstacles that create eddies.	floodplain	(Lehane et al. 2002)
Eddies	flow	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the flow regimes of eddies.	floodplain, meander belt	(National Research Council 2002)
Eddies	water quality*	-	-	-	-
Food supply	terrestrial and amphibious prey	subsidization	Terrestrial and amphibious prey species in the floodplain supply food in the aquatic habitat due to incidental use or their life-history requirements.	floodplain	(Albertson et al. 2018)
Food supply	terrestrial organic matter	subsidization	Transfer of organic matter from the floodplain to the aquatic habitat supplies food for freshwater fishes and mussels.	floodplain	(Brett et al. 2017)
Food supply	aquatic insects	subsidization	Some life-history stages of aquatic insects (e.g., adult stage) require use of the floodplain, aquatic insects also need terrestrially sourced nutrients and organic matter.	bank, beach, floodplain	(Harabis 2017)
Food supply	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Jones et al. 2012)
Glides	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the flow regimes of glides.	floodplain, meander belt	(National Research Council 2002)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Glides	water quality*	-	-	-	-
Host species (availability of)	water quality	filtration	Terrestrial sources of nitrates filtered by the floodplain affect the ability of mussels to attach to host.	floodplain	(Moore and Bringolf 2018)
Host species (availability of)	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects host attachment by mussels.	floodplain, meander belt	(National Research Council 2002; Modesto et al. 2018)
Upstream habitat	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects upstream habitat.	floodplain, meander belt	(National Research Council 2002)
Upstream habitat	water quality*	-	-	-	-
Lake benthic habitat	sediment	filtration, erosion	Erosion and filtration of contaminants in the floodplain affects sediment quality and quantity in benthic habitat.	bank, beach, floodplain	(Crane 2017)
Lake benthic habitat	water quality*	-	-	-	-
Lake littoral habitat	aquatic vegetation	erosion, filtration, subsidization	Filtration and erosion in the floodplain, and littoral habitat alteration affects the presence of aquatic vegetation in lake littoral habitats.	bank, beach, floodplain	(Doi et al. 2010)
Lake littoral habitat	water quality*	-	-	-	-
Lake pelagic habitat	water quality*	-	-	-	-
Migration/Movement corridors	sensory cues	subsidization, filtration	Sensory cues that support homing or initiate migration may come from or be disrupted by contaminants from the floodplain.	floodplain	(Scholz et al. 1976)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Migration/Movement corridors	flow and level	infiltration	Infiltration in the floodplain affects flow rates and water level which affects hydrological connections between critical habitats.	floodplain	(Crook et al. 2015)
Migration/Movement corridors	water quality*	-	-	-	-
Photic environment	artificial light	filtration, isolation	Filtration in the floodplain of, and isolation from, light pollution (street lights, houses, etc.) affects parental care behaviour of a fish, timing of migration, and dial movements of prey.	floodplain	(Foster et al. 2016; Reid et al. 2019)
Photic environment	shade	shading	Shading from riparian vegetation, overhanging banks, and LWD in the overbank zone affect the quantity and quality of light in the aquatic habitat.	bank, floodplain	(Pusey and Arthington 2003)
Photic environment	turbidity	erosion, filtration	Riparian vegetation in the floodplain affects sediment load in the waterbody by control of erosion and filtration of surface water that would otherwise increase turbidity.	bank, beach, floodplain	(Vargas-Luna et al. 2018)
Photic environment	water colour	subsidization, filtration	Lack of browning or greening of water due to filtration of terrestrial nutrient or organic matter in the floodplain affects the photic environment.	floodplain	(Karlsson et al. 2009)
Pools	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the connectivity of pools in the waterbody.	floodplain, meander belt	(National Research Council 2002)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Pools	LWD	subsidization	The addition of LWD from the floodplain increases the presence of pools in rivers and streams.	floodplain	(Davidson and Eaton 2013)
Pools	water quality*	-	-	-	-
Riffles	exposed coarse sediment	erosion, meandering, subsidization	Erosion control in the floodplain reduces sediment load in the waterbody which maintains exposed coarse sediment. Meandering and erosion of beaches and banks subsidizes coarse sediment.	bank, beach, floodplain	(National Research Council 2002)
Riffles	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the production of riffles as they require appropriate flow regimes.	floodplain, meander belt	(National Research Council 2002)
Riffles	LWD	subsidization	The addition of LWD from the floodplain increases the presence of riffles in rivers and streams.	floodplain	(Davidson and Eaton 2013)
Riffles	water quality*	-	-	-	-
Runs	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the production of runs as they require appropriate flow regimes.	floodplain, meander belt	(National Research Council 2002)
Runs	water quality*	-	-	-	-
Shoals	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects whether the shoal is submerged.	floodplain, meander belt	(National Research Council 2002)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Shoals	sediment	meandering, erosion	Erosion of banks and beaches, and meandering in the meander belt affects sedimentation in the riparian zone, which can add or remove shoals.	bank, beach, floodplain, meander belt	(National Research Council 2002)
Shoals	water quality*	-	-	-	-
Sympatric species	-	meandering, subsidization	Hierarchical, dendritic, spatially fragmented systems may exhibit high genetic diversity. Allowing natural processes to create dendritic channels and oxbow lakes could support sympatric speciation.	floodplain, meander belt	(Ruzzante et al. 2019)
Wetlands	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(National Research Council 2002)
Wetlands	flow and level	infiltration, groundwater discharge	Wetlands are maintained through flow from rivers and streams, groundwater inputs, and run-off from floodplain.	floodplain, groundwater recharge area, meander belt	(National Research Council 2002)
Wetlands	water quality*	-	-	-	-

A second literature review was undertaken to determine the most current scientific evidence to provide guidance on riparian features that affect water quality. Riparian features affect water quality attributes with a subset of the same processes by which they affect aquatic habitat features (Table 3).

The review showed that water quality attributes are usually affected by sets of riparian features through a combination of processes. The level of contaminants in the aquatic habitat, for example, is influenced by several riparian features (bank, beach and floodplain) which, through a combination of four processes (erosion, filtration, infiltration, isolation), filter water and sediments and thus prevent contaminants from entering the aquatic habitat.

Table 3: Riparian features and processes that impact water quality attributes (see Caskenette et al. (2020) for source information).

Aquatic Attributes	Process	Details	Riparian Features	Source(s)
Contaminants	erosion, filtration, infiltration, isolation	Contaminants in surface water and sediments are filtered by riparian vegetation and sediments (through infiltration) in the floodplain and are prevented from entering the aquatic habitat through erosion control and isolation.	bank, beach, floodplain	(Yu et al. 2019; Reid et al. 2019)
Dissolved oxygen	erosion, filtration	Natural levels of dissolved oxygen available to fishes and mussels in a waterbody can be maintained through filtration of nutrient and through control of sedimentation that would otherwise fill interstitial spaces.	bank, beach, floodplain	(Wood and Armitage 1997; Crossman et al. 2019)
Nutrients (P, N, C, Ca)	erosion, filtration, infiltration, subsidization	Erosion, filtration, infiltration, and subsidization in a properly functioning floodplain maintains natural levels of nutrients in waterbodies.	bank, beach, floodplain	(Stutter et al. 2019)
pH	erosion, filtration, infiltration, subsidization	pH buffering capacities of soils affects pH of surface and subsurface water, erosion inputs acidified soils into water, and leaf litter affects aquatic pH.	Bank, beach, floodplain	(Hruška et al. 2001)

Aquatic Attributes	Process	Details	Riparian Features	Source(s)
Temperature	shading, infiltration	Shading of surface and subsurface water by undercut banks and riparian vegetation in the floodplain, and infiltration that recharges in the groundwater recharge area contributes to maintaining natural water temperature ranges.	bank, beach, floodplain, groundwater recharge area	(Chu et al. 2008; Albertson et al. 2018)

Riparian features that support the functions of freshwater fishes and mussels

Riparian features can directly provide for functions of freshwater fishes and mussels. A literature review was conducted to identify the most current scientific evidence in regards to how riparian features directly affect the functions of freshwater fishes and mussels. However, there was a sparsity of available literature and information explicit to Canada. In addition, most examples will be species specific. Some examples are: fish that deposit eggs on beaches or floodplains, which directly supports dispersal, reproduction, and rearing during intermittent flooding events, and foraging for terrestrial food sources outside of the aquatic habitat (e.g., capturing insects on riparian vegetation, feeding in flooded riparian zones).

Delineating protected area in the riparian zone

The review of existing RPAs and Recovery Strategies showed a large range in recommended widths of riparian protection (0–30 m) underlining the importance of considering the species specific requirements and landscape features when recommending Critical Habitat protection in the riparian zone. The inconsistencies between species, and absence of recommendations for many species, may also signify both the variation and uncertainty about the extent to which riparian zones need to be protected to maintain species' functions. When defining Critical Habitat in the Recovery Strategy, a clear description of the geographic area to be protected is provided (DFO 2015). This should include the geographic area representing riparian features that are considered Critical Habitat. The extent of riparian Critical Habitat protected should be grounded in an empirical understanding of the processes that impact the ability of the riparian zone to support freshwater fishes and mussels' functions (Figure 5).

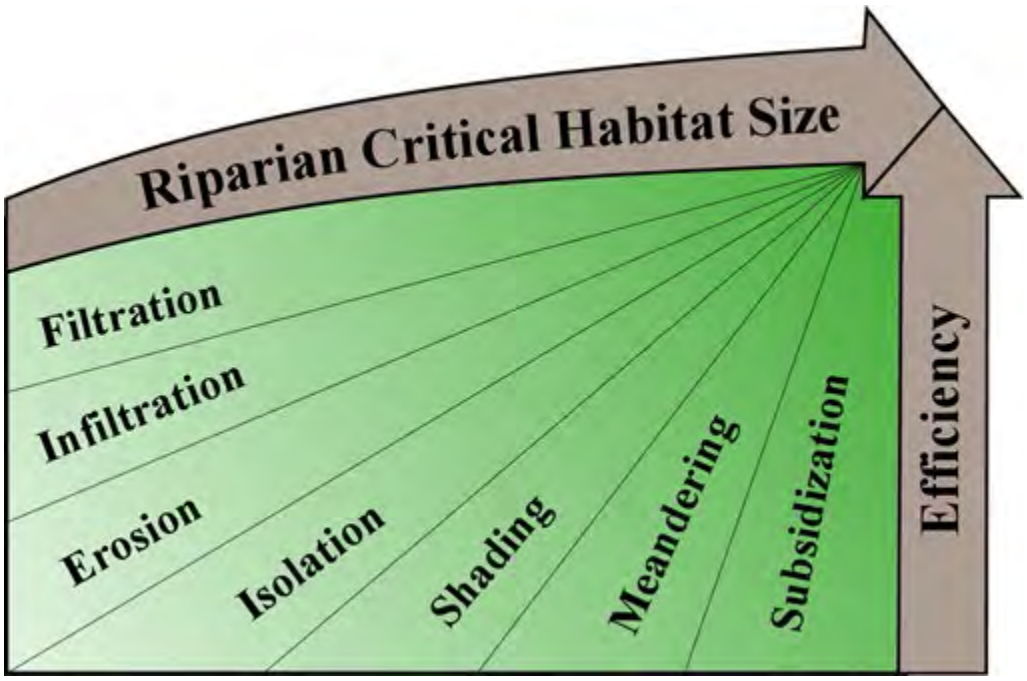


Figure 5. The size of Critical Habitat protected determines which riparian processes are supported by the riparian habitat and the efficiency of the riparian processes. The greater the size of riparian critical habitat that is protected, the greater the number and efficiency of processes supported. For simplicity, the efficiency of the processes are shown here to increase linearly with riparian Critical Habitat size, however, it is important to note that the shape of the response curve for individual processes will depend on the riparian attributes.

Current literature and appropriate guidance on regional riparian processes and species specific needs should be taken into account to determine the relationship between the amount of riparian habitat protected and its influence on the quality of the aquatic habitat feature of interest. It is also important to consider the shape of the response curve and any dependencies of the attributes of the riparian zone (e.g., slope, land use, soil type). Consequently, a single value for the extent of riparian Critical Habitat to be protected will likely not be representative of all species or landscapes. This provides a challenge when developing a national standard.

A formal meta-analysis that was beyond the scope of this CSAS meeting is required to inform further guidance on threshold values per region for delineating protected riparian zone in perspective of each of the identified process (i.e., erosion, filtration, infiltration, isolation, meandering, shading, and subsidization).

Sources of uncertainty

There are inherent uncertainties in the advice outlined above. One source of uncertainty is linked with the identification of the aquatic habitat features important for the freshwater fishes and mussel species in the Recovery Documents. Since riparian Critical Habitat delineation is based on aquatic features identification found in the recovery documents, if their identification was to be inaccurate or missing, the suite of riparian features needed to support the functions of a given species as well as its riparian Critical Habitat would also be inaccurate.

Meta-analyses may provide more precise width recommendations than individual studies, and an examination of heterogeneity that many individual studies are not able to provide. However, even meta-analyses are not able to capture the range of climates encountered across Canada,

since they may be limited in scope to a narrow range of land uses (e.g., agriculture) and shorter-term studies. Many of the reviews and meta-analyses included were performed in agricultural areas and because of this, there was more information regarding erosion, filtration, and infiltration than there was for isolation, meandering, shading or subsidization. Although the scientific basis for the development of guidance on the extent of the riparian zone that is important for features that constitute Critical Habitat is sound, the data available for the literature review was heavily skewed towards agricultural systems and warmer months. Hence, there is uncertainty about how the riparian features are impacting aquatic features through the different processes in the full range of northern climates. In particular, there is uncertainty regarding the impact of frazil and anchor ice formation induced by colder temperatures due to a lack of insulating vegetation after riparian removal. When determining riparian Critical Habitat widths for Species at Risk, biologists should consult regional process-based guidelines for riparian buffers and appropriate species-specific requirements when available

Uncertainty linked to the natural state of the riparian habitat was also identified, as it has a considerable impact on its capability to provide the functional processes. For example, an altered riparian vegetation community, such as a lawn or cultivated field, may not provide key functional processes like provision of large woody debris or solar shading. Although riparian habitat is key in the survival and recovery of freshwater fishes and mussels, further studies are needed to assess the effectiveness of riparian Critical Habitat to fully mitigate identified threats to the species. Future studies, evaluations, effectiveness assessments or new information may eventually provide a more specific riparian habitat width range to be protected for freshwater fishes and mussels.

As in all peer-review processes, the science advice developed depends on which experts were present at the meeting. Best attempts were made to include the full range of expertise needed to assess the importance of Critical Habitat in the riparian zone for freshwater species at risk, but subject matter experts for Fluvial Geomorphology were unable to attend the meeting. The process would have benefitted from participation of fluvial geomorphological knowledge holders, and this may have impacted the science advice.

CONCLUSIONS AND ADVICE

Riparian features are not consistently included as Critical Habitat for listed freshwater fishes and mussels. An evidence-based approach was developed to guide the identification of features (e.g., bank, beach, floodplain, groundwater recharge area) in the riparian zone as Critical Habitat. Riparian Critical Habitat are riparian features that: maintain the quality of aquatic features and water quality attributes identified as Critical Habitat, and are directly used by fishes and mussels. Riparian features should be considered as Critical Habitat when they 1) are necessary to maintain aquatic features identified as Critical Habitat; 2) are necessary to maintain water flow and water quality upstream of Critical Habitat, and/or 3) support functions necessary for the survival or recovery of listed freshwater fishes and mussels species or their host species.

The relevant riparian features and the processes by which they affect aquatic features and water quality attributes were identified. These seven main processes by which riparian features affect aquatic features and water quality attributes are: erosion, filtration, infiltration, isolation, meandering, shading, and subsidization.

The guidance on how to determine when riparian features constitute Critical Habitat and the extent of the riparian zone required for features that constitute Critical Habitat is based on the current best available information. Given that many factors may influence the riparian Critical

Habitat delineation among sites and species, the quantitative aspect of the guidance is limited. Further meta-analyses are required to provide guidance on the extent of riparian habitat that is needed to support these seven processes in specific landscapes (e.g., forested vs grasslands, high vs low topography). Not all species will be equally affected by the riparian zone. For example, species that are not sensitive to water quality, prefer turbid, warm waters, or live in the pelagic zone of a large lake, probably require less riparian Critical Habitat.

As habitat requirements differ between species and ecosystems, the delineation of riparian Critical Habitat should be species- and site-specific and is best evaluated by species experts based on the biology of individual species using knowledge of the local landscape and regional riparian processes. Using a case study it is demonstrated how practitioners may apply the guidance provided to determine riparian Critical Habitat for a listed species (Appendix 1). To facilitate riparian Critical Habitat designation, the guidance suggests to gather important species- and site-specific information by identifying:

- the aquatic habitat features that support the life cycle functions necessary for the survival of the species and their underlying Critical Habitat attributes;
- the processes needed in order to maintain the aquatic Critical Habitat features identified previously, as well as the species water quality attributes requirements and the process(es) needed to maintain them;
- any additional process(es) specific to the type of ecosystem in which the species is found;
- the riparian Habitat features that support freshwater fishes and mussels' life cycle functions (i.e., riparian Critical Habitat) through their impact on the identified processes.

OTHER CONSIDERATIONS

Resilience to natural variation and extreme events

The goal of protecting riparian habitat is to ensure that there is sufficient area to provide the ecosystem services (i.e., processes) that the aquatic habitat requires; which also means maintaining a large enough riparian zone to allow for proper function and resilience of riparian features to natural variation and to extreme events. Long term studies may be required to capture any loss of utility of Critical Habitat in the riparian zone due to limited protection.

Native (site potential) vegetation

Provision of essential processes by riparian Critical Habitat is contingent on the presence of a native vegetation community typical of the local biogeoclimatic zone. Naturalness refers to how much a system has already been changed, directly or indirectly by human activities. An altered riparian vegetation community, such as a lawn or cultivated field, may not provide key functional processes like provision of LWD inputs or solar shading. For instance, source distances for riparian wood inputs and therefore buffer widths will be contingent on the natural site potential vegetation (tree) height. It is therefore implicit in the designation of riparian Critical Habitat that a native vegetation community be present or if absent, that it be actively or passively restored to an appropriate vegetation community.

Scale

The magnitude of the influence of the riparian habitat on the aquatic habitat depends on the size of the waterbody. Smaller waterbodies (e.g., small streams) may have stronger connections with the riparian habitat than larger waterbodies (e.g., large lakes). However, regulations often

scale with waterbody size (e.g., a multiple of channel width), resulting in less protection – in terms of distance from high water mark for smaller waterbodies. This is due to the fact that riparian habitat, in terms of the extent of the terrestrial habitat that interacts directly with the aquatic habitat, scales with waterbody size.

Connectivity

Riparian Critical Habitat will generally need to be located on both sides of a river or stream, adjacent to the aquatic Critical Habitat features that riparian processes support. However, riparian habitat upstream of the identified aquatic Critical Habitat (including non-fish-bearing reaches) may also be identified if the features of upstream riparian habitat are necessary to maintain features of downstream aquatic habitat. This may occur, for example, when lack of upstream riparian habitat results in diminished bank stability and excessive sediment or nutrient inputs that adversely affect downstream aquatic Critical Habitat or when lack of shading affects downstream water quality (temperature, dissolved oxygen) or contributes to a water quality barrier (e.g., to fish movement) between aquatic Critical Habitat features.

Upland areas

Performance of the riparian zone is often dependent on the state and use of the upland areas. Although the science advice in this document pertains to Critical Habitat associated with the riparian zone, it is important to note that identifying riparian Critical Habitat will not mitigate threats to upland areas. Some upland areas may also be disproportionately important in maintaining attributes of aquatic Critical Habitat features, and therefore may warrant protection as Critical Habitat. Furthermore, identifying Critical Habitat in the riparian zone or even upland areas, is not a substitute for adequately managing land use at the broader scale.

Host species

Under the current SARA guidelines, the availability of a host species is considered a Critical Habitat feature when necessary for the survival, recovery, and resilience of a SARA listed species. Current SARA policy does not, however, consider the habitat that supports the host as Critical Habitat. However, activities occurring outside the identified critical habitat that reduce the availability of hosts inside the Critical Habitat may be considered an activity likely to destroy Critical Habitat. This may be an oversight; we feel that the inclusion of the habitat of the host species as Critical Habitat should be considered on a case-by case basis. If availability of a host species is limiting the survival or recovery of a listed species, then the habitat of the host species may also need to be considered Critical Habitat for extreme events and/or effects of climate change.

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SOURCES OF INFORMATION

This Science Advisory Report is from the CSAS national science advisory meeting of March 3–4, 2020 entitled “Guidance on the identification of Critical Habitat in the riparian zone for freshwater species at risk”. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Caskenette, A.L., T.C. Durhack, E.C. Enders. 2020. Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/049.

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APPENDIX 1. SALISH SUCKER CASE STUDY

The Salish Sucker (*Catostomus* sp. cf. *catostomus*) is a small bodied freshwater fish that is found in low elevation, meandering headwater streams, sloughs, marshes and beaver ponds in eleven watersheds in the Fraser Valley between Surrey and Chilliwack in southern British Columbia (Fisheries and Oceans Canada 2019). Salish Sucker require a mixture of shallow and deep pools, riffles, and glides as habitat to support all of their life stages. Connectivity of these aquatic habitats is important, as different life stages make use of different habitat types. Riffle habitat with water depths of more than 70 cm is used for spawning, and populations that do not have riffle habitat near their marsh or pond have been known to travel long distances in order to find suitable riffle habitat for spawning. Shallow pools and glides are used as nursery and rearing habitat by young-of-the-year Salish Sucker, while juvenile and adults are most often found in the deep pool habitat (pools deeper than 70 cm). Adequate dissolved oxygen levels (≥ 4 $mg \cdot l^{-1}$), water temperatures between 6 and 23 °C and low levels of sediment, nutrients and toxins are required in all aquatic Critical Habitat to support survival of Salish Sucker.

Riparian habitat has been identified as Critical Habitat for Salish Sucker in the Recovery Strategy (Fisheries and Oceans Canada 2019), specifically a continuous strip of native vegetation along the entire length of aquatic Critical Habitat. All seven of the processes provided by riparian habitat are required by Salish Sucker, with erosion, infiltration, filtration, and isolation providing protection to water quality attributes from agricultural runoff and sedimentation from residential land development, subsidization providing LWD for the formation of pools and is a source of terrestrial insects, a major food source of adult, juvenile, and young-of-the-year fish, shading providing cover and temperature control, and meandering causing additions of LWD and the formation of cover and pools (Table A1).

Table A1: Guidance for riparian Critical Habitat designation for Salish Sucker.

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Pool	flow and level, LWD, water quality*	infiltration, meandering, subsidization	floodplain, meander belt
Riffle	exposed coarse sediment, flow and level, LWD, water quality*	erosion, infiltration, meandering, subsidization	bank, beach, floodplain, meander belt
Glide	flow, water quality*	infiltration, meandering	floodplain, meander belt
Cover	aquatic vegetation, interstitial spaces, flow and level, LWD, small woody debris, water quality*	erosion, filtration, infiltration, meandering, recruitment, shading, subsidization	floodplain, bank, meander belt, beach,
Food supply	terrestrial prey, aquatic insects	subsidization	bank, beach, floodplain
Migration /movement corridors	sensory cues, flow and level, water quality*	filtration, infiltration, subsidization,	floodplain
Photic environment	turbidity, shade	erosion, filtration, shading	bank, beach, floodplain
Water Quality Attributes*			
	contaminants, dissolved oxygen, nutrients, temperature	erosion, filtration, infiltration, isolation, shading, subsidization	bank, beach, floodplain, groundwater recharge area

THIS REPORT IS AVAILABLE FROM THE:

Canadian Science Advisory Secretariat (CSAS)
National Capital Region
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ISSN 1919-5087
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Correct Citation for this Publication:

DFO. 2020. Guidance on the identification of Critical Habitat in the riparian zone for freshwater species at risk. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/040.

Aussi disponible en français :

MPO. 2020. Lignes directrices sur la désignation de l'habitat essentiel dans la zone riveraine des espèces d'eau douce en péril. Secr. can. de consult. sci. du MPO, Avis sci. 2020/040.

8.3 Review of Information to Guide the Identification of Critical Habitat in the Riparian Zone for Listed Freshwater Fishes and Mussels

Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2020/049

National Capital Region

Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels

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August 2020

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca



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ISSN 1919-5044

Correct citation for this publication:

Caskenette, A.L., Durhack, T.C., and Enders, E.C. 2020. Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/049. vii + 67 p.

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ABSTRACT

Fisheries and Oceans Canada's Species at Risk Program provides protection of the habitat necessary for the survival or recovery of listed freshwater fishes and mussels. It is well documented that the riparian zone is essential for the maintenance of freshwater aquatic habitats, fishes, and mussels. Despite this extensive body of literature, riparian features are not consistently included as Critical Habitat for listed freshwater fishes and mussels. An evidence based approach was required to guide the identification of features in the riparian zone as Critical Habitat. Riparian Critical Habitat are riparian features that: maintain the quality of aquatic features identified as Critical Habitat, and are directly used by fishes and mussels. We performed a literature review to determine the relevant riparian features, and the processes by which they affect aquatic features and water quality attributes. From these literature reviews we identified seven main processes by which riparian features affect aquatic features and water quality attributes: erosion, filtration, infiltration, isolation, meandering, shading, and subsidization. In addition, we identified riparian features that may directly support freshwater fishes and mussels' functions depending on their life history. Meta-analyses, reviews, and primary research articles were assessed to provide some guidance on the extent of riparian habitat required to support these seven processes. We outlined the current state of the literature regarding the extent of habitat required, and denoted where more empirical evidence is required. The dependencies of each process on attributes of the floodplain and other important considerations were summarised and can be consulted to determine what riparian features should be protected as Critical Habitat for a listed species. We have included additional resources to aid in the application of this guidance when defining the geographical area to be protected. Finally, five case-studies were used to provide an example of how practitioners may apply the guidance provided here to determine riparian Critical Habitat for a listed species.

INTRODUCTION

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent advisory panel to the Minister of Environment and Climate Change Canada, assesses the conservation status of wildlife species based on a status report (Figure 1). Members of COSEWIC are wildlife biology experts from academia, government, non-governmental organizations, the private sector, and indigenous knowledge-holders.

Once COSEWIC has assessed a given species as special concern, threatened, endangered, extirpated or extinct, the Minister of Environment and Climate Change Canada (ECCC) considers the species for listing under *Species at Risk Act* (SARA). ECCC sub delegates the assessment of aquatic species to the Minister of Fisheries and Oceans Canada (DFO). Depending on their status, species at risk are listed in one of following categories: data deficient, special concern, threatened, endangered, extirpated or extinct (Figure 2). Under the *Act*, species or designatable units (DUs) listed as threatened, endangered or extirpated and their critical habitats receive protection. The most current List of Wildlife Species at Risk in Canada is available at the Species at Risk Registry website.

The goals of the *Species at Risk Act* are to avoid wildlife species from becoming extinct or extirpated, help with the recovery of threatened, endangered or extirpated, species, and ensure that species of special concern do not become threatened or endangered.

There are many anthropogenic and natural threats that may endanger wildlife species. The International Union for Conservation of Nature (IUNC) threat categories that can impact freshwater aquatic resources include (Salafsky et al. 2008; Faber-Langendoen et al. 2012; Master et al. 2012):

- **Residential and commercial development** – Housing, urban, commercial, industrial, tourism, and recreation areas can all alter or destroy habitat such that it is a detriment to a species.
- **Agriculture and aquaculture** – Agriculture and aquaculture can cause pollution, and aquaculture can lead to negative species interactions resulting from escapees, and disease and pathogen transmission.
- **Energy production and mining** – Mining and quarrying can result in habitat loss or degradation if it occurs below the high water mark or in the floodplain.
- **Transportation and service corridors** – Roads, railways, utility and service lines can modify or reduce habitat and may result in barriers to movement.
- **Biological resource use** – Fishing and harvesting aquatic resources; either by targeted fishing for a particular species or as incidental harvesting such as fisheries bycatch can affect a the fish community, logging and wood harvesting; forestry activities or gathering terrestrial plants; removal of terrestrial plants for control (i.e., invasive species).
- **Human intrusions and disturbance** – Recreational activities, works and activities can modify habitat, reduce fitness or kill individuals.
- **Natural system modifications** – Fire and/or fire suppression, dams, water management, and other ecosystem modification that can alter habitat.
- **Pollution** – Discharge of household/urban waste, industrial, military, agricultural and forestry effluents, garbage and solid waste, and air-borne pollutants into the environment may impact species abundance.

- **Geological events** – Volcanoes, earthquakes, tsunamis, avalanches, and landslides can destroy or severely alter habitat where they occur.
- **Climate change** – Climate change can result in habitat shifting and alteration, droughts, temperature extremes, storms, and flooding making it difficult or even impossible for many species to survive in their current distribution range.

In most instances, more than one of these anthropogenic or natural factors is having an impact on biodiversity. While some of the listed threats may act directly on the aquatic habitat, many occur outside of the aquatic habitat in the riparian zone, i.e., the area between the high water mark and the upland area. The following threats are likely to act in particular on the riparian habitat: residential and commercial development, agriculture, forestry, mining, road crossings, and recreational activities.

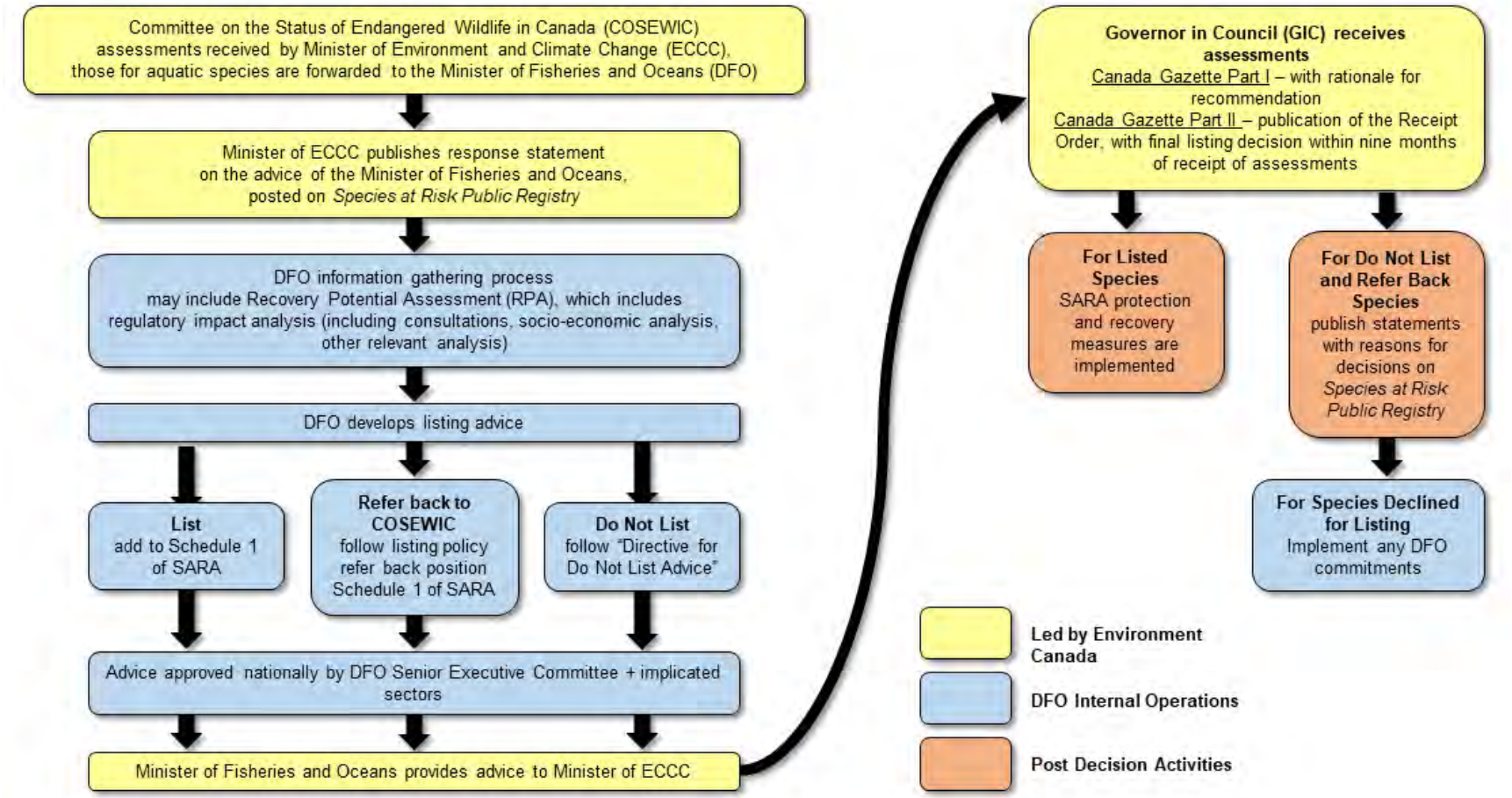


Figure 1: Listing process for Species at Risk.

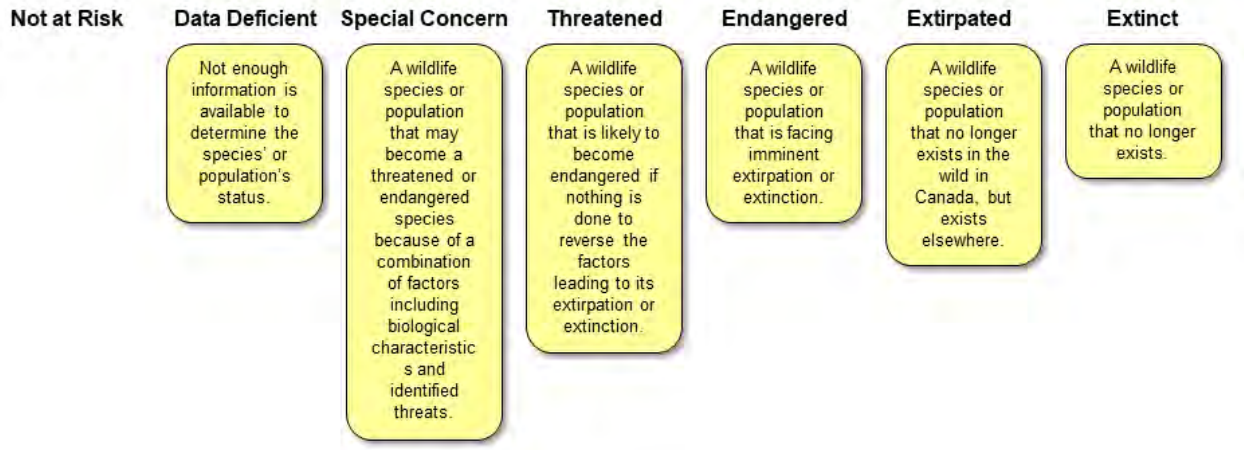


Figure 2: Species at Risk categories. Every Recovery Strategy and Action Plan developed for a species listed in Schedule 1 of the Act as Threatened, Endangered or Extirpated[1] must identify that species' Critical Habitat, to the extent possible.

DFO's Species at Risk program is responsible for carrying out DFO's mandate under the *Species at Risk Act* (SARA) to protect, recover, and conserve all listed aquatic species at risk in Canada. When an aquatic species is listed on Schedule 1 of SARA as threatened, endangered or extirpated, DFO is required to identify and protect habitat needed for the survival and recovery of the species (Figure 3), which is linked to the population and distribution objectives established in the Recovery Strategy. The identification is based on the best available information (Figure 4). According to SARA, Critical Habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species". For aquatic species, the Critical Habitat may include areas in the riparian zone.

[1] Species listed as Extirpated under SARA may not require the identification of Critical Habitat unless a program of re-introduction is proposed.

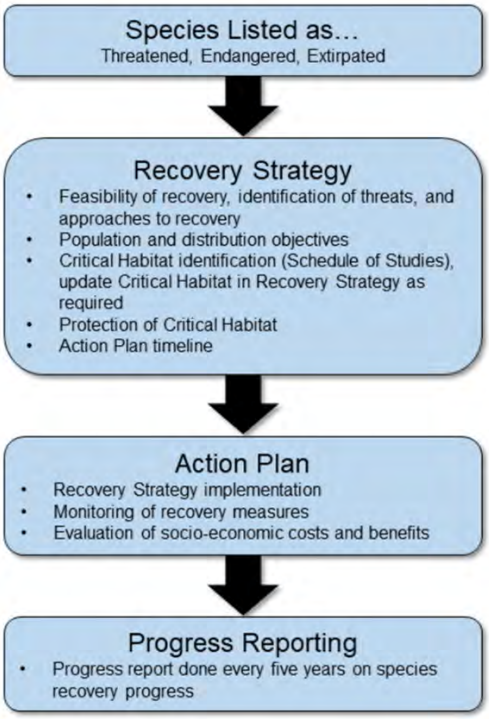


Figure 3: Process followed for protection and recovery of at risk species used by DFO following SARA. Critical Habitat is designated in the Recovery Strategy.

In the DFO (2015) “Guidelines for the identification of Critical Habitat for aquatic species at risk”, riparian zones are defined as features outside the aquatic ecosystem which support the establishment and maintenance of deep and shallow pool features, supply food for migrating and juvenile fish of many species, and influence water temperature (e.g., tree shade). However, as this riparian zone definition is based on the requirements of only a few fish species, it may not represent the features that support most freshwater fishes and mussels’ life cycle processes taking place in Critical Habitat (i.e., functions). Consequently, guidance is required that builds upon and complements the Department’s existing approaches to identify riparian Critical Habitat, in order to make scientifically-defensible decisions about the identification of Critical Habitat in the freshwater riparian zone.

For the purpose of this research document, riparian zone was defined as the area located between a waterbody’s high water mark and the upland area. However, other factors such as groundwater recharge areas that may extend further than the riparian zone but still affect aquatic and/or riparian features may also be considered.

The Species at Risk program has requested advice from DFO Science to ensure a more rigorous and systematic approach to identify Critical Habitat in the riparian zone. The purpose of this research document is to provide guidance on the identification of Critical Habitat in the riparian zone for freshwater species at risk.

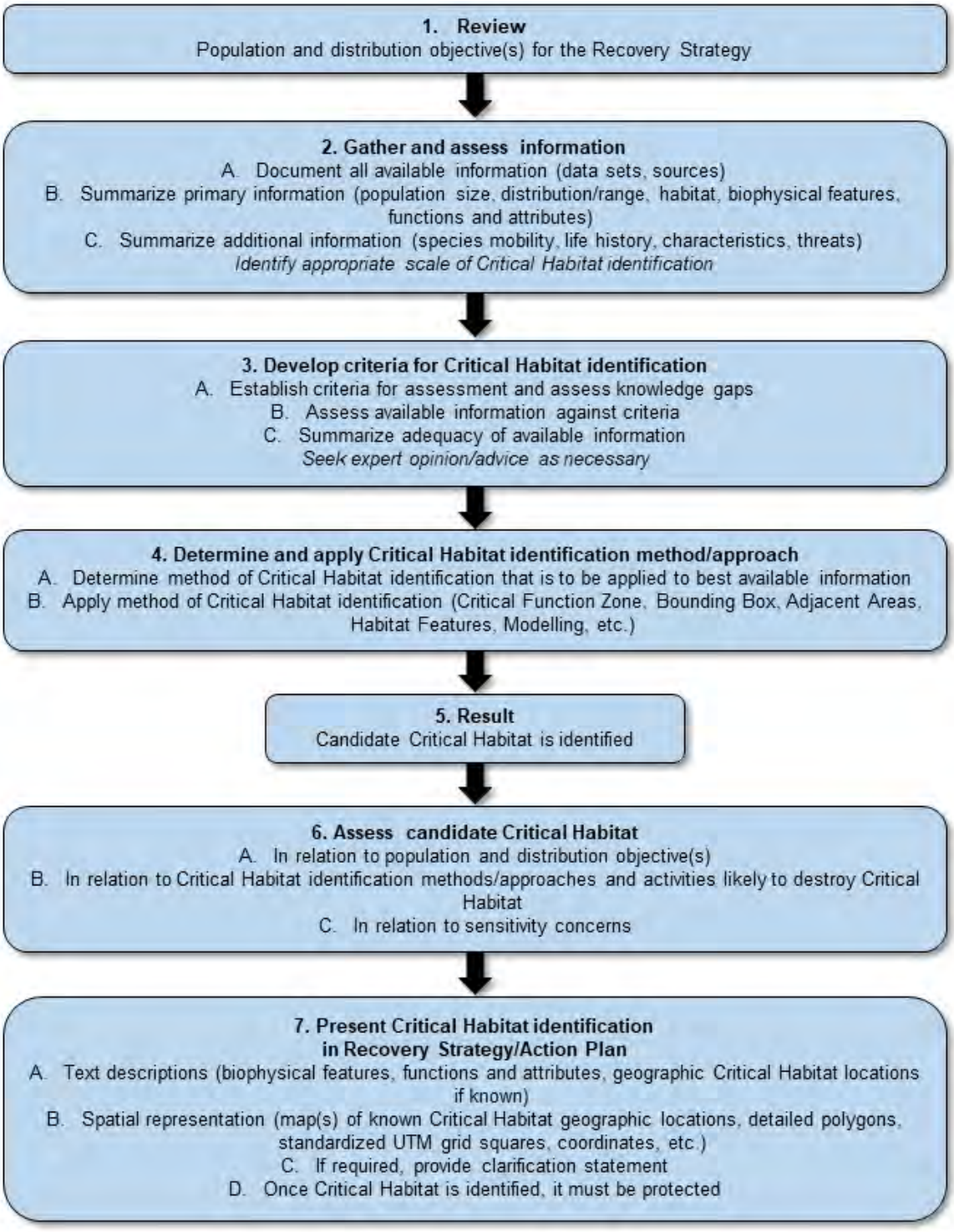


Figure 4: Steps for identification of Critical Habitat of a species or designatable unit of a species for the development of the Recovery Strategy/Action Plan.

The specific objectives are to:

1. Provide guidance on how to determine when riparian features constitute Critical Habitat,

2. Identify the suite of riparian features that provides for freshwater fishes and mussels' functions,
3. Provide, where available, Science Advice on the extent of the riparian zone that is important for features that constitute Critical Habitat, and
4. Present case studies illustrating the use of the guidance for practitioners.

WHEN RIPARIAN HABITAT IS CRITICAL HABITAT

SARA provides protection of the habitat of listed freshwater fishes and mussels since many of the threats to persistence are habitat related, and these habitats will need to be protected to ensure recovery. To determine Critical Habitat, a biophysical description is used. The biophysical elements of Critical Habitat are broken down into: functions, features, and attributes (Figure 5). Functions describe a species' use of habitat and are supported by feature(s) (DFO 2015). Features are the biophysical components of the Critical Habitat that have the capacity to support a function necessary to achieve the species' population and distribution objectives (DFO 2015). Some features designated as Critical Habitat may support functions indirectly by supporting or reinforcing other features (DFO 2015). These features may be outside of the aquatic ecosystem, i.e., in the riparian zones. Every feature is comprised of many attributes, which are the measurable characteristics that enable the feature to support the species' functions (DFO 2015). Attributes provide the greatest level of information about a feature, the quality of the feature, and the mechanism by which the feature is able to support a particular life-cycle requirements of a species (DFO 2015).

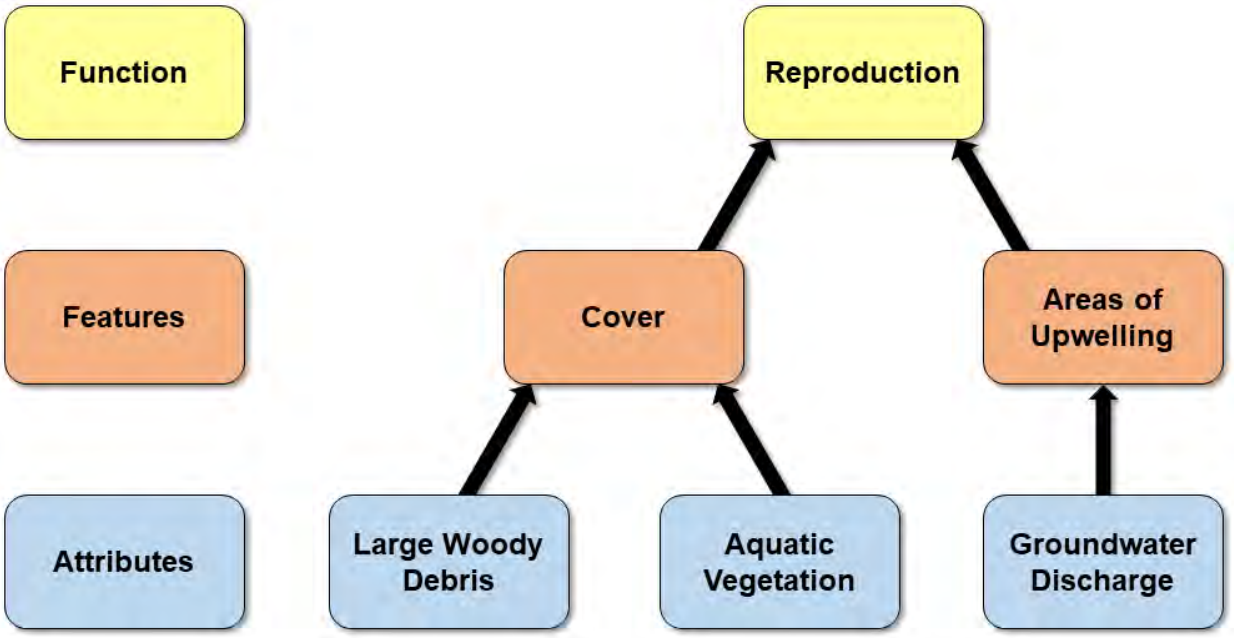


Figure 5: Flow chart representing examples of life-history functions, critical habitat features, and critical habitat attributes.

There is an extensive body of literature outlining the importance of the riparian zone for freshwater aquatic habitats (Pusey and Arthington 2003; Lind et al. 2019), freshwater fishes (Murdoch et al. 2020), and mussels (Zawal et al. 2016). Despite that riparian features clearly support the maintenance of the aquatic habitat, they are not consistently included as Critical

Habitat. For species assessed by COSEWIC as threatened, endangered or extirpated, DFO Science conducts a Recovery Potential Assessment (RPA) in which candidate Critical Habitat may be outlined (Figure 1). This research document contains information to the extent possible to determine the feasibility of recovery of the species (ECCC 2017). The science advice contained in the RPA is used in the development of a Recovery Strategy for species that are deemed to be recoverable (Figure 4). The Recovery Strategy identifies threats to a species or its habitat, defines Critical Habitat to the extent possible, and sets population and distribution objectives for the recovery of the species (ECCC 2017). The process is led by the Species at Risk program (Figure 1).

IDENTIFICATION OF RIPARIAN CRITICAL HABITAT FOR CURRENTLY LISTED SPECIES

Of the 34 RPA reports currently available for freshwater fish and mussel species listed in the SARA registry as threatened, endangered or extirpated, ten mention riparian zones when discussing habitat needs for the species (nine fishes, one mussel). Of the ten species where riparian zones are mentioned, eight were stream or river dwelling and two were lake dwellers. Six RPAs mention ‘riparian habitat’ or ‘riparian vegetation’, while four RPA reports mention specific riparian features/attributes including: woody debris, terrestrial food sources, undercut banks, cover, bank stability, shade, and protection from adjacent land use. The RPA for several species indicated that there was currently a lack of data or understanding when attempting to define candidate Critical Habitat for the species, which may have contributed to the lack of inclusion of riparian zones as candidate Critical Habitat.

Of the available Recovery Strategies for species listed as threatened or endangered, 33 fish species/populations and ten mussel species were found to have Recovery Strategies. Of these, nine fish species (twelve populations) had riparian habitat included as part of their Critical Habitat. Of the nine fish species, five are river dwelling species and four are lake dwelling (seven populations). Four Recovery Strategies only specified riparian habitat to that basic level, while the other eight Recovery Strategies addressed the contributions of riparian habitat to aquatic habitat including: protection of the integrity of other aquatic features such as riffle and shallow pool habitat, large and small woody debris input, localized bank stability, shade to help control instream temperatures, terrestrial insect/food input, limiting added nutrients or contaminants, and maintaining natural channel morphology.

Almost all of the Recovery Strategies we reviewed, including the ones that did not include riparian zones as Critical Habitat, incorporated the loss, damage or reduction of riparian zones as a threat to the species, and included protection or recovery of riparian zones in the recovery planning sections. Taken together, this indicates a need for guidance on how to determine when riparian features constitute Critical Habitat.

HOW TO DETERMINE IF RIPARIAN HABITAT IS CRITICAL HABITAT

Richardson et al. (2010) suggested that riparian habitat should be considered as Critical Habitat if impaired riparian performance affects aquatic habitat quality or water quality in a way that negatively impacts the survival or recovery of a species at risk. Riparian performance is impaired if the riparian features (Figure 6) are not able to support the life-history functions of fishes and mussels. Therefore, riparian features should be considered as Critical Habitat if they are necessary to maintain aquatic habitat or water quality attributes required for the survival or recovery of freshwater fishes and mussels (Figure 7a). If a riparian feature affects aquatic habitat features identified as Critical Habitat, that is a clear path forward for identifying the riparian feature as Critical Habitat (Richardson et al. 2010). Current SARA guidelines on determining Critical Habitat do not provide guidance on how to include water quality as Critical

Habitat (DFO 2015) since water quality isn't a feature but rather a set of attributes common to most aquatic features. In this sense, any riparian feature that affects water quality, in turn affects any aquatic features that would be impaired by poor water quality. However, riparian features located upstream of aquatic Critical Habitat features may influence water flow and quality attributes of aquatic Critical Habitat, and should also be considered when defining riparian Critical Habitat.

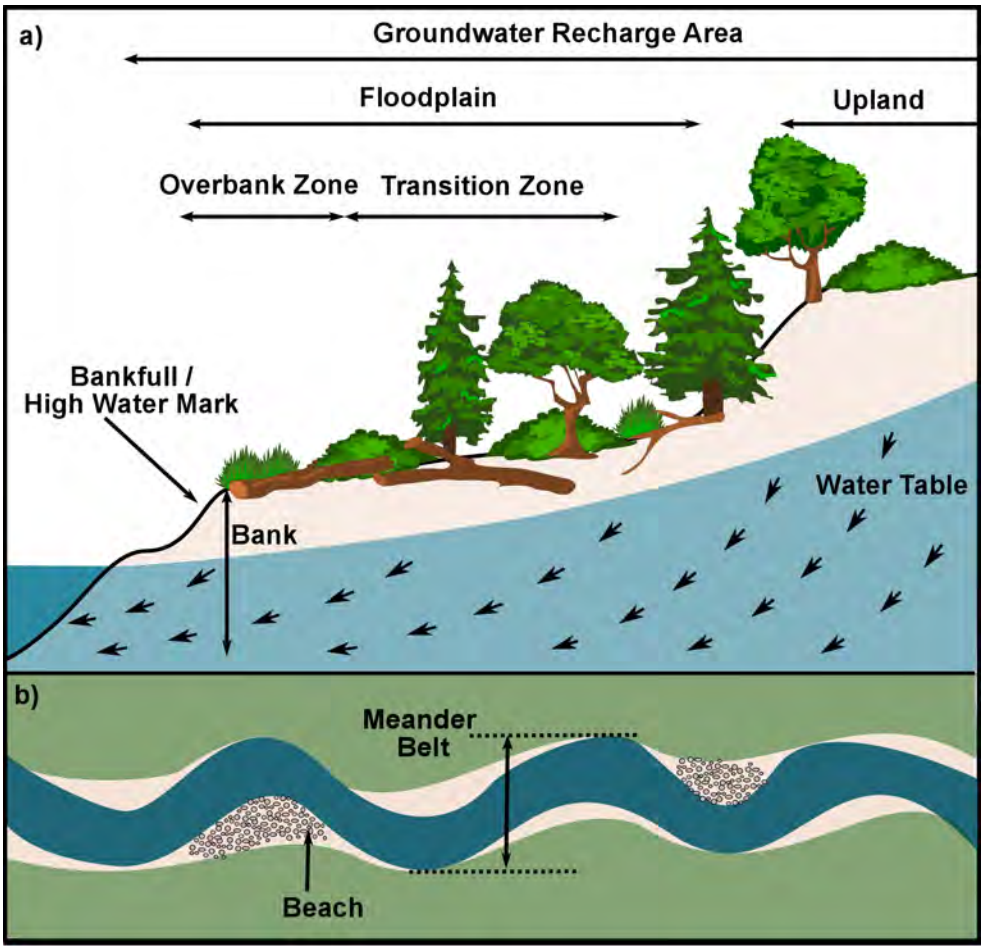


Figure 6: Schematic of riparian features from two different perspectives, cross-sectional (a) and aerial (b).

The boundary between terrestrial and aquatic habitats isn't necessarily a barrier for freshwater fishes and mussels. Due to changes in water level (i.e., flooding), the ability to tolerate desiccation or life-history requirements, riparian features may also directly support the functions of some freshwater fishes or mussels. Riparian features that directly support functions required for the survival or recovery of freshwater fishes and mussels should also be included as Critical Habitat (Figure 7b).

Consequently, we suggest that riparian features are Critical Habitat when they:

1. are necessary to maintain aquatic features identified as Critical Habitat,
2. are necessary to maintain water flow and quality upstream of Critical Habitat; or
3. support functions necessary for the survival or recovery of a listed wildlife species.

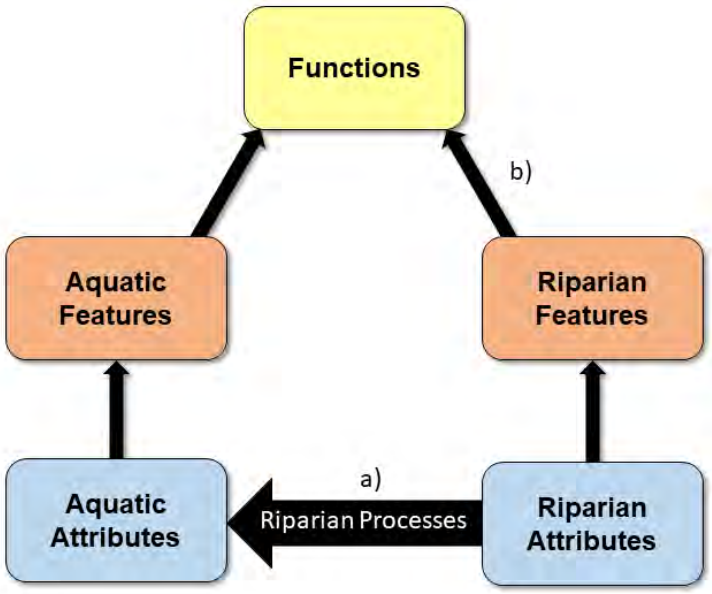


Figure 7: Riparian features can constitute Critical Habitat through a) their indirect effects of riparian processes on aquatic features considered critical habitat or b) through direct effects on a species' functions.

RIPARIAN FEATURES THAT AFFECT AQUATIC HABITAT FEATURES AND WATER QUALITY ATTRIBUTES

The definition of the riparian zone used in this research document is the area located between a waterbody's high water mark and the upland area. The ecosystem in the riparian zone has unique physical, geomorphological, and chemical properties. The riparian ecosystem acts as an interface between aquatic and terrestrial habitats, and is sensitive to environmental change (Naiman and and Décamps 1997). Activities that occur in the riparian zone have direct implications for the aquatic habitat due to the strong connections between aquatic and riparian features.

While there are many nuanced and varied ways that riparian features interact with aquatic features, they do so by the means of a few processes. The seven main processes by which riparian features support aquatic features are: erosion, filtration, infiltration, isolation, meandering, shading, and subsidization (Figure 8). These processes are dynamic and occur within a range of natural of variation that needs to be considered when defining riparian areas as critical habitat.

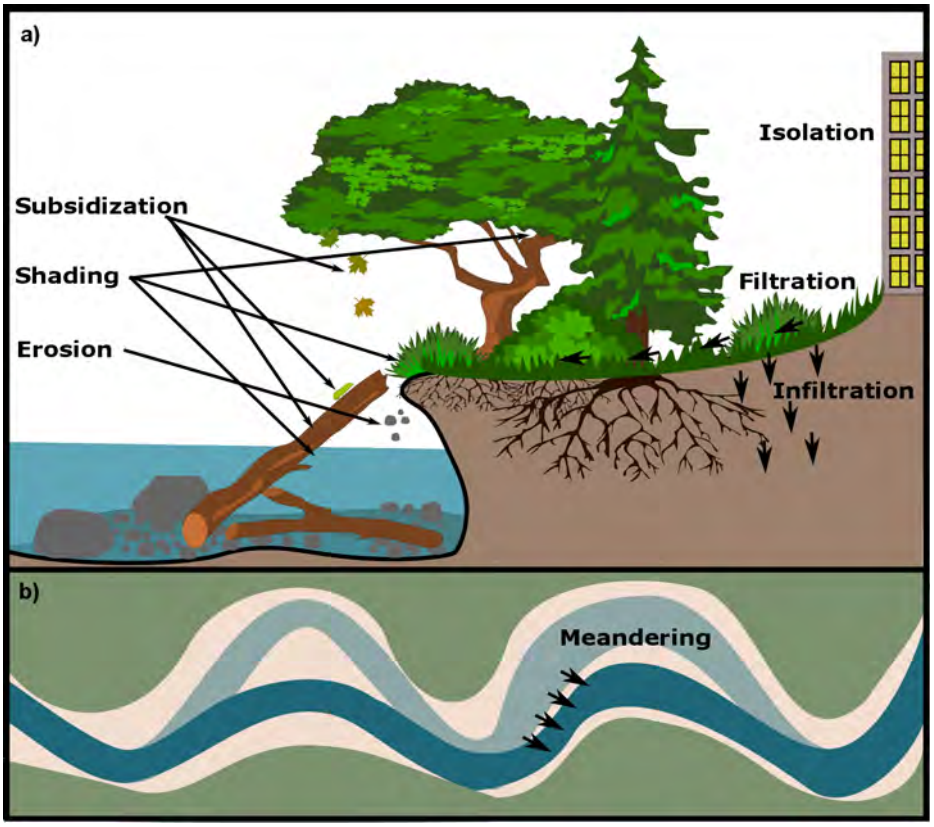


Figure 8: The seven main processes by which features in the riparian zone maintain aquatic features from two different perspectives, cross-sectional (a) and aerial (b).

Erosion

Erosion is the process of soil gradually wearing away by wind, water or gravity. When erosion is occurring within a natural range of variation, it controls sedimentation and siltation; supporting aquatic attributes such as aquatic vegetation and interstitial spaces. Natural levels of erosion prevents contaminants and excess nutrients in the soil of the overbank zone from entering the waterbody (Fox et al. 2016) and maintains water clarity. Controlling sedimentation maintains spaces between coarse sediment, affecting dissolved oxygen levels in the waterbody (Wood and Armitage 1997). These attributes support features such as backwater, cover, eddies, lake benthic habitat, lake littoral habitat, photic environment, riffles, shoals, and wetlands. Erosion in the floodplain is moderated through riparian vegetation by maintaining bank and beach structure (Mondal and Patel 2018).

Filtration

Filtration is the process of removing matter, light or sound from air or water. Filtration prevents contaminants and excess nutrients in surface and subsurface water in the riparian zone from entering a waterbody (Miller et al. 2016; Yu et al. 2019). Riparian vegetation maintains aquatic features such as the acoustic and photic environment by filtering artificial light and sound from the riparian zone and upland areas. When riparian vegetation and soils are maintained in their natural state, their filtration capacity maintains water quality attributes of many aquatic features (Smiley, Jr. et al. 2011; Yu et al. 2019). A lack of contaminants, and maintenance of natural levels of pH and nutrients (i.e., water quality) is an attribute of several aquatic features including:

backwater, cover, eddies, food availability, host species, lake benthic habitat, lake littoral habitat, lake pelagic habitat, migration/movement corridors, and wetlands.

Infiltration

Infiltration is the process by which surface water enters the soil. Riparian vegetation provides shading and structure that prevents evaporation, runoff, and allows surface water in the riparian zone to infiltrate into the water table. Natural levels of infiltration affects the movement of surface and subsurface water into the waterbody thereby maintaining natural flow and water levels. Flow and level directly impact many aquatic habitat features including backwater, cover, eddies, glides, host species, upstream habitat, migration and movement corridors, pools, riffles, runs, shoals, and wetlands.

Infiltration into the soil in the floodplain allows for filtration to occur before contaminants and excess nutrients can enter waterbodies maintaining water quality (National Research Council 2002). The infiltration of surface water in the riparian zone prevents warm water from running off directly into the water body altering water temperature (Herb et al. 2008), recharging groundwater reserves that provide areas of upwelling in waterbodies (Chu et al. 2008). Infiltration can occur over diffuse areas of low infiltration rates or localised areas of high infiltration rates that allow for precipitation to infiltrate the water table quickly.

Isolation

Isolation is the process of causing a place or thing to be distanced from a disturbance. The intensity of noise and light decreases the farther away the source. Therefore, the riparian zone isolates the water body from noise and light pollution that can affect the acoustic and photic environment. Restrictions on human use of a riparian zone can isolate waterbodies from physical disturbances such as trails within the waterbody. The protection of riparian zones from human use (e.g., agriculture and forestry) or development (e.g., mining and road construction) provides isolation from sources of contamination, excess nutrients, and excessive vibrations.

Meandering

Meandering is the process of a stream or river moving back and forth, changing shape as it flows across a floodplain or valley eroding and depositing sediments on alternating banks (Callander 1978). Natural levels of meandering by a river or stream creates habitat features such as cover, backwater, and shoals. Meandering affects flow and level of rivers and streams through the changes in river or stream morphology (DFO et al. 2011). Meandering may also support sympatric speciation through creating barriers to gene flow (Ruzzante et al. 2019).

Shading

Shading is the process of adjusting the amount of light admitted onto a surface. Shading in the aquatic habitat by vegetation, large woody debris (LWD), and undercut banks provides cover (Raines and Miranda 2016; Vargas-Luna et al. 2018) and maintains the photic environment. Shading by riparian vegetation maintains natural variation in temperature of water in the aquatic habitat (Broadmeadow and Nisbet 2004), and of surface and subsurface water in the riparian habitat (Moore et al. 2005).

Subsidization

Subsidization is the process of transferring energy, food, and structural components from the terrestrial habitat to the aquatic habitat. Riparian features provide food for fishes (e.g., terrestrial insects), mussels (e.g., organic matter) and their aquatic prey (e.g., nutrients and organic

matter). Nutrient subsidies provide energy and support aquatic vegetation, which provides cover and supports features such as backwater and wetlands. In addition, riparian vegetation and soil subsidies in the aquatic habitat provide sensory cues that may direct fish migration along their migration corridors. Natural riparian vegetation provides carbon, nitrogen, and phosphorus needed for primary production in the aquatic habitat (Brett et al. 2017). Natural weathering of bedrock supplies the calcium pool in catchment soils and riparian vegetation, which is then is exported to waterbodies (Reid et al. 2019).

Coarse sediment, such as gravel and boulders from banks and beaches, in the riparian zone is transferred into waterbodies as a result of erosion processes and meandering. The subsidization of wood, also termed wood recruitment, is the addition of wood into waterbodies from the associated riparian trees as a result of the mortality of individual trees, disturbances affecting multiple trees or meandering of a river or stream (Warren et al. 2009). Wood and coarse sediment subsidization has many roles including creating habitat (e.g., pools), providing cover (e.g., LWD and root wads), and changing channel dynamics in streams and rivers. LWD in rivers can alter flow dynamics reducing the formation of destructive frazil and anchor ice (Nilsson et al. 2013).

THE EFFECT OF RIPARIAN FEATURES ON AQUATIC FEATURES

We performed a literature review to determine current scientific evidence regarding the effect of riparian features on aquatic features and water quality attributes. The literature review was conducted by searching for articles that correspond with a general set of search terms developed to identify articles regarding the effect of the riparian zone on freshwater habitats, and then refined for specific aquatic habitat features from a standardized list of Critical Habitat features and specific aquatic water quality attributes identified in a preliminary search of articles on water quality (Appendix 1). To determine which riparian features may be considered Critical Habitat through their impact on aquatic Critical Habitat features (Figure 7a), their associated processes were outlined for each aquatic feature (Table 1) and water quality attribute (Table 2).

Table 1: The features in the riparian zone that have an effect on aquatic features, and the processes by which these riparian features impact them. The details pertaining to water quality attributes are found in a separate table (Table 2) to reduce redundancies.

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Acoustic environment	sound intensity	filtration, isolation	Riparian features filter out and isolate waterbodies from anthropogenic noise (e.g., road/bridge traffic, urbanization) that can interfere with acoustic signal-to-noise ratios, mask signals or alter organismal behavior.	beach, floodplain	(Mickle and Higgs 2018; Reid et al. 2019)
Areas of upwelling	groundwater discharge	infiltration	Upwelling in the freshwater habitat is caused by groundwater discharge that is recharged in the groundwater recharge area.	floodplain, groundwater recharge area	(Ouellet et al. 2017)
Areas of upwelling	water quality*	-	-	-	-
Backwater	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation can reduce flow to create backwater and is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Cheng and Yong-ming 2008; Jones et al. 2012)
Backwater	-	meandering	Channel migration in the meander belt creates backwater.	meander belt	(Biron et al. 2018)
Backwater	-	erosion	Riparian vegetation maintain banks from eroding and separating backwater from the waterbody.	bank, beach, floodplain	(Mondal and Patel 2018)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Backwater	large woody debris (LWD)	subsidization	Backwater is created by LWD being recruited from the floodplain.	floodplain	(Lehane et al. 2002; Seo et al. 2010)
Backwater	water quality*	-	-	-	-
Cover	groundwater discharge	infiltration	Upwelling groundwater is recharged in the groundwater recharge area.	floodplain, groundwater recharge area	(Malcolm et al. 2005)
Cover	interstitial spaces	erosion	Vegetation in the floodplain controls erosion, which prevents sedimentation that fills interstitial spaces.	bank, beach, floodplain	(Wohl 2015)
Cover	-	shading, erosion, meandering	Undercut banks are maintained through erosion control in the floodplain and created by meandering in the meander belt.	bank, beach, floodplain, meander belt	(Florsheim et al. 2008; Vargas-Luna et al. 2018)
Cover	LWD	subsidization, shading	LWD in the floodplain provides shading. LWD that falls into the aquatic habitat from the floodplain creates complex habitat and cover.	floodplain	(Crook and Robertson 1999)
Cover	small woody debris	subsidization	Small woody debris that falls into the aquatic habitat from the floodplain creates shelter for juveniles and small-bodied fishes.	floodplain	(Enefalk and Bergman 2016)
Cover	-	shading	Overhanging riparian vegetation in the overbank zone provides cover.	bank, floodplain	(Raines and Miranda 2016)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Cover	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the availability of refugia and cover.	floodplain, meander belt	(National Research Council 2002; Logez et al. 2016)
Cover	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation provides cover and is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Jones et al. 2012; Massicotte et al. 2015)
Eddies	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation causes swirling and is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Nepf 2012; Jones et al. 2012)
Eddies	LWD	subsidization	LWD that falls into the aquatic habitat from the terrestrial habitat creates obstacles that create eddies.	floodplain	(Lehane et al. 2002)
Eddies	flow	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the flow regimes of eddies.	floodplain, meander belt	(National Research Council 2002)
Eddies	water quality*	-	-	-	-

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Food supply	terrestrial and amphibious prey	subsidization	Terrestrial and amphibious prey species in the floodplain supply food in the aquatic habitat due to incidental use or their life-history requirements.	floodplain	(Albertson et al. 2018)
Food supply	terrestrial organic matter	subsidization	Transfer of organic matter from the floodplain to the aquatic habitat supplies food for freshwater fishes and mussels.	floodplain	(Brett et al. 2017)
Food supply	aquatic insects	subsidization	Some life-history stages of aquatic insects (e.g., adult stage) require use of the floodplain, aquatic insects also need terrestrially sourced nutrients and organic matter.	bank, beach, floodplain	(Harabis 2017)
Food supply	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(Jones et al. 2012)
Glides	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the flow regimes of glides.	floodplain, meander belt	(National Research Council 2002)
Glides	water quality*	-	-	-	-

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Host species (availability of)	water quality	filtration	Terrestrial sources of nitrates filtered by the floodplain affect the ability of mussels to attach to host.	floodplain	(Moore and Bringolf 2018)
Host species (availability of)	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects host attachment by mussels.	floodplain, meander belt	(National Research Council 2002; Modesto et al. 2018)
Upstream habitat	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects upstream habitat.	floodplain, meander belt	(National Research Council 2002)
Upstream habitat	water quality*	-	-	-	-
Lake benthic habitat	sediment	filtration, erosion	Erosion and filtration of contaminants in the floodplain affects sediment quality and quantity in benthic habitat.	bank, beach, floodplain	(Crane 2017)
Lake benthic habitat	water quality*	-	-	-	-
Lake littoral habitat	aquatic vegetation	erosion, filtration, subsidization	Filtration and erosion in the floodplain, and littoral habitat alteration affects the presence of aquatic vegetation in lake littoral habitats.	bank, beach, floodplain	(Doi et al. 2010)
Lake littoral habitat	water quality*	-	-	-	-

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Lake pelagic habitat	water quality*	-	-	-	-
Migration/Movement corridors	sensory cues	subsidization, filtration	Sensory cues that support homing or initiate migration may come from or be disrupted by contaminants from the floodplain.	floodplain	(Scholz et al. 1976)
Migration/Movement corridors	flow and level	infiltration	Infiltration in the floodplain affects flow rates and water level which affects hydrological connections between critical habitats.	floodplain	(Crook et al. 2015)
Migration/Movement corridors	water quality*	-	-	-	-
Photic environment	artificial light	filtration, isolation	Filtration in the floodplain of, and isolation from, light pollution (street lights, houses, etc.) affects parental care behaviour of a fish, timing of migration, and dial movements of prey.	floodplain	(Foster et al. 2016; Reid et al. 2019)
Photic environment	shade	shading	Shading from riparian vegetation, overhanging banks, and LWD in the overbank zone affect the quantity and quality of light in the aquatic habitat.	bank, floodplain	(Pusey and Arthington 2003)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Photic environment	turbidity	erosion, filtration	Riparian vegetation in the floodplain affects sediment load in the waterbody by control of erosion and filtration of surface water that would otherwise increase turbidity.	bank, beach, floodplain	(Vargas-Luna et al. 2018)
Photic environment	water colour	subsidization, filtration	Lack of browning or greening of water due to filtration of terrestrial nutrient or organic matter in the floodplain affects the photic environment.	floodplain	(Karlsson et al. 2009)
Pools	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the connectivity of pools in the waterbody.	floodplain, meander belt	(National Research Council 2002)
Pools	LWD	subsidization	The addition of LWD from the floodplain increases the presence of pools in rivers and streams.	floodplain	(Davidson and Eaton 2013)
Pools	water quality*	-	-	-	-
Riffles	exposed coarse sediment	erosion, meandering, subsidization	Erosion control in the floodplain reduces sediment load in the waterbody which maintains exposed coarse sediment. Meandering and erosion of beaches and banks subsidizes coarse sediment.	bank, beach, floodplain	(National Research Council 2002)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Riffles	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the production of riffles as they require appropriate flow regimes.	floodplain, meander belt	(National Research Council 2002)
Riffles	LWD	subsidization	The addition of LWD from the floodplain increases the presence of riffles in rivers and streams.	floodplain	(Davidson and Eaton 2013)
Riffles	water quality*	-	-	-	-
Runs	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects the production of runs as they require appropriate flow regimes.	floodplain, meander belt	(National Research Council 2002)
Runs	water quality*	-	-	-	-
Shoals	flow and level	infiltration, meandering	Infiltration in the floodplain and meandering in the meander belt affects flow rates and water level which affects whether the shoal is submerged.	floodplain, meander belt	(National Research Council 2002)

Aquatic features	Aquatic attributes	Process	Details	Riparian features	Source(s)
Shoals	sediment	meandering, erosion	Erosion of banks and beaches, and meandering in the meander belt affects sedimentation in the riparian zone, which can add or remove shoals.	bank, beach, floodplain, meander belt	(National Research Council 2002)
Shoals	water quality*	-	-	-	-
Sympatric species	-	meandering, subsidization	Hierarchical, dendritic, spatially fragmented systems may exhibit high genetic diversity. Allowing natural processes to create dendritic channels and oxbow lakes could support sympatric speciation.	floodplain, meander belt	(Ruzzante et al. 2019)
Wetlands	aquatic vegetation	erosion, filtration, subsidization	Aquatic vegetation is supported by the floodplain through control of sedimentation, siltation, water clarity, light, and nutrient inputs.	bank, beach, floodplain	(National Research Council 2002)
Wetlands	flow and level	infiltration, groundwater discharge	Wetlands are maintained through flow from rivers and streams, groundwater inputs, and run-off from floodplain.	floodplain, groundwater recharge area, meander belt	(National Research Council 2002)
Wetlands	water quality*	-	-	-	-

Table 2: Riparian features and processes that impact water quality attributes.

Aquatic Attributes	Process	Details	Riparian Features	Source(s)
Contaminants	erosion, filtration, infiltration, isolation	Contaminants in surface water and sediments are filtered by riparian vegetation and sediments (through infiltration) in the floodplain and are prevented from entering the aquatic habitat through erosion control and isolation.	bank, beach, floodplain	(Yu et al. 2019; Reid et al. 2019)
Dissolved oxygen	erosion, filtration	Natural levels of dissolved oxygen available to fishes and mussels in a waterbody can be maintained through filtration of nutrient and through control of sedimentation that would otherwise fill interstitial spaces.	bank, beach, floodplain	(Wood and Armitage 1997; Crossman et al. 2019)
Nutrients (P, N, C, Ca)	erosion, filtration, infiltration, subsidization	Erosion, filtration, infiltration, and subsidization in a properly functioning floodplain maintains natural levels of nutrients in waterbodies.	bank, beach, floodplain	(Stutter et al. 2019)
pH	erosion, filtration, infiltration, subsidization	pH buffering capacities of soils affects pH of surface and subsurface water, erosion inputs acidified soils into water, and leaf litter affects aquatic pH.	Bank, beach, floodplain	(Hruška et al. 2001)
Temperature	shading, infiltration	Shading of surface and subsurface water by undercut banks and riparian vegetation in the floodplain, and infiltration that recharges in the groundwater recharge area contributes to maintaining natural water temperature ranges.	bank, beach, floodplain, groundwater recharge area	(Chu et al. 2008; Albertson et al. 2018)

RIPARIAN FEATURES THAT SUPPORT THE FUNCTIONS OF FRESHWATER FISHES AND MUSSELS

The previous section described how riparian features may be considered critical habitat through their impact on aquatic Critical Habitat. Riparian features may also directly provide for the functions of freshwater fishes and mussels (Figure 7b). We performed a literature review to determine the most current scientific evidence regarding the effect of riparian features on the functions of freshwater fishes and mussels. The literature review was performed with a general set of search terms that represent the riparian zone and then refined for specific functions from a standardized list of functions (Glossary, Appendix 1). This review resulted in very few papers, denoting a sparsity of literature; in fact the lack of information on the precise effects of riparian features on the functions of freshwater fishes and mussels has been previously noted (Richardson et al. 2010).

A protected riparian zone supports several functions of freshwater fishes and mussels by making the waterbody more difficult to access, providing isolation from: harvest, introduction of invasive species, and trails and roads that may cross waterbodies and destroy habitat.

The features in the riparian zone directly support feeding and foraging of freshwater fishes or mussels that utilize terrestrial habitats during any part of their life-cycle. This will be species specific, for example fish that deposit eggs on beaches (Martin et al. 2004). Dry floodplains would be considered a riparian feature that directly supports dispersal, reproduction, and rearing for species that utilize this feature during intermittent flooding events (Henning et al. 2006, 2007). Some fishes use banks and beaches to migrate and move past barriers (e.g., eels; Trancart et al. 2018). The availability of terrestrial insects as food would be considered a riparian feature rather than a subsidized aquatic feature if the foraging occurs outside of the aquatic habitat (e.g., insects on riparian vegetation).

DELINEATING PROTECTED AREA IN THE RIPARIAN ZONE

DELINEATION OF RIPARIAN CRITICAL HABITAT FOR CURRENTLY LISTED SPECIES

Ten of the 34 RPAs available for fish and mussel species listed in the SARA registry as threatened or endangered specifically mentioned riparian habitat. In most RPAs, Critical Habitat was not defined spatially, whereas for two species, spatial judgements were made. The RPA for Salish Sucker (*Catostomus* sp.) expressed that a continuous riparian zone with a width of 5–30 m from the top of the bank was required (Pearson 2015). The RPA for Redside Dace (*Clinostomus elongatus*) suggested a width of 30 m adjacent to the meander belt (DFO 2019). The actual determination of spatial areas that contain Critical Habitat, when not specifically defined in the RPA, can be based on Science (in RPAs) or Species at Risk Program's interpretation of an RPA (as for many Great Lakes species).

Several Recovery Strategies provided guidance on how large of a riparian zone should be protected as Critical Habitat, however, there are variations on the extent of protection. For four species of Threespine Stickleback (*Gasterosteus aculeatus*, eight populations), the Recovery Strategies stated that Critical Habitat includes a 15 m riparian width around lakes where the species is found and a 30 m width around stream and marshes connecting these lakes (Fisheries and Oceans Canada 2019a). The Recovery Strategy for the St. Lawrence River population of Striped Bass (*Morone saxatilis*) only indicated the riparian zone under tidal influence as part of Critical Habitat, which is 0–2 m above the water's edge (Fisheries and

Oceans Canada 2019b), while Spotted Gar (*Lepisosteus oculatus*) Critical Habitat covers 'flooded areas' of riparian habitat (Staton et al. 2012). Speckled Dace (*Rhinichthys osculus*) Critical Habitat extends to the high water mark, but no further (Fisheries and Oceans Canada 2018a). Similarly, Carmine Shiner (*Notropis percobromus*) only includes the 'bankful channel width' (Fisheries and Oceans Canada 2013). Finally, the Nooksack Dace (*Rhinichthys cataractae* ssp.) and Salish Sucker Recovery Strategies quantified the size of the riparian zone as all riparian areas on both banks for the entire length of identified aquatic reaches of Critical Habitat (Fisheries and Oceans Canada 2019c, 2019d). For both these species, riparian Critical Habitat is deemed to be continuous and reaches inland from the top of the bank up to a width equal to the widest zone of sensitivity calculated for five riparian features and attributes: LWD, localized bank stability, channel movement, shade, and insect and debris inputs (calculated using methods consistent with those used under the British Columbia Riparian Areas Protection Regulation (Government of British Columbia 2019); i.e., 5–30 m depending on stream characteristics).

Taken together, the large range in recommended widths of riparian protection (0–30 m) in the RPAs and Recovery Strategies signifies the importance of considering the species requirements and the landscape features when recommending Critical Habitat protection in the riparian zone. The inconsistencies between species, and absence of recommendations for many species, may also signify a lack of clarity regarding how far into the riparian zone do riparian Critical Habitat features need to be protected to maintain species' functions.

PROCESSES

When defining Critical Habitat in the Recovery Strategy, it must include a clear description of the geographic area to be protected (DFO 2015). This includes the geographic area representing riparian features that are considered Critical Habitat.

The extent of riparian Critical Habitat protected should be grounded in an empirical understanding of the processes that impact the ability of the riparian zone to support freshwater fishes and mussels' functions. Current literature on these processes and species specific needs must be taken into account to determine the relationship between the amount of habitat protected and its influence on the quality of the aquatic habitat feature of interest. It is also important to consider the shape of the response curve and any dependencies of the attributes of the riparian zone (e.g., slope, land use, soil type) (Gene et al. 2019). Consequently, a single value for the extent of Critical Habitat to be protected will likely not be representative of all species or landscapes. This provides a challenge when developing a national standard.

To provide some context in terms of the information available on extent of habitat, meta-analyses and reviews, along with relevant empirical studies were consulted for each of the processes associated with riparian features. This is by no means a comprehensive summary of all research that has been performed on the topic; which would require a formal meta-analysis that was beyond the scope of this research document. Any values provided below should not be considered targets.

Erosion

The ability of features in the riparian zone to control erosion depends on many factors, however, there is a general consensus that the four main factors to be considered are the riparian attributes: slope, vegetation, soil type, and average annual precipitation (Nigel et al. 2013).

In a field study in the Portneuf region, Quebec, slopes greater than 8% (slope % = rise/run * 100) were found to be prone to erosion, leading the authors to suggest that protection of the entire slope – from the waterbody to the ledge upland – may be required (Nigel et al. 2013). The

extent of protection for shallower slopes will depend on the other three factors, i.e., vegetation, sediment, and run-off.

Ratio of root depth to bank height, root density, and surface protection are the three metrics that can be studied to understand the ability of vegetation to control erosion in the floodplain (Rosgen 2001). These metrics must be examined over a sufficient length of the shoreline as connectivity of riparian vegetation affects erosion (Rosgen 2001). The influence of vegetation on erosion is greater the higher the percentage of root depth, root density, and surface protection along the reach. Without vegetation providing sufficient root depth, root density, and surface protection, the erodibility of bank sediments and streamflow will lead to bank instability and erosion (Sweeney and Newbold 2014). Due to the deeper root systems of trees, forested floodplains are thought to provide greater protection from erosion than other vegetation types (Sweeney and Newbold 2014; Rood et al. 2015). However, grasses, which typically have a higher root density than trees, have been shown to be more efficient at preventing erosion than trees on shallower slopes (Lyons et al. 2000).

Sediments that are not compacted and/or contain more clay and organic materials are more resistant to erosion than compacted soils and/or sediments consisting of sand or silt (Blanco and Lal 2010). The water content of the soils also affects erosion, with saturated soils holding less water, leading to more runoff. Larger unstable aggregates of soil are more likely to erode (Blanco and Lal 2010).

Precipitation that flows into surface streams is called runoff. The runoff rate impacts the ability of features in the riparian zone to control erosion. Runoff is affected by meteorological factors (i.e., precipitation) as well as the physical geology and topography of the land. Unusually wet years or disturbances to upland areas will have a greater potential for increased runoff and erosion (Lee et al. 2004). Areas with higher annual rainfall and impervious upland cover (e.g., pavement) may need a greater extent of the riparian zone protected. Resilience to future environmental changes, which may increase the severity and frequency of extreme weather events need to be considered when defining riparian Critical Habitat.

Filtration and Infiltration

Riparian zones diminish the effects of runoff from agriculture and other sources of pollution on the aquatic environment through plant uptake, soil storage, and groundwater mixing. Infiltration of surface water in the floodplain reduces overland flow into waterbodies, thereby minimizing flood events and scouring. As with erosion, floodplains will be most effective at controlling runoff when water flow (overland and subsurface) is evenly distributed and soil infiltration rates are high (e.g., unsaturated sediments that are not compacted or frozen).

Localised areas of high infiltration rates that allow for precipitation to infiltrate the water table rapidly (e.g., cracks in bedrock, macropore flow) can negate the filtration capacity of a riparian zone (Orozco-Lopez et al. 2018). Depressional wetlands and other landscape features that hold water (e.g., dense vegetation) and reduce overland flow are of disproportionally higher importance in the floodplain for increasing filtration and infiltration. In addition, the presence of trees and LWD in the floodplain increases hydraulic roughness, slowing down overland flows and increasing storage capacity; thereby allowing waterbodies to recover quicker from high discharge events (Keeton et al. 2017).

Vegetation in the riparian zone can also act as a barrier to filter out noise and light pollution. Road traffic noise can be reduced by 5 m of moderately dense forest (Ow and Ghosh 2017) acting similar to artificial sound barriers constructed in populated areas.

Process-based model simulations show that the filtration and infiltration of contaminants and excess nutrients from agriculture in the riparian zone depends mainly on vegetation, slope, soil texture, the magnitude of the pollution source, contaminant type, and whether the contaminants are attached to sediment (and the size of the sediment) or dissolved in water (Dosskey et al. 2008). This leads to a wide variety of recommendations for widths. For example, when contaminants are dissolved in water, come from a plentiful source (e.g., a large active farm), and the floodplain is sloped and comprised mainly of clay, then no width would be sufficient for removing contamination or excess nutrients (Dosskey et al. 2008). In contrast, contaminants that are attached to large particles of sediment, come from a weak source, with a flat floodplain comprised of fine soils, then a 100% effectiveness could be achieved at almost any width of riparian zone.

A meta-analysis focused on agricultural lands in Sweden but also included literature from Canada and many other countries, found that riparian zones are 77–100% efficient at filtering sediment at a width of 8.8 m (range: 3.3–18 m, 44 papers), 75–100% effective at filtering nitrogen at 11 m (range: 0.7–30 m, 28 papers), and 75–98% effective at filtering phosphorus at 11 m (range: 4–18 m, 22 papers) (Lind et al. 2019). The variation in efficiency across studies was highly dependent on slope (Lind et al. 2019) and while not shown, most likely also affected by the other environmental conditions on which the filtration ability of the riparian zone depends. The response curve for sediment removal saturated at forest widths of ~30 m in a meta-analysis on forest buffers from Europe, US, and Ontario. However, the response curve for nitrate removal did not appear to saturate below widths of at least 80 m and depended on subsurface flow rates (Sweeney and Newbold 2014).

In many parts of Canada, an additional factor to be considered are limits to filtration and infiltration in the winter and spring when snow is present, grasses are flattened, and the soil is frozen. For example, most studies in landscapes dominated by agriculture regarding the ability of vegetation in the riparian zone to reduce phosphorus concentrations in waterbodies occur in warm or temperate climates (Kieta et al. 2018). A review of studies conducted in cold climates found a very wide range (from -36% to 89%) of phosphorus removal efficiencies of riparian zones that ranged from 5–50 m and comprised mainly of grasses and shrubs (Kieta et al. 2018).

Isolation

Riparian zones can act to isolate the waterbody from: sources of pollution, contaminants, invasive species, and excess nutrients; or from human use (e.g., fishing, trails) and development that can directly impact freshwater fishes and mussels' functions. The harder a waterbody is to get to, the less likely that it will be exploited. For example, the more remote a waterbody, defined by road access or visibility, the less fishing pressure and likelihood of introduction of invasive species (Drake and Mandrak 2014; Kizuka et al. 2014) suggesting that ease of access increases use.

Meandering

The movement of a stream or river across its floodplain is a natural process. The area between the furthest edge of the bends in a meandering river or stream is called the "meander belt" and the natural width of this belt will depend on the slope of the floodplain, channel depth, and presence of erosion-resistant sediments. Natural meandering by a river or stream is unlikely if the slope of the area adjacent to the stream banks is greater than 10%, while slopes less than 4% allow for meandering or braiding (Rosgen 1994). Satellite imagery can be used to determine if the river or stream has evidence of meandering (e.g., oxbow lakes, sinuosity or changes in channel location over time).

Shading

Shading by trees affects water temperature and provides cover. The ability of a forest to regulate water temperature depends on forest width, density, composition, length, and age (Feld et al. 2018). A 30 m forest on either side of the waterbody may protect from temperature increases (Sweeney and Newbold 2014; Feld et al. 2018), and is most effective for streams less than 5 m wide (Feld et al. 2018). The extent of the riparian zone required to maintain undercut banks will depend on erosion and meandering (see above).

Shading leads to a unique microclimate in forested riparian zones with different temperatures and humidity levels than open areas. Soil temperatures in forested riparian zones can be up to 10–15 °C lower under forested canopies during the daytime and 1–2 °C higher at night, likely affecting the temperature of surface and surface water entering waterbodies (Moore et al. 2005). Similarly, it has been speculated that warming of shallow ground water in harvested forests could result in increases water temperatures in streams.

Subsidization

There exists a general understanding of the importance of terrestrial subsidies for freshwater fishes and mussels (Richardson and Sato 2015). Productive riparian floodplains with grasses, trees, and shrubs contribute animals (i.e., insects, amphibians, and small mammals), leaf litter organic matter, pollen, fruits, and seeds to freshwater food webs. In general, subsidies to streams are greater from older, unharvested forests (Richardson and Sato 2015) and the use of terrestrial subsidies by fishes increases with increased aquatic pollution (Kraus et al. 2016).

A meta-analysis focused on agricultural lands in Sweden but included literature from Canada and many other countries, identified the need for a forest of 25 m (range 15–33 m, 4 papers) for insects, and 53 m (range 20–100 m, 6 papers) for amphibians and small mammals (Lind et al. 2019). Subsidies of terrestrial insects are significantly higher in undeveloped lakes (Francis and Schindler 2009) suggesting that development should be limited along lake shorelines to maintain insect subsidies. Transitions in components of the forest ecosystem (e.g., woody debris, leaf litter and hummus composition, and soil chemistry) occurred at around 10–20 m from the edge of streams in the southern Appalachians, which may denote the extent of the forest that interacts strongly with (i.e., subsidizes) the waterbodies studied (Clinton et al. 2010).

It has been suggested that floodplains should be protected to the width equal to ~30 m or the height of mature trees to support wood recruitment (Sweeney and Newbold 2014). There is also evidence that there is more LWD in waterbodies that are surrounded by older forest stands (Lind et al. 2019). Allowing a river to meander can also increase the recruitment of LWD to rivers and streams.

OTHER CONSIDERATIONS

Resilience to natural variation and extreme events

The goal of protecting riparian habitat is to ensure that there is enough area to provide the ecosystem services (i.e., processes) that it provides to the aquatic habitat. That also means maintaining a large enough riparian zone to allow for proper functioning and resilience of riparian features to natural variation and to extreme events. Resilience refers to how likely a system is to change if exposed to pressure, and its ability to recover following a disturbance (DFO 2011). Long term studies may be required to capture any loss of utility of Critical Habitat in the riparian zone due to limited protection. This speaks to the ability of any proposed widths of riparian zones to maintain the terrestrial attributes necessary to support the processes identified.

Natural (site potential) vegetation

Provision of essential processes by riparian Critical Habitat is contingent on the presence of a natural vegetation community typical of the local biogeoclimatic zone. Naturalness refers to how much a system has already been changed, directly or indirectly by human activities (DFO 2011). An altered riparian vegetation community, such as a lawn or cultivated field, may not provide key functional processes like provision of LWD inputs or solar shading. It is therefore implicit in the designation of riparian Critical Habitat that a natural vegetation community be present or if absent, that it be actively or passively restored to an appropriate vegetation community. Passive restoration through natural plant succession may require cessation of any land use activities preventing revegetation (e.g., mowing, grazing, agriculture). The natural target vegetation community can be categorized as the site potential vegetative state, which may range from low ground cover to shrubs to trees, depending on local soil conditions, climate, and moisture availability. It is important to remember that the site potential vegetation is the future potential for the site, and that existing human impacts do not influence the outcome. It should be noted, however, that if permanent infrastructure (rip-rap, buildings) is present in the riparian zone then it may not be possible to restore it to provision of natural biophysical functioning.

Scale

The magnitude of the influence of the riparian habitat on the aquatic habitat depends on the size of the waterbody. Smaller waterbodies (e.g., small streams) may have stronger connections with the riparian habitat than larger waterbodies (e.g., large lakes). However, regulations often scale with waterbody size (e.g., a multiple of channel width), resulting in less protection – in terms of distance from high water mark--for smaller waterbodies. This is due to riparian habitat, in terms of the extent of the terrestrial habitat that interacts directly with the aquatic habitat, scaling with waterbody size (Naiman and Décamps 1997). However, the extent of the riparian zone that directly interacts with the waterbody also depends on the position of the waterbody within a drainage network, the hydraulic regime, and the local geomorphology (Naiman and Décamps 1997). These aspects should be considered when defining riparian Critical Habitat based on waterbody size.

Connectivity

Riparian Critical Habitat will generally need to be located on both sides of the stream adjacent to the aquatic Critical Habitat features that riparian processes support. However, riparian habitat upstream of the identified aquatic Critical Habitat (including non-fish-bearing reaches) may also be identified if the features of upstream riparian habitat are necessary to maintain features of downstream aquatic habitat. This may occur, for example, when lack of upstream riparian habitat results in diminished bank stability and excessive sediment or nutrient inputs that adversely affect downstream aquatic Critical Habitat or when lack of shading affects downstream water quality (e.g., temperature, dissolved oxygen) or contributes to a water quality barrier between aquatic Critical Habitat features. The appropriate length of site-specific upstream riparian Critical Habitat will depend on the process that it supports, local context, and habitat requirement of the listed species. For example, the Recovery Strategy for Vancouver Island Lamprey (*Entosphenus macrostomus*) identified 100 m of upstream riparian habitat on steep spawning streams to maintain bank stability above lamprey spawning sites (MacConnachie and Wade 2016), but appropriate upstream distances could be much longer for temperature regulation (e.g., 2.5 km upstream; (Barton et al. 1985; Cross et al. 2013)).

Upland areas

Performance of the riparian zone is often dependent on the state and use of the upland areas. Although the science advice in this document pertains to Critical Habitat associated with the riparian zone, it is important to note that identifying riparian Critical Habitat will not mitigate threats to upland areas. Some upland areas may also be disproportionately important in maintaining attributes of aquatic Critical Habitat features, and therefore warrant protection. For example, the source of the geothermally heated water for the Liard Hot Springs snail (*Physella wright*) is located far outside what would be considered the riparian zone (Heron 2007). Once identified, the source location may warrant Critical Habitat designation to prevent drilling activities from interrupting the water supply to the hot spring. Similarly, discrete upland (non-riparian) areas may be essential for groundwater recharge or supply of stream base flow during prolonged low-flow periods. Furthermore, identifying Critical Habitat in the riparian zone or even upland areas, is not a substitute to adequately managing land use at the broader scale.

Host species

Under the current SARA guidelines, the availability of a host species is a considered Critical Habitat feature when necessary for the survival, recovery, and resilience of a SARA listed species. SARA does not, however, consider the habitat that supports the host as Critical Habitat. Activities occurring outside the identified critical habitat that reduce the availability of hosts inside the Critical Habitat may be considered an activity likely to destroy Critical Habitat. This may be an oversite; we feel that the inclusion of the habitat of the host species as Critical Habitat should be considered on a case-by case basis. If availability of a host species is limiting the survival or recovery of a listed species, then the habitat of the host species may also need to be considered Critical Habitat

Uncertainties

There are inherent uncertainties in the advice outlined above. Meta-analyses may provide more precise width recommendations than individual studies, and an examination of heterogeneity that many individual studies are not able to provide. However, even meta-analyses are not able to capture the range of climates encountered across Canada, tend to be limited in scope to a certain type of land use (e.g., agriculture), and due to their inclusion requirements may be limited to short-term studies. Many of the reviews and meta-analyses included above were performed in agricultural areas; because of this, there was more information regarding erosion, filtration, and infiltration than there was for isolation, meandering, shading or subsidization.

Additional resources

When defining the geographic area to be protected, additional resources may be required to determine the slope, sediment, and land cover in the area occupied by the listed species. In addition, it is important to consider the provincial guidelines for protecting riparian zones around waterbodies.

Slope data

GIS information can be downloaded or requested from the following databases:

Natural Resources Canada - Topographic Information

Government of Canada – Geospatial Data Extraction

Soil data

GIS information can be downloaded or requested from the following databases:

Canadian Soil Information Service

Government of Canada – Open Government – Detailed Soil Survey

Government of Canada – Open Government – Soils of Canada, Derived

Natural Resources Canada – Canadian Forest Service Publications: Digital mapping of soil properties in Canadian managed forests at 250 m of resolution using the k-nearest neighbor method.

Land cover data

GIS information can be downloaded or requested from the following database:

Government of Canada – Open Government – 2015 Land Cover of Canada

Provincial guidelines

When identifying Critical Habitat for SARA listed species, biologists and managers work with the provinces where the populations are located. Provinces maintain their own regulations regarding riparian habitat for the protection of waterbodies from land use practices. We reviewed existing provincial regulations, guidance, and best-practice documents and have compiled a list of those reviewed to show the differences across the country (Appendix 2). The SARA program is required to consult with the respective province on Critical Habitat designation, and often works closely with provincial regulators to establish protected zones using current provincial regulations.

CASE STUDIES

Not all species will be equally affected by the riparian zone. For example, species that are not sensitive to water quality, prefer turbid, warm waters, and live in the pelagic zone of a large lake, probably require less riparian Critical Habitat. As habitat requirements differ between species and ecosystems, the delineation of riparian Critical Habitat should be species- and site-specific and is best evaluated by species experts based on the biology of individual species using knowledge of the local landscape.

In this final chapter, we present five case studies using Mapleleaf (*Quadrula quadrula*), Redside Dace (*Clinostomus elongatus*), Salish Sucker (*Catostomus sp.*), Spring Cisco (*Coregonus sp.*), and Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) to illustrate the use of the guidance developed in this report. These case studies are by no means to be considered as a replacement for the current Critical Habitat designation.

MAPLELEAF

Mapleleaf, a freshwater mussel, is found in Canadian waters in parts of Manitoba and Ontario and are separated into two designatable units (DU): the Great Lakes – Upper St. Lawrence DU in Ontario and the Saskatchewan – Nelson River DU in Manitoba. In 2016, the Great Lakes – Upper St. Lawrence DU was downlisted from threatened status to special concern status and the Saskatchewan – Nelson River DU was downlisted from endangered status to threatened status (Fisheries and Oceans Canada 2018b). Mapleleaf requires a host species, Channel Catfish (*Ictalurus punctatus*), as part of the reproduction and development life stage.

Mapleleaf requires wetlands and runs in medium to large rivers with slow to fast flow and substrates of coarse gravel, fine gravel, sand, clay/mud mixtures, and/or mud. Water quality attributes required for survival include low contaminant levels, dissolved oxygen levels above >4 $mg \cdot l^{-1}$, and water temperatures between 0–27 °C (Table 5). A supply of plankton, including organic detritus and protozoans, is required for adult and juvenile food sources (Fisheries and Oceans Canada 2018b).

The host species, Channel Catfish require similar habitat to the Mapleleaf, generally living in streams with moderate to swift flow, with gravel, rubble, sand or mud bottoms. Channel Catfish spend the majority of their time in a residence found in holes or under cover such as sunken logs, undercut banks or rocks and also males use these areas to build a nest, which they defend during spawning. Terrestrial insects and vegetation are often sources of food for both Channel Catfish and the fish species that they prey upon. Channel Catfish is abundant and widely distributed. Consequently, their availability should not be limiting to the Mapleleaf.

The processes required to support the Critical Habitat features to support Mapleleaf include erosion, filtration, subsidization, infiltration, groundwater discharge, and meandering (Table 1). To support these processes, Critical Habitat needs to include the riparian habitat features floodplain, meander belt, bank, and recharge areas adjacent to aquatic Critical Habitat (Table 3). In addition, banks, beaches, and floodplains adjacent to upstream habitat may need to be protected to maintain the water quality and flow of aquatic Critical Habitat.

Table 3: Guidance for riparian Critical Habitat designation for Mapleleaf.

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Food supply	aquatic vegetation, leaf litter	filtration, subsidization	bank, floodplain
Runs	flow and level, coarse sediment, water quality*	erosion, infiltration, meandering, subsidization	bank, floodplain, meander belt
Upstream habitat	flow and level, water quality*	meandering, infiltration	floodplain, meander belt
Wetlands	aquatic vegetation, flow and level, water quality*	erosion, filtration, infiltration, subsidization	bank, floodplain, meander belt, groundwater recharge area
Water Quality Attributes*			
	contaminants, dissolved oxygen, nutrients, pH, temperature	erosion, filtration, infiltration, isolation, subsidization	bank, floodplain

REDSIDE DACE

Redside Dace requires pools, riffles, and areas of upwelling as Critical Habitat features to support functions necessary for the survival of the species (DFO 2019). The maintenance of these Critical Habitat features require erosion, infiltration, meandering, shading, and subsidization (Table 1). In addition, Redside Dace have specific requirements for water quality attributes including clear water <24 °C with dissolved oxygen >7 $mg \cdot l^{-1}$ (DFO 2019). To maintain these water quality attributes, the additional process of filtration is required (Table 1).

Redside Dace occurs in streams that are prone to the process of meandering. Current empirical evidence suggests that to enable meandering to occur, the width of the meander belt should be considered Critical Habitat (Table 4). Beyond the meander belt, the slope, sediment, and vegetation in the remaining floodplain will determine the extent of the riparian features to be considered Critical Habitat. Features that hold water and allow for infiltration (e.g., dense vegetation, wetlands) within the groundwater recharge area should be considered Critical Habitat to maintain areas of upwelling. The bank, beach, floodplain, and meander belt upstream of aquatic Critical Habitat, may also be considered Critical Habitat to protect water quality and flow of aquatic Critical Habitat. Finally, the meander belt and floodplain adjacent to migration and movement corridors connecting aquatic Critical Habitat may need protection to ensure water quality and flow.

Table 4: Guidance for riparian Critical Habitat designation for Redside Dace.

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Areas of upwelling	groundwater discharge, water quality*	infiltration	floodplain, groundwater recharge area
Cover	LWD, overhanging riparian vegetation, undercut banks, water quality*	erosion, meandering, shading, subsidization	bank, floodplain
Food supply	terrestrial insects	subsidization	floodplain
Movement/ migration corridors	flow and level, water quality*	infiltration, meandering	floodplain, meander belt
Pools	flow and level, LWD, water quality*	infiltration, meandering, subsidization	floodplain, meander belt
Riffles	exposed coarse sediment, flow and level, LWD, water quality*	erosion, infiltration, meandering, subsidization	floodplain, meander belt
Upstream habitat	flow and level, water quality*	filtration, infiltration	floodplain

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Wetlands	flow and level, water quality*	infiltration	floodplain, groundwater recharge areas
Water Quality Attributes*			
	dissolved oxygen, temperature, turbidity	erosion, infiltration, meandering, shading	bank, beach, floodplain, meander belt

SALISH SUCKER

The Salish Sucker is a small bodied freshwater fish that is found in low elevation, meandering headwater streams, sloughs, marshes and beaver ponds in eleven watersheds in the Fraser Valley between Surrey and Chilliwack in southern British Columbia (Fisheries and Oceans Canada, 2019d). Salish Sucker require a mixture of shallow and deep pools, riffles, and glides as habitat to support all of their life stages. Connectivity of these aquatic habitats is important, as different life stages make use of different habitat types. Riffle habitat with water depths of more than 70 cm is used for spawning, and populations that do not have riffle habitat near their marsh or pond have been known to travel long distances in order to find suitable riffle habitat for spawning. Shallow pools and glides are used as nursery and rearing habitat by young-of-the-year Salish Sucker, while juvenile and adults are most often found in the deep pool habitat (pools deeper than 70 cm). Adequate dissolved oxygen levels (≥ 4 mg·l^{-1}), water temperatures between 6 and 23 °C and low levels of sediment, nutrients and toxins are required in all aquatic Critical Habitat to support survival of Salish Sucker.

Riparian habitat has been identified as Critical Habitat for Salish Sucker in the Recovery Strategy (Fisheries and Oceans Canada, 2019d), specifically a continuous strip of native vegetation along the entire length of aquatic Critical Habitat. All seven of the processes provided by riparian habitat are required by Salish Sucker, with erosion, infiltration, filtration, and isolation providing protection to water quality attributes from agricultural runoff and sedimentation from residential land development, subsidization providing LWD for the formation of pools and is a source of terrestrial insects, a major food source of adult, juvenile, and young-of-the-year fish, shading providing cover and temperature control, and meandering causing additions of LWD and the formation of cover and pools (Table 5).

Table 5: Guidance for riparian Critical Habitat designation for Salish Sucker

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Pool	flow and level, LWD, water quality*	infiltration, meandering, subsidization	floodplain, meander belt
Riffle	exposed coarse sediment, flow and level, LWD, water quality*	erosion, infiltration, meandering, subsidization	bank, beach, floodplain, meander belt
Glide	flow, water quality*	infiltration, meandering	floodplain, meander belt
Cover	aquatic vegetation, interstitial spaces, flow and level, LWD, small woody debris, water quality*	erosion, filtration, infiltration, meandering, recruitment, shading, subsidization	floodplain, bank, meander belt, beach,
Food supply	terrestrial prey, aquatic insects	subsidization	bank, beach, floodplain
Migration /movement corridors	sensory cues, flow and level, water quality*	filtration, infiltration, subsidization,	floodplain
Photic environment	turbidity, shade	erosion, filtration, shading	bank, beach, floodplain
Upstream habitat	flow and level, water quality*	filtration, infiltration	floodplain
Water Quality Attributes*			
	contaminants, dissolved oxygen, nutrients, temperature	erosion, filtration, infiltration, isolation, shading, subsidization	bank, beach, floodplain, groundwater recharge area

SPRING CISCO

Spring Cisco is endemic to Lac des Écorces in Quebec and therefore the entire lake has been deemed Critical Habitat for this species (DFO 2014). Spring Cisco require cool, well oxygenated water, especially while spawning (i.e., <6 °C), and appear to make vertical migrations into the deeper areas of the lake to regulate temperature (DFO 2010). Erosion has been observed at Lac des Écorces leading to sedimentation of the benthic habitat in the lake (DFO 2010). The removal of riparian vegetation by residents and contamination from waste water and agricultural run-off were identified as important primary threats for Spring Cisco (DFO 2010).

Preserving habitat quality in the benthic habitat is crucial for the survival of Spring Cisco (DFO 2010). For erosion, additional protection may be required for riparian features depending on the slope and sediment (Table 6). According to the topographic map, changes in elevation of 60 m can occur in as little as 100 m from the shoreline, suggesting that some areas around the lake will have very steep slopes and protection should extend to the upland edge of the floodplain in these areas. To enable shading by trees 30 m from the high water mark may be considered Critical Habitat, however, the impact of shading by trees may not significantly contribute to the temperature of a lake of this size. In addition, the riparian zones adjacent to tributaries of the lake (i.e., upstream habitat) which are not currently considered aquatic Critical Habitat for Spring Cisco, may also need to be considered riparian Critical Habitat.

Table 6: Guidance for riparian Critical Habitat designation for Spring Cisco.

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Lake benthic habitat	sediment, water quality*	erosion	bank, beach, floodplain
Upstream habitat	flow, water quality*	infiltration	floodplain
Water Quality Attributes*			
	dissolved oxygen	erosion, filtration	bank, beach, floodplain
	temperature	shading, infiltration	floodplain
	contaminants	erosion, filtration, infiltration, isolation	bank, beach, floodplain
	nutrients (P, N, C, Ca)	erosion, filtration, infiltration, subsidization	bank, beach, floodplain

WESTSLOPE CUTTHROAT TROUT

Westslope Cutthroat Trout requires a multitude of aquatic habitat features including river and stream segments that are comprised of riffle, run, pool, and backwater features for stream-resident populations and lakes for adfluvial populations (COSEWIC, 2016). The maintenance of these aquatic habitat features require erosion, infiltration, meandering, shading, and subsidization (Table 1). In addition, Westslope Cutthroat Trout have specific requirements for water quality attributes including clear, cool, aerated water (Fisheries and Oceans Canada 2019e). To maintain these water quality attributes, the additional process of filtration is required (Table 1).

Westslope Cutthroat Trout occur in headwater streams that are subject to meandering processes to lesser extent than Redside Dace, but stream meandering still occurs. Consequently, given the scientific evidence, this suggests the width of the meander belt should be considered as Critical Habitat (Table 7). Due to its mountainous habitat, for Westslope Cutthroat Trout, slope in the remaining floodplain will determine the extent of the riparian features to be considered Critical Habitat, with sediment and vegetation playing lesser roles. Where slope is greater than 8%, the entire floodplain to the upland ledge will need to be protected to control erosion. Features that hold water and allow for infiltration (e.g., dense vegetation, wetlands) within the groundwater recharge area should be considered Critical Habitat to maintain areas of upwelling. In addition, riparian features adjacent to upstream habitat of aquatic Critical Habitat may be considered Critical Habitat to protect water quality, level, and flow. Finally, riparian habitat adjacent to migration and movement corridors connecting aquatic Critical Habitat may need protection to ensure water quality and flow.

Table 7: Guidance for riparian Critical Habitat designation for Westslope Cutthroat Trout

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Areas of upwelling	groundwater discharge, water quality*	infiltration	floodplain, groundwater recharge area
Backwater	structure, water quality*	erosion, meandering	bank, floodplain, meander belt
Cover	LWD, undercut banks, overhanging riparian vegetation. water quality*	erosion, meandering, shading, subsidization	floodplain, meander belt
Food supply	terrestrial insects	subsidization	floodplain
Migration/movement corridors	flow and level, water quality*	infiltration	floodplain
Pools	flow and level, LWD, water quality*	infiltration, meandering, subsidization	floodplain, meander belt

Aquatic Features	Aquatic Attributes	Processes	Riparian Features
Riffles	exposed coarse sediment, flow and level, LWD, water quality*	erosion, meandering, subsidization	bank, floodplain, meander belt
Upstream habitat	flow and level, water quality*	infiltration, meandering	floodplain, meander belt
Water Quality Attributes*			
	dissolved oxygen, temperature, turbidity	erosion, filtration, infiltration, groundwater discharge, meandering, shading	bank, floodplain, groundwater recharge area, meander belt

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GLOSSARY

Acoustic environment: Relating to sound in an environment.

Anthropogenic: Anything originating from human activity.

(Aquatic species) Habitat: Spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly to carry out their life processes or areas where aquatic species formerly occurred and have the potential to be reintroduced.

Areas of upwelling: Areas where deep, cold water rises toward the surface; these areas are often rich in nutrients.

Attribute: Attributes are measurable properties or characteristics of a feature. Attributes describe how a given feature supports the identified functions necessary for the species' life processes. Together, the attributes allow the feature to support the function. In essence, attributes provide the greatest level of information about a feature.

Attachment: The physical connection by which a mussel is attached.

Avoidance: Finding protection or cover from predators or adverse environmental conditions.

Backwater: A still water section of a stream or river beside the main flow but separated by a ridge or land or habitat at the margin of a riffle or run; often separated from the source during dry seasons.

Bank: The land directly on the edge of a waterbody.

Beach: A pebbly or sandy shore between high- and low-water marks.

Beach rubbing: The act of rubbing part(s) of the body on a substrate.

Birthing: The act of giving birth to young.

Communication: The sharing of information; a means of connection.

Contaminants: Substances that are considered to be toxic to organisms or having an effect on water quality.

Courtship: The behaviour of animals aimed at attracting a mate.

Cover: Something that supports species needs such as resting, predator avoidance, and protects against adverse environmental conditions.

Critical Habitat: Habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the Recovery Strategy or in an Action Plan for the species.

Dispersal: The movement of individuals away from their natal site to other habitats and other individuals.

Dissolved oxygen: The level of free oxygen dissolved in water that is available to living organisms.

Eddies: The swirling of water and the reverse current created when the water flows past an obstacle.

Erosion: Erosion is the process of soil gradually wearing away by wind, water or gravity.

Feature: Features are the essential structural components that provide the requisite function(s) to meet the species' needs. Features may change over time and usually comprise more than one attribute. A change or disruption to the feature or any of its attributes may affect the function and its ability to meet the biological needs of the species.

Feeding: Eating food or prey.

Filtration: Filtration is the process of removing matter, light or sound from air or water.

Floodplain: An area of low-lying ground directly surrounding a river, often subject to flooding.

Food supply: The quality/quantity/accessibility of food.

Foraging: Searching for food or prey.

Forest: An area of land covered mainly by trees.

Function: A life-cycle process of the listed species taking place in Critical Habitat. The identification of Critical Habitat must describe how the functions support a life process necessary for the survival or recovery of species at risk.

Glides: Slow-moving, non-turbulent flow; a glide is too shallow to be a pool and the current is too slow to be a run.

Groundwater recharge area: An area of land where precipitation and surface water is able to infiltrate the ground and enter the water table.

Growth: The process that a living organism goes through as it transitions through various life stages to adulthood.

Host species: The presence of a species able to host smaller organisms while they complete a life-cycle process necessary for survival or recovery.

Incubation: A phase in which eggs or embryos are kept clean and/or the biophysical and chemical properties of the eggs or embryos are maintained.

Infiltration: Infiltration is the process by which surface water enters the soil.

Upstream habitat: The habitat within a stream that is upstream of a critical habitat feature.

Isolation: Isolation is the process of causing a place or thing to be distanced from a disturbance.

Lake benthic habitat: Lake bottom.

Lake littoral habitat: Shallow, nearshore area often with rooted vegetation.

Lake pelagic habitat: Open water beyond littoral area; water column.

Larval settling: A phase in which swimming larvae transform and adopt a benthic lifestyle.

Meandering: Meandering is the process of a stream or river moving back and forth, changing shape as it flows across a floodplain or valley eroding and depositing sediments on alternating banks.

Meander belt: The space that a meandering watercourse occupies on its floodplain.

Migration: The periodic or seasonal movement of large numbers of individuals from one area or population to another.

Migration/movement corridors: Contiguous areas of natural habitat through which animals are able to migrate and move.

Molting: The shedding of an outer layer of epidermis.

Nest building: The act of creating a nest.

Nest defense: The act of defending a nest against predators, heterospecifics or conspecifics.

Nutrients (P, N, C, Ca): Organic and inorganic substances in the water than can be used by an organism to survive, grow and reproduce.

Overwintering: Spending winter in or at a particular place.

Photic environment: The uppermost layer of a waterbody that receives sunlight. Depth of photic environment can change dependent on turbidity of water.

Physical space: Space surrounding an individual.

Pools: Deeper areas of still water.

Rearing: Supporting offspring development to maturity or self-sufficiency, usually through nurturing care.

Reproduction: The process by which organisms give rise to offspring, and which fundamentally consists of the segregation of a portion of the parental body by a sexual or asexual process and its subsequent growth and differentiation into a new individual, which includes but is not limited to mating, spawning, gestation, birthing, calving, whelping, and dispersion.

Reproductive isolation: Habitat barriers that prevent members of different species from producing offspring, maintaining the integrity of the species by reducing gene flow between related species.

Residence: a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating.

Resting: A bodily state characterized by reduced functional and metabolic activities.

Riffles: Fast flowing, well-aerated and shallow areas.

Riparian habitat: The blend of streambed, water, trees, shrubs, and grasses in an area, which provides or directly influences aquatic habitat.

Riparian Zone: The area located between a waterbody's edge and the upland area.

Runs: Moderate current and smooth surface water.

Salinity: The level of dissolved inorganic salt in a waterbody.

Shading: Shading is the process of adjusting the amount of light admitted onto a surface.

Slope: The degree of incline of land surrounding a waterbody. Affects how surface water and precipitation enter a waterbody, with steeper slopes contributing surface waters much faster and possibly leading to increased contamination and nutrient loading.

Socializing: Refers to the developmental processes through which individuals learn necessary behaviours such as but not limited to foraging, migration, and altruistic behaviours.

Staging: Congregation of individuals in preparation for reproduction or migration.

Subsidization: Subsidization is the process of transferring energy, food, and structural components from the terrestrial habitat to the aquatic habitat.

Shoals: Relatively shallow areas that may or may not be near the waterbody margin; these areas may become unsubmerged during periods of low rainfall.

Sympatric species: The presence in sufficient abundance of species that co-exist in sympatry with another and is required for the maintenance of the ecological and evolutionary processes driving reproductive isolation and sympatric species pairs.

Wetlands: Land submerged or permeated by water, either permanently or temporarily, and are characterized by vegetation adapted to saturated soil conditions. Areas included, but not limited to are: fresh and salt water marshes, swamps, bogs, fens, seasonally flooded forest, and sloughs.

Wood recruitment: Wood recruitment is the addition of wood into waterbodies from the associated riparian forest as a result of the mortality of individual trees, disturbances affecting multiple trees or meandering of a river or stream channel.

APPENDIX 1: LITERATURE REVIEW

The review followed the key components and principals of a systematic review (Collaboration for Environmental Evidence 2018) with reduced documentation steps to limit the amount of time required to complete the review. The steps were as follows: 1) develop a list of search terms and Boolean operators, 2) search literature databases using the search terms, 3) identify inclusion criteria to determine if studies were included for further evaluation, and 4) extract data.

The final list of search terms were placed in four categories: 1) aquatic critical habitat feature; species of interest; 2) different types or terms for freshwater habitats; 3) different terms for riparian habitat; and 4) terms linking riparian and freshwater (Table A1.1).

Articles include peer-reviewed journals and grey literature. Our main search focused on Web of Science as this is a primary science-based database of peer-reviewed literature. We used DFO library to obtain access to any literature that may not be available in an online format. Only the English language was used during the search and only English language results were included. We also included papers that were identified during targeted searches or exploration based on references or papers sent to us from colleagues.

Each paper was first screened at the title and abstract level for relevance (Figure A1.1). Papers that met the inclusion criteria were then assessed at the full text level. Briefly, papers were included if they identified riparian habitat and their link to functions, aquatic features or water quality attributes relevant to fishes or mussels. Results of recent papers (i.e., last 5-10 years) were given precedence over older papers that may provide outdated information.

Table A1.1: Terms and Boolean operators used to search Web of Science and ProQuest literature databases.

Aquatic feature or water quality attribute or function	**Aquatic features, functions, and water quality attributes from a standardized list and related terms (Table 2)**
	AND
Subject	(Fish* OR Mussel* OR Mollusc*)
	AND
Freshwater	("Fresh water" OR Freshwater* OR Stream* OR River* OR Wetland* OR Marsh* OR Swamp* OR Lake*)
	AND
Riparian	(Riparian* OR Terrestrial* OR Shoreline* OR Land* OR Buffer* OR Forest* OR Anthro*)
	AND
Link	(Impact* OR Affect* OR Effect* OR Subsid* OR Link*)

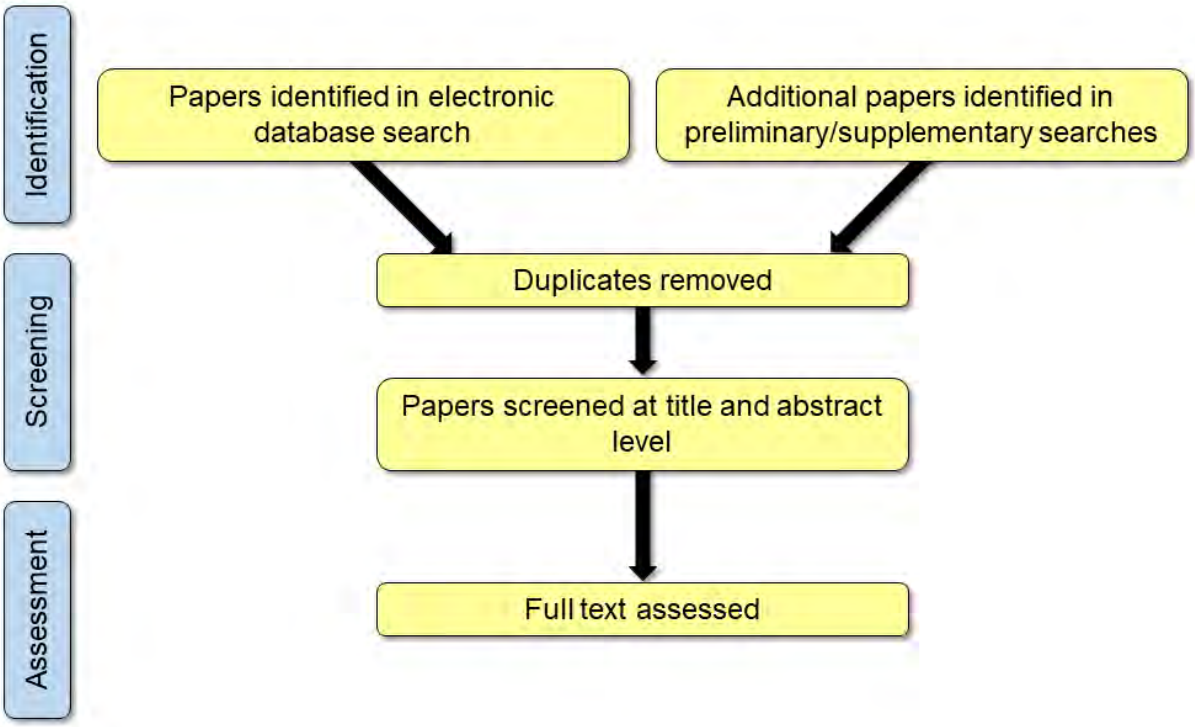


Figure A1.1: Literature review work flow.

OVERVIEW OF LITERATURE REVIEW RESULTS

Of the over thirteen thousand papers gathered for this analysis, 762 unique articles, books, and reports were screened at the abstract/title level and 185 full texts were assessed (Table A1.2). Of the 762 unique articles screened at abstract/title level, the oldest article is from 1976, and there is a steadily increasing number of articles over time (Figure A1.2a). The five most popular journals were: Freshwater Biology (42 articles), Canadian Journal of Fisheries and Aquatic Science (29 articles), Hydrobiologia (27 articles), River Research and Applications (25 articles), and Science of the Total Environment (24 articles). Word clouds created from the top 100 words in the titles show that most papers are related to rivers or streams rather than lakes and wetlands, and that research on fish was more prevalent in the database than on mussels (Figure A1.2b).

A1 REFERENCES

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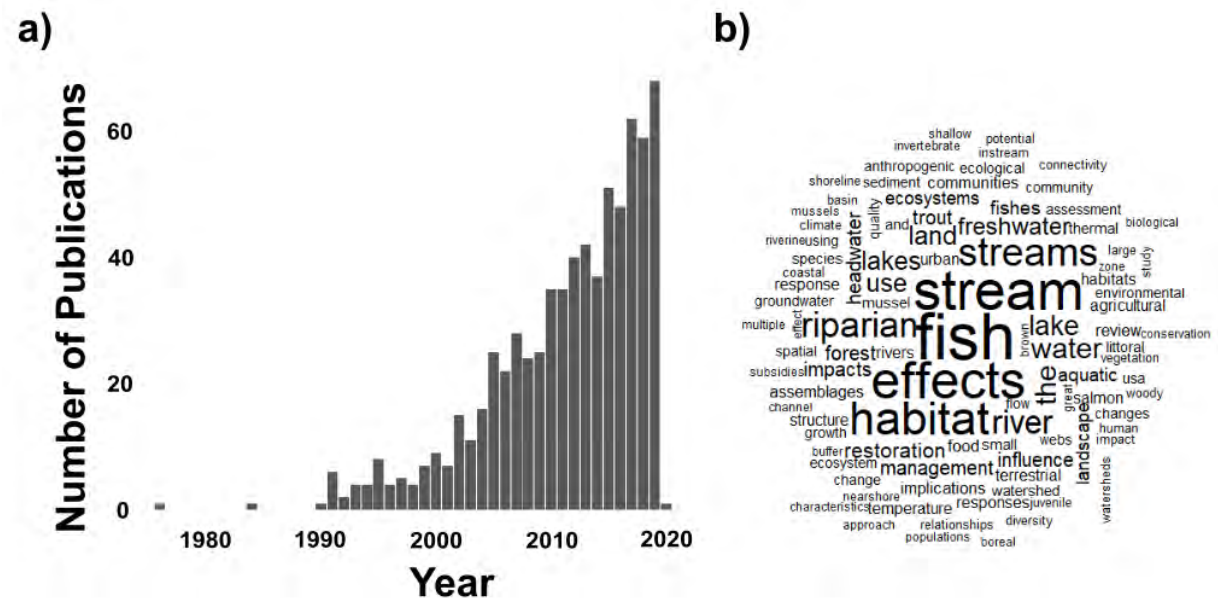


Figure A1.2: Information about articles, reports, and books found in literature review. (a) Number of publications per year and (b) word cloud created from the top 100 words in the examined titles.

Table A1.2: Terms used in the literature reserach and number of results.

Aquatic features, water quality attributes, and functions	Terms	After duplicates removed	Screened at title/abstract	Full text assessed
Features				
acoustic environment	(acoustic* OR soundscape* OR noise*)	143	14	10
areas of upwelling	(upwelling* OR groundwater* OR "ground water")	325	37	10
backwater	(backwater* OR "back water")	48	17	8
cover	(cover* OR refug* OR shelter*)	1617	119	9
eddies	(eddies OR eddy)	20	4	4
food supply	("food supply" OR "food availability" OR "prey availability" OR subsid*)	574	48	10
glides	glide*	9	7	4
host species	Subject REDUCED to just (mollusc and mussel*); (host*)	81	12	4
upstream habitat	(inlet* OR outlet* OR "upstream habitat" OR headwater*)	687	78	10
lake benthic habitat	Freshwater REDUCED to just Lake*; (bottom OR benthic)	465	28	5
lake littoral habitat	Freshwater REDUCED to just Lake*; (littoral* OR "near shore" OR nearshore)	416	41	6
lake pelagic habitat	Freshwater REDUCED to just Lake*; (pelagic* OR "open water" OR "water column")	288	20	2
migration/movement corridors	("migration corridor*" OR connectivit* OR "movement corridor*" OR "barrier free" OR "contiguous habitat*")	656	36	11
photic environment	(photic* OR light* OR clarity)	448	41	4

Aquatic features, water quality attributes, and functions	Terms	After duplicates removed	Screened at title/abstract	Full text assessed
physical space	("physical space" OR "activity space")	4	0	0
pools	(pool* OR "still water")	484	70	6
riffles	(riffle* OR aerat*)	168	58	7
runs	run*	372	28	3
shoals	(shoal* OR sandbar* OR sandbank* OR "sand bank" OR "sand bar" OR "gravel bar" OR "gravelbar")	68	10	5
sympatric species	("sympatric species" OR "sympatric pairs")	8	1	1
Water Quality Attributes				
dissolved oxygen	(oxygen OR hypoxia OR anox*)	666	27	5
temperature	"water temperature*"	424	71	8
contaminants	(contaminant* OR metal* OR chemical* OR pesticide* OR herbicide*)	1827	85	13
salinity	(salinity OR salt*)	872	13	4
nutrients (P,N,C, Calcium)	(Phosph* OR Nitr* OR Carbon* OR calcium)	1810	100	12
pH	pH	465	58	10
Functions				
attachment	attachment	2	0	0
avoidance	(avoidance OR Burying OR Camouflaging OR Hiding OR "taking cover" OR "taking refuge")	40	0	0
beach rubbing	"beach rubbing"	0	0	0
birthing	birthing	1	0	0
communication	(communication OR calling OR vocalization OR socializing)	24	0	0
courtship	courtship	0	0	0

Aquatic features, water quality attributes, and functions	Terms	After duplicates removed	Screened at title/abstract	Full text assessed
dispersal	(dispersal OR drifting OR "passive movement")	99	1	1
feeding	feed*	124	2	2
foraging	forag*	37	0	0
growth	(growth OR ageing OR development OR maturation)	379	0	0
incubation	incubation	5	1	1
larval settling	"larval settling"	0	0	0
migration	migration	75	1	1
molting	molting	0	0	0
nest building	("nest building" OR "den creation" OR "nest creation" OR "redd creation")	1	0	0
nest defense	"nest defense"	0	0	0
overwintering	(overwintering OR "over wintering")	4	0	0
rearing	(rearing OR nursing OR nurturing OR suckling)	36	6	5
reproduction	(repro* OR breeding OR "egg deposition" OR "mating" OR "fertilization" OR "spawning")	237	4	4
reproductive isolation	("reproductive isolation" OR "natural mate selection' OR "maintenance of sympatry")	3	0	0
resting	(rest* OR diapausis OR hibernation OR dormancy)	21	0	0
socializing	social*	26	0	0
staging	staging	104	0	0

APPENDIX 2: CANADIAN JURISDICTIONAL REGULATION AND RECOMMENDATIONS

Many provinces and territories have their own regulations and recommendations regarding the extent of habitat surrounding waterbodies that should be protected depending on the source of disturbance (i.e., agriculture, forestry or development) (Table A2.1).

Table A2.1: Riparian buffer widths for water features and aquatic species protection as found in government regulations and recommendations across Canadian Provinces and Territories.

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
Agriculture					
Alberta	Regulation	1–30	open waterbody	herbicide application, width dependent on application style and herbicide type	Government of Alberta 2010
Alberta	Regulation	0	open body of water	insecticides for pest control purposes up to and including the bed and shore of an open body of water provided the insecticide does not enter into or onto the body of water	Government of Alberta 2010
Alberta	Regulation	0	open body of water	rodenticides for pest control purposes up to and including the bed and shore of an open body of water provided the insecticide does not enter into or onto the body of water	Government of Alberta 2010
British Columbia	Regulation	30	water supply intake	pesticide application around a water supply for livestock or irrigation	Government of British Columbia 2016
New Brunswick	Regulation	30–75	intake of a public water supply system	agricultural activities	Government of New Brunswick 2001

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
New Brunswick	Regulation	15–75	intake of a public water supply system	pesticide application	Government of New Brunswick 2001
New Brunswick	Regulation	15–75	intake of a public water supply system	livestock grazing	Government of New Brunswick 2001
New Brunswick	Regulation	5	intake of a public water supply system	hay removal	Government of New Brunswick 2001
New Brunswick	Regulation	30–75	any watercourse	installation and operation of gasoline or diesel powered pumps	Government of New Brunswick 2001
New Brunswick	Regulation	30–75	within 1 km of the intake of a public water supply system	pesticide application	Government of New Brunswick 2001
Newfoundland Labrador	Regulation	30	neighbouring well	pesticide application	Government of Newfoundland and Labrador 2013
Newfoundland Labrador	Best Practices	15–400	all waterbodies	dependent on land use. increases with slope greater than 30% of the width of the buffer zone	Agriculture and Agri-Food Canada
Ontario	Recommendation	30	all waterbodies	agriculture activities	ECCC 2013
Prince Edward Island	Regulation	15–30	all waterbodies	buffer zones 15 m wide must be maintained next to all watercourses and wetlands. the regulations also require the planting of 10 m wide grassed headlands at the end of all row of cropland that ends within 200 m of a watercourse or wetland	Agriculture and Agri-Food Canada; Government of Prince Edward Island 2016

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
Québec	Regulation	1–100	open body of water	pesticide application without aircraft, dependent on slope	Gouvernement du Québec 2018
Québec	Regulation	30-100	open body of water	Pesticide application with aircraft	Gouvernement du Québec 2018
Québec	Regulation	3	open body of water	cultivation of soil for agriculture purposes	Gouvernement du Québec 2019
Saskatchewan	Recommendation	10–30	all waterbodies	guide for landowners on improving riparian zones on their property	Huel 1998
Yukon	Regulation	30	open body of water	pesticide application, unless permit allows	Government of Yukon 1994
Forestry					
Alberta	Regulation	0	open body of water	insecticides for pest control purposes up to and including the bed and shore of an open body of water provided the insecticide does not enter into or onto the body of water	Government of Alberta 2010
Alberta	Regulation	1–30	open waterbody	herbicide application, width dependent on application type	Government of Alberta 2010
Alberta	Ground Rules	30	small permanent streams	ground rules apply to timber harvest	Alberta Sustainable Resource Development 2005
Alberta	Ground Rules	60	large permanent streams	ground rules apply to timber harvest	Alberta Sustainable Resource Developmen, 2005

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
British Columbia	Regulation	0–50	streams	width depends on classification of stream and if fish bearing	Tschaplinski and Pike 2010
British Columbia	Regulation	0–10	lakes, wetlands	width depends on classification of waterbody	Tschaplinski and Pike 2010
British Columbia	Regulation	1–10	waterbody, dry stream or wetland	pesticide application around a waterbody, 10 m unless permitted for certain applications.	Government of British Columbia 2016
New Brunswick	Regulation	15–75	intake of a public water supply system	tree planting	Government of New Brunswick 2001
New Brunswick	Regulation	15–75	intake of a public water supply system	selection cutting	Government of New Brunswick 2001
New Brunswick	Regulation	30–75	any watercourse	installation and operation of gasoline or diesel powered pumps	Government of New Brunswick 2001
Newfoundland Labrador	Best Practices	15–400	all waterbodies	dependent on land use. increases with slope greater than 30% of the width of the buffer zone	Agriculture and Agri-Food Canada
Nova Scotia	Regulation	20–60	all waterbodies	forest sustainability regulations	Agriculture and Agri-Food Canada
Ontario	Recommendation	30	all waterbodies	forestry activities	ECCC 2013
Prince Edward Island	Regulation	20–30	all waterbodies	buffer zones 15 metres wide must be maintained next to all watercourses and wetlands.	Agriculture and Agri-Food Canada; Government of Prince Edward Island 2016

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
Québec	Regulation	1–100	open body of water	pesticide application without aircraft, dependent on slope	Gouvernement du Québec 2018
Québec	Regulation	30-100	open body of water	Pesticide application with aircraft	Gouvernement du Québec 2018
Québec	Regulation	20	lakes and rivers	forestry activities, from the edge of the riparian ecotone (10-15 m)	Gouvernement du Québec 2017; Gouvernement du Québec 2019
Saskatchewan	Recommendation	10–30	all waterbodies	guide for landowners on improving riparian zones on their property	Huel 1998
Yukon	Regulation	30	open body of water	pesticide application, unless permit allows	Government of Yukon 1994
Yukon	Regulation	5–80	streams and rivers	dependent on stream class	Yukon Energy, Mines and Resources Forestry Management Branch 2011a
Yukon	Regulation	20–60	lakes	dependent on lake class	Yukon Energy, Mines and Resources Forestry Management Branch 2011a
Yukon	Regulation	5–60	wetlands	dependent on wetland class	Yukon Energy, Mines and Resources Forestry Management Branch 2011b
Development					
Alberta	Regulation	1–30	open body of water	herbicide application, width dependent on application type	Government of Alberta 2010
Alberta	Regulation	250	surface water intake	mosquito control pesticide application	Government of Alberta 2010

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
Alberta	Regulation	0	open body of water	insecticides for pest control purposes up to and including the bed and shore of an open body of water provided the insecticide does not enter into or onto the body of water	Government of Alberta 2010
Alberta	Regulation	0	open body of water	rodenticides for pest control purposes up to and including the bed and shore of an open body of water provided the insecticide does not enter into or onto the body of water	Government of Alberta 2010
British Columbia	Regulation	30	water intake or well	pesticide application around a water intake or well	Government of British Columbia 2016
British Columbia	Regulation	1–10	waterbody, dry stream or wetland	pesticide application around a waterbody, 10 m unless permitted for certain applications.	Government of British Columbia 2016
British Columbia	Regulation	30	all waterbodies	development activities in the municipalities and regional districts in the lower mainland, much of vancouver island, and areas f the southern interior of the province	Government of British Columbia 2019
Manitoba	Regulation	3–35	all waterbodies	application of substances containing nitrogen or phosphorus	Government of Manitoba 2008
Manitoba	Regulation	15–30	all waterbodies	development, dependent on land use and waterbody type	Government of Manitoba 2011

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
New Brunswick	Regulation	5	all watercourses	landscaping	Government of New Brunswick 2001
New Brunswick	Regulation	15	all watercourses	tree removal	Government of New Brunswick 2001
New Brunswick	Regulation	30–75	all watercourse	installation and operation of gasoline or diesel powered pumps	Government of New Brunswick 2001
Newfoundland Labrador	Best Practices	15–400	all waterbodies	dependent on land use. increases with slope greater than 30% of the width of the buffer zone	Agriculture and Agri-Food Canada
Nova Scotia	Regulation	0–1	all waterbodies	any activity near or in a watercourse	Province of Nova Scotia 2015
Ontario	Recommendation	120	all waterbodies	significant habitat of endangered and threatened species	Government of Ontario 2010
Ontario	Recommendation	120	wetlands	significant wetlands and significant coastal wetlands	Government of Ontario 2010
Ontario	Recommendation	120–300	fish habitat	inland lake trout lake (at capacity) on the Canadian shield 300 m all other fish habitat 120 m	Government of Ontario 2010
Québec	Regulation	3–100	open body of water	pesticide application	Gouvernement du Québec 2018
Québec	Regulation	15–20	open body of water	structures, undertakings and works for municipal, commercial, industrial, public or public access purposes	Gouvernement du Québec 2019

Jurisdiction	Incentive	Width of buffer (m)	Habitat requiring buffer	Comments	Source
City of Mont-Laurier, Québec	Regulation	3–15	Lac des Écorces	dependent on property type, for entire border of Lac des Écorces for protection of Spring Cisco	DFO 2014
Saskatchewan	Recommendation	10–30	all waterbodies	guide for landowners on improving riparian zones on their property	Huel 1998
Yukon	Regulation	30	open body of water	pesticide application, unless permit allows	Government of Yukon 1994
Whitehorse, Yukon	Regulation	50	all waterbodies	minimum riparian setback zone within municipal limits. does not apply to private lands	UMA Engineering Ltd., Environmental Dynamics Inc. 2004

A2 REFERENCES

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8.4 Curricula Vitae

C. Thomas Hoggarth

Education

1980 to 1985 **University of Waterloo, Department of Biology**
Graduated Honours Co-op B.Sc. Specializing in fish ecology and toxicology.

Work Experience

Jan. 2017 – Present **Regional Director, Aquatic Ecosystems**
Fisheries and Oceans Canada

Responsible and accountable for the management of the Fish and Fish Habitat Protection Program, the Species at Risk Program, the Aquatic Invasive Species Program and the Aquaculture Program. Duties include:

- exercising executive managerial authority and providing recommendations and advice on the exercise of that authority;
- managing substantial scientific and professional activities;
- providing recommendations on the development of significant policies, programs or scientific, professional or technical activities; and
- exercising a primary influence over the development of policies and programs for the use of human, financial or material resources;
- exercising managerial authority over the Fisheries Protection Program, Species at Risk Program, the Oceans Program and the Aquatic Invasive Species Program.

Specific tasks include:

- Provide input and direction on the Fisheries Act Review process.
- Providing direction and approvals of many staffing actions, including implementation of staff competitions, approvals for the hiring of indeterminate, determinate, student and casual staff.
- Responsible for the development and implementation of financial work plans.
- Working with provincial, territorial and other partners to support ongoing program understanding and delivery.
- Completing regulatory reviews in an effective and timely manner.
- Working with national colleagues in ensuring establishment of a robust Program consistent with the goals of the amended Fisheries Act.
- Providing weekly updates to the Regional Director General and the Deputy Minister on our progress toward Marine Conservation Targets.
- Co-chair regional coordination committee in the Eastern Arctic for the advancement of Marine Protected Areas.

- Provide direction and input into the Treasury Board Submission for the approvals of the Regional Aquatic Invasive Species Program.
- Facilitate the movement of the Asian Carp Staff from the Science Program into the Ecosystems Program.
- Staff the newly formed Regional Aquatic Invasive Species Program.
- Approve recovery strategies and action plans for several species at risk.
- Approve contribution agreements under the Recreational Fisheries Conservation Partnership Program.
- Provide input and manage the staff grievance on the linking of staff to the National Model Work Description.
- Management co-chair of the occupation health and safety committee.

Nov. 2015 **Regional Manager, Regulatory Review**
Jan. 2017 **Fisheries and Oceans Canada**

Provides leadership to the Program and oversee the implementation of the regulatory and policy frameworks, procedures and tools related to the consistent implementation of Fisheries Protection Program's regulatory mandate under the *Fisheries Act,* the *Species at Risk Act* their associated regulations, as well as providing support to environmental assessment processes and other applicable legislation.

Participates in the development of regulatory and policy frameworks, standards, guidelines, procedures and tools related to the consistent implementation of Fisheries Protection Program regulatory mandate).

Provides overall direction and strategic planning as well as supervision and management to multiple work units. Accountable for ensuring staff and program alignment with strategic and national priorities and that expected outcomes are achieved.

Oversees ongoing consultation and engagement with clients with regard to fisheries protection measures including offsetting plans; and plans and oversees compliance promotion and management activities.

Resolves and manages complex problems and issues, determines solutions and ensures regulatory decisions are consistent with legislation, program and Departmental policies, priorities and objectives.

Provides advice and participates in the development of regional priorities and provides input into national priorities and objectives and horizontal coordination for the Fisheries Protection Program across the Program and in other sectors.

Interprets results, conclusions and recommendations of reports and scientific studies to determine their broad implications on the Fisheries Protection Program policies, priorities and objectives and other program areas of the Department.

Undertakes strategic planning related to compliance monitoring and makes recommendations and compliance decisions for enforcement activity.

Member of the regional and national Ecosystems Management team.

Leads and/or participates in developing, presenting and defending Departmental or Program positions on matters related to FPP regulatory policy frameworks and their implementation.

Represents the FPP and/or the Department in external fora including public hearings.

Mar. 2013 **Team Leader, Client Liaison, Partnerships, Standards and Guidelines**
Nov 2015 **Fisheries and Oceans Canada**

Responsible for managing multiple teams and programs within the Fisheries Protection Program. These include:

- Federal Contaminated Sites Action Plan
- Recreational Fisheries Conservation Partnership Program
- Standards and Guidelines Team
- Partnership and Client Liaison Team
- Geographic Information Systems Team

Reporting directly to the Regional Director, I provide a leadership role in:

- Development and implementation of partnership agreements
- Development and implementation of standards and guidelines and undertakes outreach and promotion of compliance with standards, guidelines and supporting tools to proponents.
- Senior advisor to internal and external stakeholders on the establishment of guidelines, regulations or standards to support the delivery of the Fisheries Protection Program (FPP).
- Oversees the development of material for proponents related to new standards and guidelines and other tools as they are introduced.
- Establish Regional work plans based on assigned resources/budgets.
- Provide input into the development of activities and work plans brought forward through national committees, sub-committees and working groups including national subcommittees.
- Represents the Program, Region and/or the Department on external forums and leads and/or participates in developing, presenting and defending Departmental or Program positions on matters related to FPP policy and regulatory frameworks and their implementation.
- Develop protocols and assist in the coordination of Aboriginal consultations and may participate in consultations with Aboriginal groups in collaboration with or in support to other FPP units.

Sept. 2008 – Mar. 2013 **Habitat Team Leader, Eastern Ontario District, Ontario Great Lakes Area, Fisheries and Oceans Canada.**

Provide direction to staff in the Prescott and Peterborough office on the implementation of the Fish Habitat Management Program. This includes various federal legeslation and policies including the *Fisheries Act*, the *Species at Risk Act,* the Policy for the Management of Fish Habitat, the *Canadian Environmental Assessment Act*, and the Standard Operating Policies, procedures and directives related to the national habitat program. Duties include:

- Represent the Depart at the Panel Hearings for the New Nuclear at Darlington Project.
- Supervision of the Senior Biologists.
- Represent DFO on issues relating to environmental impacts on fish and fish habitat and provide advice to senior management where appropriate.
- Oversee departmental, interdepartmental and intergovernmental environmental assessment reviews of proposed development projects to ensure Fishery resources and habitats are protected in accordance with the Fisheries Act and Species at Risk Act, and potential environmental impacts are examined as required under the Canadian Environmental Assessment Act.
- Represent the department on Area committees and working groups including Conservation Authorities, Ontario Ministry of Natural Resources, and First Nations to address departmental, interdepartmental and intergovernmental environmental issues.
- Have departmental signing authority for signing off on decision of significance within environmental assessments and the course of action decisions, as per the *Canadian Environmental Assessment Act*.
- Provide response to technical inquiries and draft background information for use in ministerial correspondence.
- Coordinate and manage the operation and activities of Eastern Ontario District biologists to ensure consistency in the application of area, regional and national DFO programs.
- Develop and implement work plans for program delivery elements within Eastern Ontario District.
- Represents DFO as spokesperson on high profile (major) projects for senior level managers, media and public and private agencies.
- Represent DFO for front line media response and review of press releases arising from results of *Fisheries Act* and SARA decisions.

Additional duties include:

- Representing DFO Habitat Management on the Nearshore Canadian Issues team for the binational negotiations of the Great Lakes Water Quality Agreement.
- Chair of the Ontario Habitat Operations Council. The intent of the Habitat Operations Council is to provide a forum where the Ontario Habitat Senior Biologists can meet and discuss consistency across the province.

- Responsible for writing and finishing the updated DFO Guidance document for the application of the federal Fisheries Act to Agricultural Drain maintenance.
- Represent DFO on the steering committee for the development of the Best Management Practices, Guide for American Eel and Waterpower in Ontario.
- Represent DFO on the writing team for the American Eel Recovery Strategy under the provincial *Endangered Species Act*.
- Working member of the Regional Diversity Advisory Group.

April 2001 **A/Regional Manager, Central and Arctic Region**
Sept. 2001 **Fisheries and Oceans Canada**

Reporting directly to the Regional Director, Ecosystem Management, I was responsible for:

- Managing the regional headquarters' Habitat Management Division in the Central and Arctic Region, taking into account the application of National policies, Regional policies and programs and linkages with other government departments.
- Providing direction to Regional HQ staff, functional direction to other Regional staff, and specialist advice to other government departments and Regional senior management.
- Representing the Regional HM program at National meetings.
- Assessing professional specialist advice from a variety of sources, and developing action plans based on this advice.
- Anticipating operational changes required due to emerging developments such as the implementation of new legislation and court decisions.
- Being the primary Regional point of contact within the Region for all Habitat Management Program activities.

June 2007 **A/District Manager, Southern Ontario District, Ontario Great**
Sept. 2008 **Lakes Area, Fisheries and Oceans Canada**.

Responsible for the management of the Southern Ontario District, Ontario Great-Lakes Area. Duties include:

- Support the Area Director in overall Habitat Management Program Delivery.
- Coordinate and manage the operation and activities of Southern Ontario District habitat management staff to ensure consistency in the application of area, regional and national DFO programs.
- Member and advisor to the Ontario Great-Lakes Area (OGLA) Management Team and OGLA Executive Committee
- Develop and implement work plans for program delivery elements within their respective Districts.
    - Direct and manage the human resources and finances of the District and provide leadership to foster and maintain a professional, progressive and innovative work environment.
    - Coordinate and collaborate with other District Managers and Area Operations Manager to ensure consistent approaches and messaging.

    - Collaborate with Area staff and other District Managers regarding all initiatives that have area-wide scope or implications for program delivery.
- Prepare budgets and staffing forecasts as well as periodic progress reports regarding program delivery.
- Represents DFO as spokesperson on high profile (major) projects for senior level managers, media and public and private agencies.
    - Responsible for front line media response and review of press releases arising from results of *Fisheries Act* and SARA investigations.
    - Identify opportunities to enhance program delivery and client service within District, Area and or Region.
    - Responsible for maintaining partnerships with Conservation Authorities, Parks Canada, Ontario Ministry of Natural Resources, First Nations etc. in the District and working with the Partnership Coordinator to strengthen these partnerships and strike up new partnerships
    - Provide guidance and review of major projects, *Fisheries Act/SARA* Investigations, *Fisheries Act* Authorizations, Ministerial Dockets and Petitions.
    - Provide Management Team liaison role for various OGLA Task Groups.
    - Lead District Management Team of habitat management and conservation and protection staff.

While in this position I have completed all staffing, human resources and financial management course required to exercise staffing sub-delegation as well as signing authority as a Responsible Centre Manager.

Staffing duties included, hiring two new staff from the EG04 pool, participate as a member of the BI03 staff board for creation of a BI03 staffing pool, hiring of a casual employee and the appointment of a person to a term position.

I have completed multiple budget reports and budget work plans for this fiscal.

Responsible for representing DFO at numerous public and private sector meetings concerning DFO regulatory review process, our role in sustainable development, and our funding programs.

While acting as District Manager I have been required to complete media interviews concerning several active regulatory files within the Southern Ontario District.

April 2007 – June 2007 **A/Habitat Coordinator, Southern Ontario District, Ontario Great Lakes Area, Fisheries and Oceans Canada.**

Responsibilities include the delivery of the fish habitat management program in Southern Ontario, duties include:

- act as senior contact and advisor to various levels of municipal, provincial and national government organizations, non-government agencies, Aboriginal groups and industry,
- plan, organize, control and direct all aspects of habitat management programs,

- initiate, plan and direct biological and bio-engineering investigative and research studies and monitoring programs to assess the environmental effects of proposed and existing developments on the fisheries resources and habitats,
- administer the budget and supervises the personnel of the Habitat Program,
- serve as senior contact for public and media inquiries dealing with all habitat issues,
- reviews high risk development proposals, analyze input from other federal departments and other levels of government, and provides recommendations with regard to habitat mitigation, compensation, monitoring, and follow-up plans for regulatory decisions
- provide guidance to staff regarding decisions and follow-up requirements on Canadian Environmental Assessment Act (CEAA) screenings, comprehensive studies,
- providing leadership and direction to District staff consistent with EPMP and DFO policy and mandate,
- supervision of Southern Ontario team leaders (BI-03s) and managing the London Office which include managing London office and the Team Leader budgets and assisting the District Manager with financial and human resources related matters,
- review and approval of District's *Fisheries Act* Authorizations, CEAA screenings etc. as per the National Signing Protocol,
- drafting and reviewing background information for dockets and briefing memoranda for the District Manager,
- development and maintenance of strategic partnerships with federal, provincial and municipal government officials, as well as NGO's and other client based groups,
- member of the Southern Ontario District's Management Team, OGLA Habitat Operations Council and Regional Habitat Coordinating Committee, act as lead OGLA management team representative for HOC task groups for southern related issues (agriculture),
- and delivering Environmental Process Modernization Plan, Risk Management Framework and compensation and mitigation training to staff and partners.

Additional duties include sitting on the Habitat Management Program's Aboriginal Consultation Working Group. This group is responsible for reviewing and providing input to drafts of a Practitioner's Guide to Aboriginal Consultation. This guide will provide administrative and policy direction on numerous issues related to Aboriginal consultation, including practical guidance to conduct consultation with Aboriginal groups.

Sept. 2006 – Jan. 2007 **A/Associate District Manager, Southern District Ontario Great Lakes Area, Fisheries and Oceans Canada.**
On assignment for four months.

Responsible for the management of the Burlington office within Southern Ontario District, Ontario Great-Lakes Area. Duties include:

- delivering the regulatory program,
- directing and managing human resources and ensuring associated administrative requirements are fulfilled,
- responding to inquiries from the public and media on high profile files or issues,
- representing the Southern District Manager or Area Director on committees and/or at meetings,
- maintaining or initiating partnership relations to further departmental approaches to regulatory responsibilities,
- managing the office budget; implementing work plans,
- delivering Environmental Process Modernization Plan, Risk Management Framework and compensation and mitigation training to staff and partners,
- and managing the implementation of the office safety program.

During this assignment I was responsible for developing Risk Management Framework training material for delivery to Aboriginal groups and DFO partners. I also delivered the National Risk Management Framework training to DFO staff.

June, 2005 **Aboriginal Inland Habitat Program Manager, Fisheries and Oceans**
June, 2007 **Canada**

On assignment with the Central and Arctic Regional Office in Winnipeg. Responsible for delivery of the Aboriginal Inland Habitat Program, duties include:

- coordinating projects with multiple levels of government, non-government agencies and aboriginal organizations and communities,
- develop and conduct consultation programs with First Nation and Métis communities within Alberta, Saskatchewan, Manitoba, Ontario and Quebec to assist in the delivery of the program,
- develop and monitor funding agreements and financial contracts with aboriginal organizations,
- and delivering Environmental Process Modernization Plan, Risk Management Framework and compensation and mitigation training to aboriginal groups and council members,
- provide input into the development of the departmental Integrated Aboriginal Policy Framework and advice to the Areas within Central and Arctic Region on the aboriginal consultation plan for the Fisheries Act Renewal.
- Develop and negotiate terms and conditions of Grants and Contribution Agreements between Aboriginal groups and the Fisheries and Oceans Canada.

Represented the Habitat Management Program on the National Policy Analysis Group (NPAG). NPAG operates as an ongoing dialogue forum, between DFO and the Assembly of First Nations, to discuss, analyze and provide recommendations related to policy and legislative reform at the national level and to provide technical advice and analysis. Among other things, NPAG considers issues with respect to oceans, aquaculture, fisheries habitat, fisheries management, stock assessment, licensing and allocation, and conservation and protection.

2001 to 2005 **Habitat Impact Assessment Biologist, BI 3, Fisheries and Oceans Canada**

Responsible for ensuring that the habitat protection provisions of the federal *Fisheries Act* are administered within the Ontario – Great Lakes Area, Parry Sound District Office, duties include:

- supervising biological staff.
- coordinating activities between enforcement staff and biological staff, completing file review including meeting requirements under the Canadian Environmental Assessment Act, reviewing all environmental assessment documents, preparing responses to these documents and working with all the RA's to complete the final Screening or Comprehensive Study Report.
- providing input in enforcement files as an expert witness.

Represented DFO on the federal government team for the completion of the Victor Diamond Project Comprehensive Study. This project required the completion of a comprehensive review under the Canadian Environmental Assessment Act. I was the lead DFO person for the completion of this EA, duties included:

- leading the federal government responsibilities under the Federal Coordination Regulations,
- writing all DFO briefing notes and dockets,
- representing DFO at Privy Council Office meetings,
- worked with DFO legal to develop our EA sign-off,
- represented all Responsible Authorities in the development of a follow-up monitoring agreement with the proponent and First Nations,
- responsible for managing a multidisciplinary team during the EA process, including terrestrial biologists, marine mammal scientists, engineers, construction managers, and the Canadian Coast Guard spills action response teams,
- preparing and delivering EA reports,
- providing advice and briefings to senior management and dealing with environmental assessment laws, regulations and policies within the context of the Canadian Environmental Assessment Act.

Additional duties include being the chair the Aboriginal Task Group for the Ontario Area. Responsibilities are providing advice on aboriginal issues for the Area Director as well as all Ontario staff.

1990 to 2001 **Fisheries Biologist, Niblett Environmental Associates Inc.**

Responsible for planning and conducting all fish and fish habitat assessments. Impact Assessments were completed for several development sectors. These included mining, hydroelectric, housing developments, recreational developments and landfills.

Coordinated numerous projects and teams conducting aquatic studies. One of the largest projects the Evaluation of the Aquatic Environment in the Serpent River Watershed. This

study assessed the long term impacts of Uranium Mining on the aquatic ecosystem. I coordinated three field crews over a period of four months conducting fish species and abundance surveys, benthic macro-invertebrate surveys and collecting sediment and water samples for contaminant analysis. This information was collected in approximately 14 lakes and 17 different river sites. This project also required the coordination of input from engineers, and terrestrial biologists.

Other projects included the large river inventory of the Brant River (James Bay), feasibility study for a commercial sturgeon fishery on the Attawapiskat River, and impact of hydro electric operations on the sturgeon populations of the Groundhog River.

Duties also included the collection, organization, analysis and presentation of all information required for tribunals. This included Ontario Municipal Board Hearings and *Fisheries Act* charges. Have been an expert witness for a *Fisheries Act* charge and for a First Nation fishing violation charge.

1988 to 1990 **Fisheries Biologist, Environmental Applications Group Ltd.**

Responsibilities included conducting all field work required for the collection of fisheries information. This data was collected to complete mining impact assessments. Field work was conducted throughout Northern Ontario and Quebec.

1985 to 1988 **Contract Biologist, Environment Canada**

Worked for several Environment Canada Scientists. Projects included oxygen depletion studies in Lake Erie, uptake rates of organochlorine pesticides in benthos and long range transportation of pesticides.

Scientific Workshops and Presentations

1989 **First International Sturgeon Conference**, Milwaukee, USA.
Presented a poster on the population characteristics of lake sturgeon within the Attawapiskat River, Northern Ontario.

1991 **Sturgeon Conference, Sponsored by Ontario Ministry of Natural Resources and the University of Guelph**
Presented a talk on the life history strategies of lake sturgeon within the Groundhog River, Ontario. The talk focused on the results of a two year radio telemetry study and how habitat characteristics within certain sections of the river affected the morphological attributes within the sturgeon population.

1995 **Sudbury 95, Mining Conference**
Co-authoured a report at this conference. The report title was “Evaluation of the Aquatic Environment in the Serpent River Watershed”. The report discussed the long term impact of uranium mining within the Serpent River Watershed.

Stephanie Martens, B.Sc.
Manager, Fish and Fish Habitat Protection Program
Fisheries and Oceans Canada
1028 Parsons Road
Edmonton, Alberta, T6X 0J4

Curriculum Vitae

SUMMARY

Ms. Martens is a Manager with the Fish and Fish Habitat Protection Program in the Ontario and Prairie Region for Fisheries and Oceans Canada. Ms. Martens has been an employee with Fisheries and Oceans Canada since January 2008. Ms. Martens began her career with the department as a Fish Habitat Protection Biologist, worked as a Senior Environmental Assessment Analyst for several years and the Senior Fisheries Protection Biologist for 3 years. Currently Stephanie is the Team Leader for the Mining, Oil & Gas Regulatory Unit in the Central & Arctic Region. Stephanie is responsible to manage the team in Edmonton, provides technical and regulatory advice for the team and on major mining projects. She also has been involved on the department's change management team to provide support for staff during transitional period into the updated Fisheries Act and has been part of the policy development and program delivery team. Stephanie is currently in the role of Manager for Regulatory Review supervising the teams from Yellowknife, Edmonton and Regina.

EXPERIENCE

Oct 2019 – Present **Manager, Regulatory Review, Fish and Fish Habitat Protection Program, Fisheries and Oceans Canada**

- Provision of leadership and guidance for the regulatory review teams located in Yellowknife, Edmonton and Regina.
- Provide guidance and advice in the planning, development, implementation and coordination of regulatory reviews under the Fisheries Act, as well as the participation of DFO in environmental assessments under the Impact Assessment Agency, Nunavut Lands Claim Agreement and Mackenzie Valley Resource Management Act.
- Provide advice to senior management staff of the implementation and application of new policies, standards, guidance documents and templates under the Fisheries Act.
- Representation of the region and department at various regional and national committees and working groups.
- Provide guidance, feedback and advice on policy and directives.
- Provide for training of new and current staff in the new program policies and directives. Lead meetings and discussions surrounding the application of our program.
- Work with team leads to establish roles and responsibilities, manage major projects, manage workloads, staff expectations and various Fisheries Act violations.
- Responsible for managing the budget, hiring, pay programs, difficult staffing situations and support of regulatory teams.
- Undertake performance evaluations of employees within the allocated schedule.
- Keep senior management up to date on current issues, referrals and project, major projects, staffing and human resource issues, budget requirements and work plans.

2019 – Oct 2019 **Team Leader; Mining, Oil & Gas – South; Fish and Fish Habitat Protection Program, Fisheries and Oceans Canada**

- Guidance and mentoring of senior biologists in regulatory review work.
- Guidance on major project review management including projects undergoing a joint review panel process.
- Work with National Change Management Team in providing staff with up to date information on the pending changes within the department related to the *Fisheries Act* changes and the program revitalization.
- Work as part of the training team to develop and deliver training modules for our staff on the program changes.
- Act in role of Regulatory Review Manager to provide supervision and guidance for the teams in Yellowknife, Regina and Edmonton.
- Work with senior bios to develop workplans, training plans and efficiencies in managing the office and our group.
- Participate in working group with DFO regional managers on an Impact Assessment Board Working Group.
- Participate in various technical, advisory and multi-stakeholder groups on behalf of the Department.
- Represent the department by providing technical and policy advice in hearings.
- Carry out project specific consultations with Indigenous Communities

2016 – 2019 **Senior Fisheries Protection Biologist, Mining, Oil & Gas SOUTH, Fisheries Protection Program, Fisheries and Oceans Canada**

- Management of regulatory review for the Mining, Oil & Gas South regulatory review unit for which includes mining, oil and gas related projects in Alberta, Saskatchewan, Manitoba and Ontario.
- Mentoring and management of fisheries protection biologists in regulatory reviews, performance management and career development.
- Providing technical and regulatory advice, recommendations and conditions regarding impacts to fish and fish habitat for staff and proponents.
- Participation in environmental assessments and Joint Review Panel Processes under the *Canadian Environmental Assessment Act*.
- Providing advice and guidance for staff in regulatory reviews, compliance and occurrence management, monitoring and follow up programs and the application of departmental legislation and policy.
- Coordination and consultation with other government departments and agencies (federal, provincial and municipal), Indigenous groups and other stakeholders.
- Participation in the development of tools, standards and guidelines related to regulatory review.
- Management of contracts with external parties regarding delivery of goods and services for the regulatory review unit.
- Represent the department on advisory, technical and multi-stakeholder groups.

2012 – 2016 **Senior Environmental Assessment Analyst, Fisheries and Oceans Canada**

- Participation in environmental assessments of proposed major projects under the *Canadian Environmental Assessment Act.*

- Providing advice and guidance on avoidance and mitigation measures as they pertain to the potential impacts to fish and fish habitat.
- Consultation and coordination of project review with other government departments, levels of governments and agencies.
- Recommendation of regulatory actions consistent with departmental policy, legislation and regulation.
- Consultation with Indigenous groups, other governments and agencies and other stakeholders.
- Representation of the department in technical working groups and multi-stakeholder groups.
- Review and assess determination of project impacts as submitted by the senior biologists.
- Lead bi-monthly team leader call to bring consistency

2008 – 2012 **Fish Habitat Protection Biologist, Fisheries and Oceans Canada**

- Reviewing a wide range of development activities including watercourse crossings, pipelines, storm water management, gravel extraction, mining activities, shoreline disruptions and other proposed works
- Providing regulatory action recommendations consistent with program policies and legislation which includes the *Fisheries Act, Species at Risk Act* and the *Canadian Environmental Assessment Act.*
- Participation in Indigenous consultation
- Coordination with provincial fisheries biologists in the review of the potential impacts of development to fish and fish habitat and recommend mitigation measures.
- Conducting pre and post construction compliance and monitoring assessment to confirm compliance with regulatory tools and verify predications made during assessment processes.

EDUCATION

B.Sc. with Specialization in Animal Biology
University of Alberta, Edmonton, Alberta, Canada, December 2007

B.Sc. in Environmental Science
University of Lethbridge, Lethbridge, Alberta, Canada, September 2000 – April 2003

PROFESSIONAL DEVELOPMENT

- Erosion and Sediment Control Practitioner, VOI Training Group, Cochrane AB
- Newbury Hydraulics Short Course, Canadian Rivers Institute, Kananaskis Country AB
- Various Occupational Health and Safety Courses
- Management Development Training program

Brandi Mogge, BSc.
Team Leader, Fish and Fish Habitat Protection Program
Fisheries and Oceans Canada
1028 Parsons Rd SW
Edmonton, Alberta T6X 0J4

Curriculum Vitae

EDUCATION

- Bachelor of Science, Honors Environmental Biology with Honors, University of Alberta, Edmonton AB, 2007

EXPERIENCE

Feb. 2020 – Present **Team Leader; Mining, Oil & Gas – South; Fish and Fish Habitat Protection Program; Ontario and Prairie Region, Fisheries and Oceans Canada**

Responsible for leading the Mining, Oil & Gas – South team based in Edmonton, AB, within DFO's Ontario and Prairie Region including:

- Providing direction and guidance to staff on implementation of the Fish and Fish Habitat Protection Program, and federal legislation and regulations including the *Fisheries Act*, the *Species at Risk Act*, the *Impact Assessment Act*, the *Metal and Diamond Mining Effluent Regulations*, and Departmental policies and procedures.
- Supervision of senior biologists
- Development of annual team work plans including workload management, travel and training
- Management of staff through program change, and development and delivery of training for staff on updated departmental policies and tools
- Represent the Region and Department on regional and national committees providing operational advice to support the development of tools and guidance, and a consistent approach to program delivery
- Representing the Department in environmental and impact assessments of proposed mining projects including cross-program and cross-Department collaboration and coordination
- Represents the Department in consultations with Indigenous communities for major mining projects in the region
- Develops strategic relationships with partners and stakeholders including provincial agencies, Indigenous communities, and industry to advance overlapping objectives and goals
- Support the development of costing, narrative and proposals for budgetary requests.

May 2019 – Feb. 2020 **Senior Fisheries Protection Biologist; Mining, Oil & Gas – South; Fish and Fish Habitat Protection Program; Central and Arctic Region, Fisheries and Oceans Canada**

- Management of regulatory reviews for mining projects under the *Fisheries Act* including participating in environmental assessments under the Canadian Environmental Assessment Act in Alberta, Saskatchewan, Manitoba and Ontario.
- Management and mentoring of up 3 - 5 staff members including performance management and career development.

- Providing advice and guidance to staff related to fish and fish habitat, regulatory reviews, compliance and occurrence management, and Indigenous consultation consistent with program policies and applicable federal legislation.
- Providing advice on mining project applications in the context of the *Fisheries Act* to proponents, other regulatory agencies, Indigenous groups and the public.
- Collaboration with provincial levels of government to establish working level relationships and approaches on species at risk issues.
- Participation in the development of regional tools, practices and standards related to regulatory review.
- Process development for collecting feedback on program and policy changes from staff and identifying issues to escalate to management for resolution, if required.
- Development of training priorities for new and existing staff.
- Guiding staff through change with the amended *Fisheries Act* and expanded Fish and Fish Habitat Protection Program.

Jan. 2019 – May 2019 **Fisheries Protection Biologist; Mining, Oil and Gas – South, Fisheries Protection Program; Central and Arctic Region; Fisheries and Oceans Canada**

See summary below.

April 2018 – Dec. 2019 **Acting Senior Fisheries Protection Biologist, Linear Development, Fisheries Protection Program, Central and Arctic Region, Fisheries and Oceans Canada**

- Management of regulatory reviews for linear development projects under the *Fisheries Act* including participating in environmental assessments under the Canadian Environmental Assessment Act in Alberta, Saskatchewan, Manitoba and Ontario.
- Management and mentoring of up to 3 staff members including performance management and career development.
- Providing advice and guidance to staff related to fish and fish habitat, regulatory reviews, compliance and occurrence management, and Indigenous consultation consistent with program policies and applicable federal legislation.
- Providing advice on linear development works and the application of the *Fisheries Act* to proponents, other regulatory agencies, Indigenous groups and the public.
- Collaboration with provincial and municipal levels of government to establish clear project information requirements, including fish passage.
- Participation in the development of regional tools, practices and standards related to regulatory review.

Feb. 2017 – present **Fisheries Protection Biologist; Mining, Oil and Gas – South; Fisheries Protection Program; Central and Arctic Region; Fisheries and Oceans Canada**

- Conduct regulatory reviews of linear development and mining projects and their impacts on fish, occurrences and monitoring reports pursuant to the *Fisheries Act* and *Species At Risk Act.* This includes review of proposed impacts, offsetting and monitoring plans.

- Prepare regulatory action recommendations consistent with Fisheries Protection Program policies and legislation, including the *Fisheries Act* and *Species at Risk Act*
- Plan and conduct sites visits for the review of development proposals, occurrences, and monitoring and compliance activities.
- Represent the Department as part of the Federal Review Team on Canadian Environmental Assessment Act led environmental assessments and Joint Review Panel
- Represent the Department on working groups and committees including the Wapiti River Water Management Plan Steering Committee and Technical Working Group, the Athabasca River Basin Initiative Working Group, and the Fisheries Sustainable Habitat (FiSH) Committee, which is comprised of oil sands operators, DFO and Alberta Government representatives with the goal of improving collaboration as it relates to Fisheries Act authorizations and requirements in the oil sands region.
- Provide regulatory advice and communicate regulatory requirements including avoidance and mitigation measures, serious harm determinations, offsetting and monitoring requirements to proponents, other regulatory agencies and Indigenous groups.
- Undertake Indigenous consultation on behalf of the Crown when DFO contemplates a decision that may impact established or potential Aboriginal rights.
- Providing briefings and memos to senior management regarding regulatory developments on mining and linear development projects.

Jan. 2013 – Jan. 2017 **Land Access Manager, Information Centre, Alberta Biodiversity Monitoring Institute**

- Negotiated annual access to ABMI sites on a variety of land types by effectively communicating the ABMI's program and science, and adhering to conditions of access including permitting, notification and reporting requirements.
- Coordinated access management and scheduling requirements with field crews.
- Assisted in the development of Standard Operating Procedures.
- Maintained landowner information database.
- Developed communication tools including brochures and data summaries for participating land holders.
- Interpreted and presented ABMI's data to the public.
- Coordinated community monitoring project with First Nations groups monitoring Yellow Rail including training on bioacoustics recorders, working with Elders on site selection and reporting.
- Worked independently and travelled throughout Alberta to negotiate access and communicate the ABMI's program.
- Co-developed and delivered an Indigenous knowledge and biodiversity project exploring biodiversity and monitoring from an Indigenous perspective including background research, methods, knowledge collection, reporting and budgeting.
- Coordinated oil sands monitoring reporting for all Centre work plans.
- Coordinated the development of an Alberta based species at risk digital map source including acquiring or creating spatial data in GIS, coordinating digitization of range data, collaborating with provincial experts on range delineation and maintaining species information data.

Brandi Mogge, BSc.
Team Leader, Fish and Fish Habitat Protection Program
Fisheries and Oceans Canada

Curriculum Vitae

Jan. 2008 – Jan. 2012 **Fish Habitat Biologist, Habitat Management Program, Central and Arctic Region, Fisheries and Oceans Canada**

- Reviewed proposals and provided advice and recommendations related to fish and fish habitat for various development activities including pipelines, mines and highway projects as they pertain to the *Fisheries Act*, including compensation and monitoring plans for *Fisheries Act* Authorizations.
- Provided proponents with advice and recommendations to identify modification options to minimize impacts to fish and fish habitat.
- Conducted pre- and post-construction monitoring site visits to ensure compliance with the *Fisheries Act* and functioning of compensation measures.
- Developed and delivered presentations to proponents and consultants.
- Coordinated project review and environmental assessments with other federal departments.
- Undertook consultation with First Nations and Métis groups across central and northern Alberta.
- Participated in provincial fisheries initiatives including annual sampling and spawn camps.

Sept. 2006 – Apr. 2007 **Undergraduate Researcher, Faculty of Science, University of Alberta**

- Conducted an extensive background literature search.
- Organized and manipulated large spatial datasets.
- Developed models to identify differences in habitat and kill site locations and prey choice between cougars and wolves using GIS, statistical analysis and model development and selection analyses.
- Presented results to the Alberta Chapter of the Wildlife Society.
- Synthesized literature and results into clear presentation of data in a final thesis.

Laura Jane Phalen

Senior Biologist
Fish and Fish Habitat Protection Program
1028 Parsons Road, SW
Edmonton, AB, T6B0L8
<personal information removed>

EDUCATION

University of Prince Edward Island (UPEI) – Charlottetown, PE

- Master of Science, Environmental Sciences – 2014
- Bachelor of Science, Biology, Honour's – 2011

WORK EXPERIENCE

Senior Biologist – Fisheries and Oceans Canada, Regulatory Review, Edmonton, AB, Canada. October 2019 – Current.

- Provide guidance and mentoring on risk assessment, potential impacts to fish and fish habitat, avoidance and mitigation measures, offsetting measures, and navigation of regulatory processes to a team of three biologists.
- Assign project files and review risk assessment documents, letters of advice, authorizations, and email communications produced by biologists to ensure consistency and alignment with department policy.
- Provide guidance and resources to biologists on learning plans, mental health in the workplace, rights and responsibilities, and other human resources topics.
- Perform work planning, identify issues to flag to senior management, review updates to policy and guidance documents, perform travel planning for staff, liaise with staff from other programs on mutual priorities.

Fisheries Protection Biologist – Fisheries and Oceans Canada, Regulatory Review, Edmonton, AB, Canada, Aug. 2016 – Current.

- Collaborate with project proponents, Canadian Environmental Assessment Agency, Environment and Climate Change Canada, Health Canada, provincial fisheries managers, other Fisheries and Oceans Canada programs to communicate federal *Fisheries Act* requirements, understand priorities of other stakeholders, and work toward finding approaches to development that incorporate multiple priorities.
- Review, assess, and provide expert advice to inform federal regulatory processes including environmental assessments and metal and diamond mining effluent regulation provisions.
- Provide regulatory oversight pertaining to the application of the federal *Fisheries Act* prohibitions as they apply to mining development in Canadian freshwater habitats.
- Assess requests for review for information requirements, avoidance and mitigation measures, and potential impact on fish and fish habitat; review monitoring reports to ensure compliance with authorization conditions; provide advice on avoidance and mitigation measures to be implemented at work sites; generate authorizations that stipulate the conditions by which work that may cause harmful alteration, disruption, or destruction of fish must be undertaken; assess the validity of required offsetting plans in relation to existing policy and the environmental context..
- Participate in Indigenous consultation where decisions are being considered under federal legislation, as well as

on potential changes to the *Fisheries Act*.

Fisheries Protection Biologist, Expert Support – Fisheries and Oceans Canada, Federal Contaminated Sites Action Plan Program, Edmonton, AB, Canada, Sep. 2016 – March 2017.

- Provide expert advice to departments overseeing the management of federally owned contaminated sites, including advice on collecting adequate information, performing risk assessments appropriately, and deciding on work plans that align with regulatory requirements under the *Fisheries Act*.

Biologist – Aquality Environmental Consulting, Edmonton, AB, Canada, Apr. 2016 – Aug. 2016.

- Managed client's regulatory requirements related to the *Fisheries Act*, Alberta Wetlands Policy, Alberta *Water Act*, and the *Public Lands Act*; ensured regulatory requirements were met in applications, on the ground, and in monitoring and information submissions.
- Performed: construction site compliance checks, rare plant species transplant success surveys, fish habitat and population assessments, riparian revegetation/stabilization, and installed erosion and sediment control materials.

Community Outreach Planner – Ellen's Creek Watershed Group. Charlottetown, PE, Canada. Feb. – Apr. 2015 (Contract position).

- Contributed to completion of a Brook Trout Conservation Plan for three streams in Charlottetown, PE.
- Ensured that other consulting parties were provided with a clear understanding of the observations made.

Stream Biologist - Ellen's Creek Watershed Group. Charlottetown, PE, Canada. June – Sept. 2014.

- Restored and maintained stream segments of Ellen's Creek to ensure fish passage potential; removed and quantified litter from the stream, cleared blocked springs, planted trees.
- Communicated with the public via several social media platforms including posting photos, updates, descriptions, and justification for the activities of the group to promote community involvement and funder support.
- Collected and consolidated field data, including litter identification counts, in-stream assessment data, and digital map creation of in-stream sections for use in data communication. Carried out graphical representation and report generation appropriate for public, funding support partners, and community-led governing board.

ACADEMIC/RESEARCH EXPERIENCE

Master of Science - UPEI, Environmental Sciences, Charlottetown, PE, Canada. Sept. 2011 – Nov. 2014.

- **Primary Goal:** Determine cellular mechanisms of immune alterations in rainbow trout (*Oncorhynchus mykiss*) following toxicant (benzo[a]pyrene) and antigen co-exposure.

Senior Honour's Thesis - UPEI, Dept.of Biology, Charlottetown, PE, Sept. 2010 – May 2011.

- **Primary goal:** Refinement and optimization of flow cytometry methods (in collaboration with a fish immunologist from the German Federal Institute of Animal Health, Freidrich-Loefller Institute) to evaluate the full range of rainbow trout leukocyte distribution changes in blood and immune tissues at different time points following toxicant (benzo[a]pyrene) and antigen co-exposure.

Research Assistant - UPEI, Department of Biology. Charlottetown, PE. May – Sept. 2009, 2010 and 2011 (full time), and September 2010 – May 2011 (part time).

- **Primary goal:** Identifying presence of, and developing a diagnostic test for lymphocystis disease virus (LCDV) in yellow perch (*Perca flavescens*) exposed to oil sands effluent in Fort McMurray, Alberta, Canada. Designed and carried out an experiment (in Fort McMurray, Alberta, Canada) to determine whether LCDV incidence was increased in yellow perch in oil sands affected waters.
- **Secondary roles:** Performed water sampling and stream velocity measurements in two watersheds in all

seasons. Assisted in ongoing laboratory and field based research projects relating to fish health and population studies in both Fort McMurray, AB and Prince Edward Island fresh and salt water environments.

Laboratory Instructor – UPEI, Department of Biology, Charlottetown, PE, Canada.

- Courses: **Environmental Toxicology** (Jan. – May 2013), **General Physiology** (Sept. – Dec. 2012), **Introductory Biology** (Sept. – May 2012, Sept 2012 – May 2013; Sept. 2009 – May 2010, Sept. 2010 – May 2011.
- Ensured materials and equipment were set up and running for various teaching laboratories, guided students through hands-on and written exercises, graded reports and exercises.

PEER-REVIEWED PUBICATIONS

Phalen LJ, Köllner B, Leclair LA, Hogan NS, van den Heuvel MR. 2014. The effects of benzo[a]pyrene on leukocyte distribution and antibody response in rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology. 147; 121-128.

Leclair LA, MacDonald GZ, **Phalen LJ**, Köllner B, Hogan NS, van den Heuvel MR. 2013. The immunological effects of oil sands surface waters and naphthenic acids on rainbow trout (*Oncorhynchus mykiss*). Aquatic Toxicology. 142–143; 185–194.

MacDonald GZ, Hogan NS, Köllner B, Thorpe KL, **Phalen LJ**, Wagner BD, van den Heuvel MR. 2013. Immunotoxic Effects of Oil Sands-Derived Naphthenic Acids to Rainbow Trout. Aquatic Toxicology. 126; 95-103.

Palmer (Phalen) LJ, Hogan NS, van den Heuvel MR. 2012. Use of Molecular Methods in the Detection of Lymphocystis Disease Virus from Yellow Perch (*Perca flavescens*). Journal of Fish Diseases. 35; 661-670.

ORAL AND POSTER PRESENTATIONS

(Presenting author in bold)

Phalen LJ, Hogan NS, Köllner B, van den Heuvel MR. Rainbow trout (*Oncorhynchus mykiss*) B cell and thrombocyte gene expression following *in vivo* exposure to benzo[a]pyrene. Candian Ecotoxicity Workshop 2015. (Oral)

Phalen LJ, Köllner B, van den Heuvel MR. Cellular level responses of rainbow trout (*Oncorhynchus mykiss*) leukocytes to benzo[a]pyrene. Aquatic Toxicity Workshop 2013, International Fish and Shellfish Immunology Conference 2013, UPEI Science Graduate Studies Day 2013. (Oral)

Phalen LJ, Hogan NS, MacDonald GZ, Thorpe KL, Köllner B, van den Heuvel MR. Immune response of rainbow trout (*Oncorhynchus mykiss*) co-exposed to benzo[a]pyrene and *Aeromonas salmonicida*. Aquatic Toxicity Workshop 2011, Society of Environmental Toxicology and Chemistry Conference 2011. (Oral)

Phalen, LJ, Köllner, B, van den Heuvel MR. Benzo[a]pyrene differentially effects immunomagnetically separated rainbow trout B cell and thrombocyte mRNA expression. Canadian Rivers Institute (CRI) days 2014. (Poster)

Phalen LJ, Köllner B, van den Heuvel, MR. Changes in immune cell populations of rainbow trout (*Oncorhynchus mykiss*) exposed to benzo[a]pyrene. Fish Immunology Workshop 2012. (Poster)

Macdonald GZ, Hogan NS, **Phalen LJ**, Thorpe KL, van den Heuvel MR. The immunologic effects of aged oil sands-derived naphthenic acids on rainbow trout co-exposed to pathogen associated molecular patterns. Society of Environmental Toxicology and Chemistry 2011. (Poster)

Phalen LJ, Hogan NS, van den Heuvel MR. Molecular identification of a yellow perch viral disease associated with exposure to oil sands process affected waters. Aquatic Toxicity Workshop 2010. (Poster)

RESUME FOR ROBYN KUTZ, B. Sc., P. Biol.

Edmonton, Alberta
Email: <email address removed>

Education: Bachelor of Science Degree in Biology
University of Lethbridge
Lethbridge, AB

Professional Membership: Alberta Society of Professional Biologists

Work History:

Company: Department of Fisheries and Oceans Canada
Edmonton, AB
Date: 2019 – current
Duties:

- Species at Risk Biologist; acting Senior Biologist (Bi-03) since July 2019.
- Collaborate with multi-level government and stakeholders on the recovery of species at risk.
- Contribute to and review species specific recovery and action plans.
- Contribute to and review species specific 5 year progress reports.
- Draft ministerial correspondences and briefing notes.
- Work with multiple levels of government and various stake holders to understand fish species and the associated complex environmental issues as they pertain the *Species at Risk Act*.
- Coordination and participate in projects and meetings that aid in the review, awareness, and/or education of environmental issues.
- Build and maintain stakeholder relations.
- Develop and deliver species specific awareness and educational conservation tools.

Company: Shell Canada/CNRL (the Shell facilities I worked at were acquired by CNRL on June 1, 2017 but my position was retained)
Peace River, AB
Date: 2014 to 2019
Duties:

- Environmental and regulatory coordinator.
- Responsible for provincial (Alberta) and Federal regulatory compliance at both Peace River Complex and Cliffdale sites entailing multiple disciplines; air, water, land, wildlife (fauna, native and imported flora) and waste.
- Completion and submission of regulatory reports and compliance related notifications (including but not limited to the *Water Act, Environmental Protection and Enhancement Act, and Public Lands Act*).
- Direct environmental matters on-site.
- Environmental incident investigations.
- Liaison with regulators, First Nations communities, stakeholders, and contractors.
- Management of contractors' delivery of environmental programs at site.
- Management of environmental (contactor) staff, compliance and budgets.
- Working within a multi-disciplinary team on-site to complete environmental tasks required for regulatory compliance and continued operation of the facility (e.g. air monitoring, wetlands, reclamation, water treatment, environmental ecosystem conservation etc).

Company: Applied Aquatic Research Ltd. (AAR)
Peace River, AB
Date: 2013 to 2014
Duties:

- Northwest Operations Manager: Area Manager responsible for AAR's Peace River office and staff including selection, development and retention. I started up the AAR Peace River office, built a clientele base, hired staff, located and set up our office space, and both managed and planned our budget and projects taking this new office into a position of positive cash flow.
- Anticipated potential issues with field programs and regulations, as it is imperative to think ahead and be flexible to work around obstacles.
- Provided both provincial (Alberta and British Columbia) and Federal regulatory requirement advice to clients; this included development of site appropriate aquatic assessment studies, review of impacts on wetlands, as well as submission of required notifications, license and project approval applications.
- Building and maintaining relationships with clients, regulators, and Metis organizations.
- Conducted statistical analysis of fish populations and aquatic habitats during completion and report writing of environmental assessments by utilizing a collection of methods and processing and analyzing large amounts of data to report overall trends.
- Develop and managed field programs and crew led numerous fish habitat assessments.
- Review/edit qualified aquatic environmental specialist (QAES) assessment reports regarding fish and their habitat.
- Developing cost estimates and project proposals for consulting work in and near waterbodies.
- Provide project related environmental risk management advice.
- Fish habitat assessments (including electrofishing and fish identification).
- Interpretation of fish and fish habitat field data.
- Providing project based advice in regards to mitigation methods, construction and remediation options, fish and fish habitat sensitivities, species at risk, as well as federal and provincial regulatory requirements.
- Drafting and editing environmental assessment reports.
- Managing projects, timelines, and staffing requirements.
- Mapping watercourse crossings along pipeline routes.
- Use of Alberta Environment and Sustainable Resource Development's Fish and Wildlife Management Information System (FWMIS) for historical information gathering.
- Working with regulators to ensure compliance during different phases of projects.
- Business development.

Company: Department of Fisheries and Oceans Canada
Lethbridge, Edmonton, and Peace River, AB
Date: 2007 – 2013
Duties:

- Review of project proposals to determine environmental impacts, writing letters of advice on how to protect fish habitat from impacts of various development activities via mitigation measures, as well as, communicating with proponents, consultants, and governmental agencies.
- Review of major project proposals (e.g. hydro-electric dam, oil and gas, mining projects etc.) and their associated impacts to fish and fish habitat.

- Authored and issued *Fisheries Act* Authorizations when projects resulted in harmful alteration, disruption, or destruction (HADD) of fish or fish habitat. This involved working with Proponents in attempts to mitigate potential project impacts, as well as approve compensation proposals for HADDs.
- Work with multiple levels of government and various stake holders on complex fish habitat management issues and environmental reviews.
- Collaborated with provincial regulators to ensure enforcement and compliance of the *Fisheries, Environmental Protection and Enhancement, and Water Acts.*
- Coordination of liaisons and consultation with different groups and departments regarding projects and their associated environmental impacts.
- Coordination of projects and meetings that aid in the review, awareness, and/or education of environmental issues relating to fish or fish habitats.
- Initiation of and participation in First Nations consultation.
- Participated as a member on a hydro-electric technical advisory committee, a watershed council, as well as the initial stages of a water management committee to contribute to the development and implementation of goals, objectives and strategies.
- On-site evaluations to monitor and determine the impacts and remediation effectiveness of developmental activities on aquatic ecosystems, as well as, ensure compliance.
- Analysis of plans for environmental mitigation, remediation and monitoring measures to determine effectiveness.
- Complete environmental reviews of projects for a variety of industries such as oil and gas, agriculture and transportation.
- Referencing *Alberta Codes of Practice* in regards to project proposals.
- Referencing and knowledge of the Federal *Fisheries Act*, federal environmental assessment legislation (CEAA) and processes, as well as, various federal policies, regulations and operational statements, which pertain to the management of fish habitat.
- Reviewing procedures used to mitigate or compensate fish habitat losses.
- Environmental assessments of development proposals/projects to determine impacts on aquatic ecosystems.
- Participated in the Fins (fish in school) program.
- Participated with DFO's Stewardship program, which included reviewing proposals and assisting with advice to proponents.
- Entry of environmental assessments, referrals, proposals, and operational data into the National habitat database with the PATH software.
- Effectively utilized Microsoft Office programs, such as, Microsoft Outlook, Microsoft Word, Microsoft Excel, and Microsoft PowerPoint.
- Use of my knowledge of various aquatic ecosystem impacts related to development activities.
- Dealing with and understanding Alberta fish species identification, life histories, fish habitat requirements, physical, chemical, and hydrological processes in aquatic environments.
- Customer service through communication and well developed interpersonal skills.
- Supervisor acting roles at the Peace River DFO office.

Company: Alberta Parks and Protected Areas
Pincher Creek, AB
Date: July – September 2006, May – October 2007
Duties:

- Revenue.

- Ensured compliance amongst park users.
- Angler surveys and fish species identification.
- Assisted Conservation Officers when needed.
- Obtained regular water samples and turbidity measurements, as well as, water temperatures of a local waterbody.
- Dealt with the public in regards to wildlife issues and provincial park regulations and compliance.
- Acquired knowledge of water body specific provincial fishing regulations.
- Answered wildlife related questions from park users.
- Reported matters of public safety to Conservation Officers.
- Worked involved a high degree of independence and decision making skills.

Company Department of Fisheries and Oceans Canada
Lethbridge, AB
Date January 2006-April 2006 and May 2006
Duties:

- Assisted with the review of water intake files for information compilation.
- Travelled to each district within Alberta to do inventory.
- Entry of environmental assessments, referrals, proposals, and operational data into the National habitat database with the PATH software.
- Effectively utilized Microsoft Office programs, such as, Microsoft Outlook, Microsoft Word, Microsoft Excel, and Microsoft PowerPoint.
- Used internet for information gathering and research, as well as, communication.
- Used departmental intranet for various tasks and information gathering.
- Reviewed proposal and wrote letter of advice.

Company: Department of Fisheries and Oceans Canada
Lethbridge, AB
Date: May 2005-November 2005
Duties:

- Various administrative duties as required. This included entry/management of financial and human resource records, as well as communication with the public in regards to inquiries.
- Reviewed environmental assessment projects/proposals. This included communication with proponents, consultants and governmental agencies. This also entailed writing letters of advice on how to protect fish habitat from impacts of various development activities, performing location analyses, assessing works on the proposed water in reference to the *Alberta Codes of Practice*, as well as, assessments in reference to Fishers and Oceans legislation, regulations, policies and operational statements.
- Assisting with the analysis of plans and environmental mitigation and monitoring measures to determine effectiveness. This included assisting with preliminary site evaluations to determine the impacts of developmental proposals on aquatic ecosystems.
- Acquired knowledge of DFO's Operational Statements and procedures.
- Field work included assisting with fish sampling, assisting with site assessments, as well as, assisting with stocking juvenile trout for the FinS (fish in schools) program.
- Responsible for entry of environmental assessments, referrals, proposals, and operational data into the National habitat database with the PATH software.
- Effectively utilized Microsoft Office programs, such as, Microsoft Outlook, Microsoft Word, Microsoft Excel, and Microsoft PowerPoint.

- Used internet for information gathering and research, as well as, communication.
- Used departmental intranet for various tasks and information gathering.

Company: Department of Fisheries and Oceans Canada
Lethbridge, AB
Date: February 2004-July 2004
Duties:

- Responsible to create, plan, and organize the Fisheries and Oceans Lethbridge office reference library which contained various types of documents/media used in the delivery of various Fisheries and Oceans programs and services, as well as information and reports received from proponents, organizations, consultants and other public agencies.
- All items in the library were entered into a Procite database. Entry into the database required review, categorization, and assessment of all documents.

GeoProcess RESEARCH ASSOCIATES
Knowledge Research Consulting

KEN GLASBERGEN M.Sc., E.R.P.G.

SENIOR ECOLOGIST/FLUVIAL GEOMORPHOLOGIST

Education & Training
M.Sc., University of Waterloo, 2014
Thesis: The Effect of Coarse Gravel on Cohesive Sediment Entrapment in an Annular Flume
Ecosystems Restoration Post Graduate Certificate, Niagara College, 1999
Bachelor of Environmental Science (Honours B.Sc. (Env)), University of Guelph, 1996

Certifications & Affiliations
American Fisheries Society
Canadian Water Resource Association

PERSONAL PROFILE

Ken Glasbergen has eighteen years of professional ecological consulting experience in the areas of freshwater fisheries, channel assessment and restoration, vegetation characterizations and environmental planning. Ken is involved in the collection of fluvial geomorphology and fish habitat data for assessment and design purposes. Ken has worked on a wide variety of projects including mine impact assessment, large scale river restoration, mine closure plans, installation of bridge crossings, dam and barrier removals, and channel realignments. Much of his work has focused on impact assessment and habitat restoration of stream and wetland systems. Ken has been involved in numerous wetland restoration projects including large-scale restoration strategies such as Project Paradise.

His environmental assessment and planning work focuses on developing natural heritage frameworks used to facilitate development planning, mitigation, and consensus building between stakeholders. Ken has been involved in watershed studies, secondary plan studies, and subwatershed studies, integrating the built form with natural heritage systems. He has completed numerous environmental impact statements and is constantly looking for new and innovative solutions for environmental planning challenges. Ken works extensively within federal, provincial and municipal regulatory policy frameworks on Environmental Impact Statements and Environmental Assessments.

Ken provides technical expertise in a peer review capacity to several First Nations communities, acting on their behalf to review proposed mining projects within their Traditional Lands. Ken provides technical review expertise in the areas of surface water, water quality and fisheries ecology. Ken also provides peer review expertise to the Department of Fisheries and Oceans Canada (DFO) related to fisheries ecology and fluvial geomorphology assessments.

RELEVANT EXPERIENCE

FLUVIAL ASSESSMENTS AND RIVER RESTORATION

Mattamy (Pickering) Homes Seaton Development Erosion Threshold Assessment & Natural Channel Design
Client: Mattamy Homes, 2017-2020
Erosion threshold assessment of and detailed design of approximately 100 m of channel, and two stormwater pond outlets for two tributaries of Ganatsekiagon Creek. The design focused on tie-ins to the proposed stormwater infrastructure, addressing local erosion and reducing the amount of disturbance to the creek.

Watercourse Realignments and Natural Channel Designs, Coté Gold Project, Gogama, Ontario
Client: IAMGOLD, Gogama Ontario, Corporation
Completed fluvial geomorphology study and natural channel designs for two watercourse realignments (totaling approximately 3 km) to support the development of the Coté Gold Project. Tasks included field assessments, hydrogeomorphic modelling, detailed natural channel designs and facilitating in securing regulatory permits for construction.

Lower Spencer Creek Restoration Plan
Client: Hamilton Conservation Authority, City of Hamilton
Complete a natural channel design and fish habitat restoration plan for the Spencer Creek between Cootes Drive and Thorpe Street in the Town of Dundas. The goal of the restoration design is to re-establish a meander channel that is recoupled with its floodplain, correcting historical straightening and entrenchment. Enhancement of Lower Spencer Creek is critical to the fishery of Cootes Paradise, Hamilton Harbour and Western Lake Ontario.

Lower Spencer Creek Fluvial Geomorphology Assessment, City of Hamilton
Client: Hamilton Conservation Authority, City of Hamilton
Completed an assessment of the Lower Spencer Creek within the Town of Dundas for the Hamilton Region Conservation Authority, using RGA and RSAT protocols channel surveying, flow monitoring, and determining critical discharge flows. Information incorporated into Flood Risk analysis and assessment to provide guidance on channel works to reduce flood risks in the Town of Dundas.

Mattamy (Waterdown) Homes UpCountry Estates Phase 2 Natural Channel Design and Monitoring
Client: Mattamy Homes, Town of Waterdown, March 2013 to Present
Re-establish a meandering channel following natural channel design principals for a reach of a Tributary of Grindstone Creek which had historically been straightened and entrenched.

Park Place Phase 2 Natural Channel Design,
Client: Country Green Homes, Town of Waterdown
Re-align a straightened branch of Borer's Creek to accommodate development. Channel re-alignment incorporated natural channel design principals with a goal of improving long term channel stability and improving fish habitat.

Ingersoll Flood Control Channel (Thames River) Geomorphology Study, Ingersoll, Ontario
Client: Upper Thames Conservation Authority
Completed a geomorphic investigation on a 25km reach of the Upper Thames River to determine the geomorphic impacts associated with historic channelization for flood control purposes. Advanced hydrogeomorphic and sediment transport modelling methods were employed to assess the active processes resulting in the field observed morphologic characteristics. Based on the existing conditions investigation, several habitat restoration revetments were proposed to increase biological productivity in the degraded reach.

Environmental Implementation Report and Functional Servicing Study: Evergreen Community
Client: Argo Developments, City of Burlington, 2018 to Present
Senior lead for the fluvial geomorphological component of the study for the conversion of agricultural lands into residential and business lands development. Work included headwater drainage assessments, meander belt width assessments, erosion threshold assessment and natural channel design.

NATURAL AREAS CHARACTERIZATION

Tremaine and Dundas Secondary Plan Subwatershed Study Update
Client: City of Burlington, City of Burlington
Worked for the City of Burlington to update the Subwatershed Study and Secondary Plan for the last remaining greenfield developable land within the City of Burlington. GRA component focused on surface water, fluvial geomorphology and helping to develop a natural heritage system for the Study Area.

Lower Spencer Creek Integrated Subwatershed Study

Client: Hamilton Conservation Authority, City of Hamilton

Provided the fluvial geomorphic component to the study, which included a detailed geomorphic assessment of Lower Spencer Creek, recommendations for improving the creek's stability and fish habitat, and considering flood mitigation measures.

Boyne Survey Phase 3 Block 2 Subwatershed Impact Study

Client: Town of Milton

Senior lead for the natural heritage component of a Block Plan for the residential development of lands within the Boyne Survey Phase 3 lands within the Town of Milton. Work included characterization of natural heritage features, establishing a natural heritage system, completing an impact assessment and developing monitoring programs.

Milton Phase 3 Lands Natural Heritage Assessment

Client: Milton Phase 3 Land Owners Group, Town of Milton

Senior lead natural heritage lead to develop a Natural Heritage System and framework to help guide development of 750 hectares of the Milton Phase 3 Lands. Natural heritage assessments include fish habitat and community assemble, vegetation surveys, breeding bird surveys, and wildlife surveys.

Little River Surface Water Aquatic Assessment

Client: Xstrata, Bathurst New Brunswick

Project manager for the surface water assessment component of the Brunswick Mine No. 12 Closure Plan program. The project involved a multi-disciplinary team which assessed all sources of contamination within the watershed, disseminating anthropogenic from naturally occurring sources, determining what is related to mine activities, its impact on aquatic life, and if remedial measures are required. The study included the development of a watershed water balance model, sediment transport model, channel stability analysis, metal loading model, fish habitat assessment model, benthic invertebrate analysis, marine sediment chemical and age analysis, and overall water and sediment quality analysis. The results of the study were used to establish a management plan for water treatment plant post mine closure and river restoration, with the goal of maintaining river stability, reducing contaminant transport, and re-establishing self-sustaining populations of Atlantic Salmon and Brook Trout.

Biodiversity Assessment Brunswick Mine No. 12

Client: Xstrata, Bathurst New Brunswick

Project manager for a study assessing the biodiversity of the mine property and the surrounding regional lands, completing an impact assessment of all mine operations and their potential impacts to biodiversity, and providing recommendations on further studies and monitoring requirements.

Biodiversity Assessment Brunswick Mine No. 6

Client: Xstrata, Bathurst New Brunswick

Project manager for a study assessing the biodiversity of the mine property and the surrounding regional lands, completing an impact assessment of all mine operations and their potential impacts to biodiversity, and providing recommendations on further studies and monitoring requirements.

Biodiversity Assessment Matabi Mine

Client: Xstrata, Northern Ontario

project manager for a study assessing the biodiversity of the mine property and the surrounding regional lands, completing an impact assessment of all mine operations and their potential impacts to biodiversity, and providing recommendations on further studies and monitoring requirements.

BacTech Mine Closure Plan,

Client: BacTech, Gowganda Ontario

Project manager for a Mine Closure Plan required as part a larger project looking to reprocess historic tailings by means of a bioleaching process for recoverable metals. The project included all hydrological, sediment transport

and biological support for the Closure Plan(s) including water and sediment quality sampling, fish community sampling, fish habitat assessment, benthic invertebrate sampling, and species at risk screening.

Cobalt Camp Surface Water Contamination Study

Client: Ontario Ministry of Northern Development and Mines, Cobalt Ontario

Project manager for a study for the Ontario Ministry of Northern Development and Mines assessing all surface water features, both riverine and lake within the Cobalt silver mining camp, to determine levels of metal and arsenic contamination due to historical mining activities and there impacts on aquatic life. The study includes extensive sampling of water and sediment quality, benthic invertebrates, fish community (assemblage and body burden analysis), tailing dust transport, and an ecological risk screening. The goal of the study was to characterize the level and spatial distribution of contaminants and their impacts to aquatic life, while tying this information to specific mine and tailings sites.

Comprehensive Broader Scale Environmental Study (CBSES) for the Town of Caledon's High Potential Mineral Aggregate Resource Area (CHPMARA) 9-A,

Client: James Dick Construction Ltd, Town of Caledon Ontario

Involved in the natural heritage component of a subwatershed study spanning three watersheds, including fisheries, vegetation, birds, wildlife, and benthic invertebrate assessments and characterizations. The natural heritage assessment, including the development of predictive fish community models, was used to assess potential impacts to natural heritage features, particularly those dependent on groundwater, based on various aggregate extraction scenarios. The assessment was used to help set the framework for future development with the Resource Area.

EXPERT REVIEW

Hardrock Gold Mine Environmental Assessment Review

Client: Long Lake 58 First Nation, Long Lac Ontario

GeoProcess lead provided a technical hydrologic peer review of the Hardrock Gold Mine Environmental Assessment, working on behalf of the Long Lake #58 First Nations. Review focused on surface water and aquatic ecology. Work includes liaising with LLFN and the mine representatives to discuss project elements and related FN interests. The review includes numerous meeting with the mine, provincial and federal agencies and the LL #58 FN community.

Magino Gold Mine Environmental Assessment Review

Client: Batchawana First Nation, Wawa Ontario

GeoProcess lead providing a technical peer review of the hydrologic, fluvial geomorphic and aquatic ecological components of the Magino Gold Mine Environmental Assessment for the Batchawana First Nation. GRA's review of the EA was to assess the project as it relates to FN interests. The review included technical meetings with the Mine representative and CEAA staff, as well as meetings with Chief and Council.

Obed Mountain Coal Mine

Client: Department of Fisheries and Oceans Canada, Hinton Alberta

Providing expert fluvial geomorphic and fish habitat advice to the Department of Fisheries and Oceans as part of their HADD investigation of the Obed Mountain Coal Mine tailing pond breach which resulted in the destruction of approximately 5 km of Athabasca Rainbow Trout, as Species at Risk, habitat. GeoProcess completed field investigations to quantify the extent of the HADD, developed construction ready natural channel and fish habitat design to restore the Apetowun Creek. GeoProcoss provided expert advice on the review of the Mine's proposed restoration plan as part of the DFO permitting process.

Grassy Mountain Coal Mine EA Review

Client: Department of Fisheries and Oceans Canada, Crows Nest Pass Alberta

Providing technical review of the Grass Mountain Coal Mine EA to the DFO, specifically focusing on fisheries ecology, fluvial geomorphology, surface water modelling (hydrology) and groundwater modelling (hydrogeology). GeoProcess's review comprised technical Supplementary Information Request (SIR) provided to CEAA on behalf of the DFO.

Sundog Creek Realignment Technical Peer Review

Client: Fisheries and Oceans Canada

Technical reviewer for a proposed diversion and realignment of Sundog Creek in Northwest Territories. Project included reviewing hydrotechnical reports, fisheries offsetting plans and design reports/drawings and developing several detailed and summarized review documents related to the proposed design and offsetting plan on behalf of the regulatory team (Fisheries and Oceans and Parks Canada).

Elbow River and Fish Creek Realignments Geomorphology and Natural Channel Design Technical Peer Review

Client: Fisheries and Oceans Canada

Technical reviewer for two river realignments and habitat enhancement plans associated with the Southwest Calgary Ring Road project. Technical reviews focused on long-term geomorphic performance of the realignments and their potential impacts to fish habitat.

Minera Panama S.A. Copper Project Environmental Assessment Peer Review,

Client: Inmet Mining Corp, Petaquilla Concession, Panama

Peer review of the Environment Assessment for the Petaquilla Copper project specifically reviewing and providing comment on fisheries and biodiversity components of the EA study. Supporting review of the hydrological and sediment transport assessments was also completed. The EA review included providing guidance on study design and impact assessment to the lead consultants.

CONFERENCES AND PUBLICATIONS

Glasbergen K., The Effect of Coarse Gravel on Cohesive Sediment Entrapment, Presented at CWRA / CGU National Conference 2012, Banff AL

Glasbergen K., The effect of coarse gravel on cohesive sediment entrapment in an annular flume, Presented at CWRA National Conference 2013, Hamilton ON

Glasbergen K., The effect of coarse gravel on cohesive sediment entrapment in an annular flume, Presented at Sediment Dynamics from the Summit to the Sea 2014, New Orleans

Glasbergen K., The Use of Unmanned Aerial (UAV) Technologies to Detect Groundwater Inputs in the Credit River, Presented at 5th International Conference on Natural Channel Systems 2016, Niagara Falls, ON

Glasbergen K., Stone M., Krishnappan B., Dixon J., Silins U. 2014. Sediment Dynamics from the Summit to the Sea., New Orleans, USA. IAHS Publ. 367, 2014. Doi:10.5194/piahs-367-157-2015. Pg 157-162.

KEN GLASBERGEN

SENIOR ECOLOGIST/FLUVIAL GEOMORPHOLOGIST

GeoProcess RESEARCH ASSOCIATES

EMPLOYMENT HISTORY

GeoProcess Research Associates Inc.
2013 - Present Principal & Senior Ecologist/Fluvial Geomorphologist

Renovo Watershed Sciences Inc.
2010 - 2015 Principal & Senior Ecologist

LGL Limited Environmental Research Associates
2000 - 2010 Senior Ecologist, Assistant Office Manager

Royal Botanical Gardens/Department of Fisheries and Oceans
1999 Aquatic Ecologist

PROFESSIONAL DEVELOPMENT

Stream Restoration Design, Dr. Robert Newbury, British Columbia Freshwater Institute

Headwater Drainage Feature Assessment: OSAP Module 10 and 11

Electorfishing Class 2 Backpack Certification, Ontario Ministry of Natural Resources

Royal Ontario Museum Ontario Fish Identification Workshop Certified

Ecological Land Classification Certified, Ontario Ministry of Natural Resources

Benthic Invertebrate (BioMAP) Water Quality Assessment Certified

Ontario Stream Assessment Protocol

GeoProcess RESEARCH ASSOCIATES
Knowledge Research Consulting

BEN PLUMB PhD, P.Eng.

RIVER ENGINEER / FLUVIAL GEOMORPHOLOGIST

Education & Training

PhD, Civil Engineering, University of Waterloo, 2017
Thesis: *Impacts of Hydromodification and Sediment Supply Alterations on Bedload Transport and Bed Morphology in Urbanizing Gravel-bed Rivers*
Supervisor: William Annable, PhD, PhD, P.Eng., P.Geo.
BASc, Civil Engineering (with Distinction), University of Waterloo, 2010
Options in Management Science and Water Resources
Guest Doctoral Student at École Polytechnique Fédérale de Lausanne, Switzerland, Laboratory of Hydraulic Constructions

Certifications & Affiliations

Professional Engineers Ontario
Association of Professional Engineers and Geoscientists of Alberta
Whitewater Rescue Technician – Level 3
Canadian Water Resources Association
Ontario Society of Professional Engineers

PERSONAL PROFILE

Ben has worked in the fields of fluvial geomorphology and river restoration since 2008. He focuses on process-based solutions to solving problems involving complex river mechanics in challenging technical and regulatory environments. Ben has extensive experience undertaking geomorphological field assessments spanning systems small to large in both urban and rural settings. He is an expert in river survey techniques, sediment sampling, hydrometric measurement, and rapid geomorphic assessments (fluvial audits) for all types of fluvial systems. His analytical expertise includes sediment transport modelling, hydrogeomorphic analysis, erosion threshold and hazard assessments. Ben has completed numerous river rehabilitation and natural channel design projects ranging from small-scale erosion protection to multi-kilometre channel realignments. He frequently acts in peer review and advisory roles in projects on geomorphology and natural channel design for various government regulators.

RELEVANT EXPERIENCE

LINEAR INFRASTRUCTURE – WATERCOURSE CROSSINGS (BRIDGES, CULVERTS AND DAMS)

Bon Air Dam Decommissioning Class EA, Cannington, Ontario (2019-Present)

Client: Chartwell Retirement Residences
Role: Technical Lead – Fluvial Geomorphology and River Engineering
Scope: Geomorphic assessments, environmental assessment, detailed design, regulatory permitting.

Highland Creek Markham Branch Flood Remediation Class EA, Scarborough, Ontario (2019-Present)

Client: Toronto and Region Conservation Authority (partnered with Morrison Hershfield)
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, 2D hydraulic modelling, erosion/sediment transport modelling.

Graham Creek Culvert Renewal, Ottawa, Ontario (2018-2020)

Client: City of Ottawa (partnered with J. L. Richards & Associates)
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, erosion impact assessment, design criteria recommendations.

Wenige Bridge Replacement – Thames River, London, Ontario (2019-2020)

Client: City of London (partnered with Parsons)
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, hydrogeomorphic modelling, geomorphology impact assessment.

East-West Road Corridor – Grindstone Creek Crossing, Waterdown, Ontario (2019-2020)

Client: City of Hamilton (partnered with Dillon Consulting)
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, design criteria recommendations.

BEN PLUMB

RIVER ENGINEER / FLUVIAL GEOMORPHOLOGIST

Credit Meadows Park Expansion – Credit River and Fletchers Creek, Mississauga, Ontario (2019-2020)

Client: City of Mississauga (partnered with Burnside)
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, erosion assessment, design criteria recommendations.

Highway 17 Bridge Replacement – Mississippi River, Ottawa, Ontario (2017)

Client: Ontario Ministry of Transportation (partnered with Dillon Consulting)
Role: Technical Lead – Fluvial Geomorphology
Scope: Scour assessment, design criteria recommendations.

LINEAR INFRASTRUCTURE – BURIED WATERCOURSE CROSSINGS

Enbridge Line 10 Fluvial Geomorphology Risk Assessment, Niagara River, Ontario (2018-2019)

Client: Enbridge Energy (partnered with Wood Environment & Infrastructure)
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic desktop assessments, erosion risk assessment, sediment transport and scour modelling.

Depth of Cover Remediation – West Line Crossings, Trent and Salmon Rivers, Ontario (2018-present)

Client: Trans-Northern Pipelines (partnered with Dillon Consulting)
Role: Technical Lead – Fluvial Geomorphology and River Engineering
Scope: Geomorphic field/desktop assessments, hydraulic modelling, detailed design, regulatory permitting.

Credit River Scour Assessment, Glen Williams, Ontario (2019-2020)

Client: Glen Ridge Estates
Role: Technical Lead – Fluvial Geomorphology and River Engineering
Scope: Geomorphic field/desktop assessments, hydraulic modelling, scour assessment, design criteria recommendations.

NATURAL CHANNEL DESIGN / EROSION CONTROL / WATERCOURSE REALIGNMENTS

Stream Realignments and Natural Channel Designs, Coté Gold Project, Gogama, Ontario (2017-present)

Client: IAMGOLD Corporation
Role: Technical Lead – Fluvial Geomorphology and River Engineering
Scope: Geomorphic field/desktop assessments, hydraulic modelling, detailed design, tender support, regulatory permitting.

Fletchers Creek Headwater Realignment and Restoration Plan, Brampton, Ontario (2016-Present)

Client: Block 51-2 Landowners Group
Role: Technical Lead – Fluvial Geomorphology
Scope: Detailed design, tender support, regulatory permitting, construction supervision, post-construction monitoring.

Parkside Place Phase 2 Realignment and Restoration Plan, Waterdown, Ontario (2017-Present)

Client: Country Green Homes
Role: Technical Lead – Fluvial Geomorphology
Scope: Detailed design, tender support, regulatory permitting, construction supervision, post-construction monitoring.

City of Markham Various Storm Infrastructure Rehabilitations, Markham, Ontario (2013-Present)

Client: City of Markham
Role: Technical Lead – Fluvial Geomorphology and River Engineering
Scope: Detailed design, tender support, regulatory permitting, construction supervision, post-construction monitoring.

Centre Tributary Realignment and Restoration Plan (2017-2018)

Client: Mattamy Homes
Role: Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, detailed design.

BEN PLUMB

RIVER ENGINEER / FLUVIAL GEOMORPHOLOGIST

FLUVIAL GEOMORPHOLOGY STUDIES – ENVIRONMENTAL RESTORATION, STORMWATER MANAGEMENT AND LAND-USE PLANNING

Don Mills Channel Flood Mitigation Geomorphology Study, Markham, Ontario (2017-2018)

Client: City of Markham
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, erosion impact assessment, infrastructure capital planning recommendations.

Ingersoll Flood Control Channel (Thames River) Geomorphology Study, Ingersoll, Ontario (2017)

Client: Upper Thames River Conservation Authority
Role: Technical Lead – Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, hydrogeomorphic modelling, habitat modelling, habitat restoration alternatives.

Spencer Creek Subwatershed Study - Geomorphology, Dundas, Ontario (2011-2015)

Client: Hamilton Conservation Authority, September 2011 – March 2015
Role: Fluvial Geomorphology
Scope: Geomorphic field/desktop assessments, hydrogeomorphic modelling, habitat modelling, habitat restoration alternatives.

Fish Passage Alternative Assessment for the Dunnville Dam, Grand River, Dunnville, Ontario (2009-2011)

Client: Ontario Ministry of Natural Resources
Role: Fluvial Geomorphology and River Engineering
Scope: Geomorphic field/desktop assessments, hydrogeomorphic modelling, physical hydraulic modelling, impact assessment.

Red Hill Creek Natural Channel Design Post-Construction Geomorphology Monitoring (2008-2013)

Client: City of Hamilton
Role: Fluvial Geomorphology
Scope: Geomorphic field monitoring, river surveying, long-term dataset analyses.

Greater Toronto Airports Authority Erosion Monitoring Program (2009-present)

Client: Greater Toronto Airports Authority
Role: Fluvial Geomorphology and River Surveyor
Scope: Geomorphic field monitoring, river surveying, long-term dataset analyses.

HYDROMETRIC / BATHYMETRIC / RIVER SURVEYS

Lower Athabasca River Navigation Study, Fort MacMurray, Alberta (2018)

Client: Transport Canada (partnered with Dillon Consulting)
Role: Hydrometric and River Surveyor
Scope: Hydrometric survey, large remote river, bathymetric survey to support hydraulic modelling, acoustic doppler profiler.

Little River Flood Study, Windsor, Ontario (2019-present)

Client: City of Windsor (partnered with Dillon Consulting)
Role: Fluvial Geomorphology and River Surveying
Scope: River surveys to support hydraulic model development, geomorphic field/desktop assessments, acoustic doppler profiler.

South Nation River Hydrometric Survey, Winchester, Ontario (2020)

Client: Parmalat (partnered with Dillon Consulting)
Role: Hydrometric and River Surveyor
Scope: Hydrometric survey, large river, bathymetric survey, acoustic doppler profiler.

Fraser River Debris Trap Study, Hope, British Columbia (2020-present)

Client: Drake Excavating Limited (partnered with Dillon Consulting)
Role: Hydrometric and River Surveyor
Scope: Hydrometric survey, large remote river, bathymetric survey to support hydraulic modelling, acoustic doppler profiler.

BEN PLUMB

RIVER ENGINEER / FLUVIAL GEOMORPHOLOGIST

TECHNICAL PEER REVIEW

- Apetowun Creek Remediation, Fisheries and Oceans Canada (2016-present)
- Elbow River and Fish Creek Realignments Natural Channel Design, Fisheries and Oceans Canada (2017-2018)
- Grassy Mountain Coal Mine Environmental Assessment, Fisheries and Oceans Canada (2017-present)
- Sundog Creek Realignment, Fisheries and Oceans Canada (2018-2019)
- Alberta Transportation Fish Passage Design Guidelines, Fisheries and Oceans Canada (2019-2020)
- Goldfield Creek Realignment, Greenstone Gold Project, Long Lake #58 First Nation (2018-2020)

SELECTED CONFERENCES AND PUBLICATIONS

Peer-Reviewed Journal Articles and Published Conference Papers

McKie C.W., C. Juez, **B. Plumb**, W. Annable, and M. Franca, In press, How large immobile sediments in gravel bed rivers impact sediment transport and bed morphology, Journal of Hydraulic Engineering.

Plumb B.D., C. Juez, W. Annable, C. McKie and M. Franca, 2019, The impact of hydrograph variability and frequency on sediment transport dynamics in a gravel-bed flume, Earth Surface Processes and Landforms, https://doi.org/10.1002/esp.4770.

Brignoli L., W. Annable and **B. Plumb**, 2018, Assessing the Accuracy of Vegetative Roughness Estimates Using Unmanned Aerial Vehicles [UAVs]. Ecological Engineering, 118, 73-83.

Plumb B.D., W. Annable, P. Thompson and M. Hassan, 2017, The impact of urbanization on temporal changes in sediment transport in a gravel-bed channel in Southern Ontario, Canada, Water Resources Research, 53, 1-16.

Plumb B.D. and W. Annable, 2014, Quasi-stable channel morphology in response to hydromodification, Schleiss, De Cesare, Franca & Pfister (Eds), River Flow 2014 – Proceedings of International Conference on Fluvial Hydraulics, Lausanne, Switzerland, ISBN 978-1-138-02674-2.

Conference Presentations (Peer-Reviewed Abstracts)

Burgess, A. and **B. Plumb**, 2019, Assessing Scour Potential in Cohesive Bed Materials: Where Traditional Modelling Assumptions and Riverbed Material Realities Diverge, Presented at the 2019 CWRA National Conference, Blue Mountain, Ontario, Canada. May 26-29, 2019.

Hirvonen, J. and **B. Plumb**, 2019, Beyond Bankfull: Establishing Suitable Design Criteria for Natural Channel Designs, Presented at the 2019 CWRA National Conference, Blue Mountain, Ontario, Canada. May 26-29, 2019.

Plumb B.D., J. Hirvonen and P. Thompson, 2018, A Review of the Impacts of Urbanization on River Morphology: Current Knowledge, Industry Practices, Challenges, and Future Opportunities, Presented at the 6th International Conference on Natural Channel Systems, Guelph, Ontario, Canada, May 23-25, 2018.

Hirvonen J.P. and **B. Plumb**, 2018, Culvert Controlled Morphology in a Constrained Urban River: A Case Study in Geomorphic Analysis for Asset Management Decisions, Presented at the 6th International Conference on Natural Channel Systems, Guelph, Ontario, Canada, May 23-25, 2018.

Plumb B.D., C. Juez, M. Franca, C. McKie, A. Schleiss and W. Annable, 2016, A laboratory study on the impact of hydrograph unsteadiness on the morphodynamics of a gravel-bed channel, EP51A-0872, Presented at the 2016 Fall Meeting, AGU, San Francisco, California, USA, December 11-15, 2016.

Plumb B.D. and W. Annable, 2016, The evolution of gravel-bed morphology due to changing hydrologic regimes: A case study of an urban watercourse in Southern Ontario, Canada, Presented at the 5th International Conference on Natural Channel Systems, Niagara Falls, Ontario, Canada, September 26-27, 2016.

Hirvonen, J.P. and **B. Plumb**, 2016, The applicability of using fractional bedload transport modelling as a tool to predict geomorphic change: A novel framework for practitioners using commonly available data, Presented at the 5th International Conference on Natural Channel Systems, Niagara Falls, Ontario, Canada, September 26-27, 2016.

Plumb B.D., M. Franca, C. Juez, A. Schleiss and W. Annable, 2016, The impact of hydrograph variability and frequency on the morphodynamics of gravel-bed rivers, Vol 18, EGU2016-14262, Presented at EGU General Assembly 2016, Vienna, Austria, April 17-22 2016.

Plumb B.D. and W. Annable, 2013, Event-based morphodynamics of urban gravel-watercourses in southern Ontario, Canada, Presented at World Environmental & Water Resources Congress, Cincinnati, Ohio, USA, May 19-23, 2013.

Annable W.K., **B. Plumb**, M. McKie, R. Schekenberger, F. Reinders, G. Moore, M. Oddi, J. DiDomenico, J. Dougan, C. Portt, 2010, Red Hill Creek - The 100+ year return frequency discharge experiment, Presented at the 4th International Conference on Natural Channel Systems, Mississauga, Ontario, Canada, September 27 – 28, 2010.

Non-Peer-Reviewed Presentations and Short Courses

Plumb B.D. and J. Hirvonen, 2018, Fluvial Geomorphology, Natural Channel Design, River Rehabilitation: From Theory to Practice, Short course presented to Fisheries and Oceans Canada, June 27, 2018.

Plumb B.D. and J. Hirvonen, 2017, Sediment Transport in Heterogeneous Mixtures: Gravel-Bed Rivers, Presented to Credit Valley Conservation Authority, November 13, 2017.

Plumb B.D. and W. Annable, 2011, Integrated study of fish passage alternatives for the Dunnville Dam on the Lower Grand River, World Water Day Graduate Research Fair, University of Waterloo, Waterloo, Ontario, March 22, 2011.

EMPLOYMENT HISTORY

GeoProcess Research Associates Inc.
2013 - Present River Engineer / Fluvial Geomorphologist

JTB Environmental Systems Inc.
2011 - 2013 Fluvial Geomorphology Specialist (contract basis)

University of Waterloo
2010 - 2016 Research Assistant in River Engineering/Geomorphology (during PhD research)
2008, 2009 Research Assistant in River Engineering/Geomorphology (two 4-month co-op placements)

Dillon Consulting Limited
2009 Water Resources Specialist (4-month co-op placement)

Preston, Nicholson, Harvey Inc. (Ontario Land Surveyors)
2003 - 2005 Land Surveyor

GeoProcess RESEARCH ASSOCIATES
Knowledge Research Consulting

MICHAEL TAKEDA M.A.Sc. P.Eng.

HYDROGEOLOGIST/GROUNDWATER MODELLER

Education & Training
M.A.Sc., Environmental and Civil Engineering, University of Waterloo, 2013
Thesis: *Evidence for methane hydrate stability zones during Pleistocene glaciation at the Bruce Nuclear Site*
B.A.Sc., Environmental and Civil Engineering *(with Distinction)*, University of Waterloo, 2010

Certifications & Affiliations
Professional Engineer, PEO
Canadian Water Resources Association

PERSONAL PROFILE

Michael Takeda is a hydrogeologist and groundwater modeller with more than 10 years' experience in the field of hydrogeology, specializing in the application of integrated groundwater/surface water models to address water resources challenges for public and private clients across Ontario and North America. Michael has acted as project lead on modelling studies conducted at both the regional and local scales, looking into the impacts of land development, quarry expansions, and mineral resource extraction on the hydrologic and hydrogeologic system.

He has played a significant role, as lead groundwater modeller, on several Provincial (Ontario) Source Water Protection studies, lending his expertise to the conceptualization and construction of multi-scale (regional and wellfield level) numerical models to assess the sustainability and security of municipal drinking water supplies, and understand the impacts of changing climate on streams and wetland features. Michael has extensive knowledge of USGS MODFLOW, GSFLOW, MODPATH and MT3DMS modelling software and has developed a number of custom complementary utilities to build, calibrate and interrogate numerical models.

RELEVANT EXPERIENCE

TECHNICAL PEER REVIEW

Hydrogeologist, Grassy Mountain Coal Mine Environmental Assessment Technical Peer Review
Client: Fisheries and Oceans Canada (Alberta), November 2017 – December 2018, 13 months

Technical reviewer for the hydrogeology (groundwater modelling) component of the Environmental Assessment for the Mount Grassy Coal Mine, with a focus on how the assessed impacts to groundwater-surface water interactions translated to impacts to fish and fish habitat. Technical reviews were completed on behalf of Fisheries and Oceans Canada and included a series of supplemental information requests (conforming with the formal EA process) related to the potential impacts to Westslope Cutthroat Trout (Species at Risk) habitat.

Hydrogeologist, Model Assessment and Review of Proposed Quarry Extension
Client: City of Hamilton (Ontario), December 2014 – July 2015, 8 months

Conducted technical peer review of an application for the expansion of an existing quarry operation on behalf of the City of Hamilton, reviewing applicant's site characterization and impact assessment results. The scope of the review included deploying an integrated surface water-groundwater model to verify the proponent's impact predictions to nearby wetlands and headwater streams using a more robust modelling tool. The results of the review and the verification modelling with the integrated surface water-groundwater model (GSFLOW) were communicated in a technical response letter along with recommendations for further monitoring.

MICHAEL TAKEDA

HYDROGEOLOGIST/GROUNDWATER MODELLER

GeoProcess RESEARCH ASSOCIATES

INTEGRATED GROUNDWATER/SURFACE WATER MODELLING

Lead Groundwater Modeller, Integrated Hydrogeologic and Hydrologic (GSFLOW) Model Development for Detour Lake Mine

Client: Detour Gold Corporation (Ontario), January 2018 – September 2018, 9 months

Managed development and application of integrated groundwater/surface water model to support operations and expansion of an open-pit gold mine operation in northern Ontario. The integrated surface water-groundwater model was used to directly link hydrogeologic effects of pit dewatering and footprint expansion to hydrologic system changes in nearby streams, lakes and wetlands. The implicit recognition of the importance of groundwater and surface water interactions built into the model has benefitted subsequent applications of the integrated model to support PTTW applications/reporting, environmental assessments, and stakeholder meetings with First Nations.

Lead Modeller, Application of Alberta Desktop Method for Minimum Flow Requirements using Integrated Groundwater-Surface Water Model

Client: Detour Gold Corporation (Ontario), March 2017– May 2017, 3 months

Completed the development of a monitoring and mitigation strategy based on the Alberta Desktop Method for a mine site in northern Ontario using an integrated GW/SW model. Consulted closely with Fisheries and Oceans Canada (DFO) and Ontario Ministry of Environment and Climate Change (MOECC) to address unique site challenges and achieve acceptable level of protection for nearby streams.

Groundwater Modeller, Phase 2 Review of Potential Cumulative Impacts to Surface Water and Groundwater from In-Situ Oil Sands Operations in the MacKay River Watershed

Client: Cumulative Environmental Management Association (Alberta), August 2014– March 2016, 19 months

Completed the construction and application of an integrated groundwater-surface water model (GSFLOW) of the MacKay Watershed to predict the cumulative impacts of in-situ oil sands development; specifically responsible for characterizing the hydrogeologic conditions and developing the groundwater component of the integrated model. The model was successfully applied to predict the cumulative impacts of enhanced operational water abstraction on environmental flows within the MacKay River subwatershed.

Lead Groundwater Modeller, Assessment of Long Term Hydrogeologic Conditions along the Eglinton Crosstown Transit Line

Client: Crosslinx Transit Solutions (Ontario), September 2016– November 2016, 3 months

The Eglinton Crosstown is a light rail transit (LRT) project currently under construction in Toronto, Ontario. Michael's involvement with this project included updating and refining the existing regional, integrated groundwater-surface water model near the LRT project, and simulating transient (daily) groundwater levels under future climate conditions. The objective of this work was the provide additional hydrogeologic insights to the client regarding the seasonal water level fluctuations within the shallow and deep groundwater aquifers around the project area.

Lead Groundwater Modeller, Whitemans Creek Tier Three Local Area Water Budget and Risk Assessment, Grand River Conservation Authority, Ontario

Client: Grand River Conservation Authority (Ontario), May 2015– November 2017, 30 months

Michael served as the lead groundwater modeller on a Tier 3 Water Budget and Risk Assessment of the Whitemans Creek subwatershed. He constructed and calibrated the groundwater flow and stream-routing component of an integrated groundwater/surface water model of the study area using the USGS GSFLOW model code. Michael worked extensively with the MOECC Water Well database (WWIS), the Permit to Take Water (PTTW) database, and the Water Taking Reporting System (WTRS) database to evaluate water use within the

Whitemans Creek subwatershed, and accurately assign groundwater abstraction rates from permits to their groundwater source.

Groundwater Modeller, Tier 3 Water Budget and Local Area Risk Assessment for the Greensville Groundwater Municipal System

Client: Conservation Halton (Ontario), March 2013 – March 2015, 24 months

Developed a transient groundwater model (upgraded to an integrated surface water/groundwater flow model) and conducted a Water Budget and Water Quantity Risk Assessment of the municipal water supply. This work was undertaken as part of the Source Protection Program (in fulfillment of the Clean Water Act, 2006). A large quarry operation was centrally located in the study area and was found to dramatically alter the local hydrologic and hydrogeologic systems. As such, the project greatly benefited from the application of an integrated groundwater-surface water modelling tool.

Groundwater Modeller, Tier 2 Water Budget, Climate Change and Ecologically Significant Groundwater Recharge Area Assessment, Ramara Creeks, Whites Creek and Talbot River Subwatersheds

Client: Lake Simcoe Region Conservation Authority (Ontario), September 2013 – October 2014, 14 months

Completed a regional analysis of geologic and hydrogeologic datasets to synthesize conceptual understanding of the region and developed the groundwater component of an integrated GW/SW model. Ecologically Significant Groundwater Recharge Areas (ESGRAs) were delineated to identify upland areas that serve as critical recharge areas for supporting downstream cold-water streams and wetlands. This project included a climate change assessment using the integrated model by inputting a range of future climates from Global Climate Models to investigate the hydrologic/hydrogeologic system response.

Hydrogeologist/Groundwater Modeller, Tier 3 Water Budget and Local Area Risk Assessment for the Kelso and Campbellville Groundwater Municipal System

Client: Conservation Halton (Ontario), April 2013 – February 2014, 13 months

Undertook the Phase 2 risk assessment components of the Tier 3 study of the municipal wells at Kelso and Campbellville, adhering to the methods specified by the MNR Water Budget and Water Quantity Risk Assessment Guide (2011) and MOE Technical Rules (2009). Developed the numerical model simulations (using an integrated groundwater-surface water model) to delineate wellhead protection areas (cone of depression) and assess the potential for water quantity threats during future land use, drought, and abstraction rates.

GROUNDWATER MODELLING EXPERIENCE

Lead Groundwater Modeller, Region of Durham Groundwater Model Update, Region of Durham, Ontario

Client: Regional Municipality of Durham (Ontario), October 2018 – Present

A groundwater modelling update for the Regional Municipality of Durham to satisfy the Region's current and ongoing Source Water Protection requirements. Constructed a 3D stratigraphic model of the study area using the YPDT-CAMC database and developed a regional groundwater flow model using the USGS MODFLOW-NWT code. Once calibrated, the model will be used to delineate WHPAs for the Region's 8 municipal wellfields, along with undertaking HVA and ESGRA analyses.

Lead Groundwater Modeller, Thermal Impact Assessment of Below-Water-Table Aggregate Extraction, Hillsburgh, Ontario

Client: Strada Aggregates (Ontario), September 2014 – February 2015, 6 months

Assessed potential for impacts to a privately-owned trout hatchery and nearby natural stream receptors using the USGS MT3D solute and heat transport code to simulate transient thermal plume migration from below water table aggregate pit. Provided guidance on mitigation measures and recommendations for improvements to the site monitoring program. Engaged with the project regulator, Ministry of Natural Resources and Forestry.

MICHAEL TAKEDA

HYDROGEOLOGIST/GROUNDWATER MODELLER

Lead Groundwater Modeller/Project Manager, Wellhead Protection Area Delineation and Vulnerability Scoring, Brantford Airport Wellfield, Ontario

Client: Grand River Conservation Authority (Ontario), January 2017 – July 2017, 7 months

Oversaw the local refinement of a regional numerical groundwater flow model for reapplication to delineate wellhead protection areas (WHPAs) for the municipal wellfield. Applied particle tracking using MODPATH code to delineate wellhead protection areas and aquifer vulnerability.

Lead Groundwater Modeller, Wellhead Protection Area Delineation, Vulnerability Scoring and Threats Assessment, Town of Shelburne, Ontario

Client: Grand River Conservation Authority (Ontario), September 2014 – May 2015, 9 months

Constructed a numerical groundwater flow model with the USGS MODFLOW-NWT model code. Oversaw the application of the model to assess water quality threats to a new municipal wellfield. Applied particle tracking using MODPATH code to delineate wellhead protection areas and aquifer vulnerability.

CONFERENCES AND PUBLICATIONS

Takeda M.G.S., Wexler E.J., Thompson P.J., and Kassenaar J.D.C., 2017, Characterization of Seasonal Thermal Plume Migration from a Below-Water-Table Aggregate Extraction Operation, *Proceedings of the Modflow & More 2017 Conference*, Golden, Colorado, May 2017.

Wexler E.J., Thompson P.J., **Takeda M.G.S.**, Malott S., Shifflett S.J., and Kassenaar J.D.C., 2017, Development and Application of an Irrigation Demand Module for the USGS GSFLOW Model, *Proceedings of the Modflow & More 2017 Conference*, Golden, Colorado, May 2017.

Thompson PJ, Wexler EJ, **Takeda M.G.S**, Kassenaar DC. 2015. Integrated Surface Water/Groundwater Modelling to Simulate Drought and Climate Change Impacts from the Reach to the Watershed Scale. Proceedings of the 2015 conference of the CNC-IAH. October 2015. Waterloo, ON.

Kassenaar J.D.C., Wexler E.J., Thompson P.J., **Takeda M.G.S.**, 2015, Strategies for Integrated Model Calibration; *Proceedings of the 2015 IAH-CNC Waterloo Conference*, Waterloo, ON, October 2015.

Takeda, M.G.S., 2014. Dusting off the source water protection models: adaptation and application of existing models to new projects; *Proceedings of the 2014 Latornell Conservation Symposium*, Alliston, ON, November 2014.

Wexler, E.J., Thompson, P.J., **Takeda, M.G.S**., Howson, K.N., Cuddy, S.E., and Kassenaar, J.D.C., 2014, Simulating climate change and extremes with an integrated surface water-groundwater model to assess hydrologic response in the Lake Simcoe watershed: Canadian Water Resources Association Conference, Hamilton, ON, June 2014.

Takeda, M.G.S., 2013. Evidence for Methane Hydrate Stability Zones during Pleistocene Glaciation at the Bruce Nuclear Site (Kincardine, Ontario). MASc Thesis. University of Waterloo. Waterloo, Canada.

EMPLOYMENT HISTORY

GeoProcess Research Associates Inc.
2017 – Present Hydrogeologist/Groundwater Modeller

Earthfx Inc.
2013 - 2017 Hydrogeologist, Project Manager

University of Waterloo
2010 - 2013 Research Assistant in Civil/Environmental Engineering (during MASc research)

Conestoga-Rovers and Associates
2007 - 2010 Assistant Hydrogeologist

GeoProcess RESEARCH ASSOCIATES
Knowledge Research Consulting

PETER JOHN THOMPSON M.A.Sc. P.Eng.

HYDROLOGIST/HYDROLOGIC MODELLER

Education & Training

M.A.Sc., Environmental and Civil Engineering, University of Waterloo, 2013
Thesis: *Event Based Characterization of Hydrologic Change in Urbanizing Southern Ontario Watersheds via High Resolution Stream Gauge Data* (Received the 2014 Canadian Society for Civil Engineering (CSCE) Hydrotechnical Engineering Award)
B.A.Sc., Civil Engineering *(with Distinction),* University of Waterloo, 2007
Option in Water Resources, Certificate in Structural Engineering

Certifications & Affiliations

Professional Engineer, Professional Engineers Ontario & Association of Professional Engineers and Geoscientists of Alberta
Canadian Water Resources Association

PERSONAL PROFILE

Pete is a specialist in surface water hydrology and hydraulics. He has over a decade of experience in hydrologic and hydrogeologic modelling and has contributed to numerous subwatershed and Source Water Protection studies across Ontario. Pete has specific expertise in the evaluating the effects of urbanization on the hydrologic regime, analyzing the future impacts of climate change on a watershed scale, the analysis of groundwater/surface water interactions with numerical models, and in-stream ecological flow needs assessment. These projects frequently have an ecological component in the assessment of hydrologic regimes, cold-water streams, groundwater dependant wetlands and impacts to habitat. Pete has managed the development of watershed-scale, fully-distributed, integrated groundwater-surface water models for Source Water Protection, climate change, and cumulative impact studies. In additional to his modelling tasks, Pete assists our clients in the development of monitoring programs, often to assess groundwater-surface interactions or the creation of baseline datasets to meet regulatory requirements.

Pete has provided technical peer review for both public and private clients during federal and provincial Environmental Assessment. Recently, Peter co-authored to the Design Criteria and Modelling chapters of the upcoming Low Impact Development Stormwater Management Guidance Manual, the MOECC's update to its 2003 Stormwater Manual. Peter holds a bachelor's and a master's degree from the University of Waterloo and is involved in ongoing research to assess and characterize the cumulative effects of development on the hydrologic regime of urban watersheds in southern Ontario.

RELEVANT EXPERIENCE

TECHNICAL PEER REVIEW

Peer Reviewer, Monte Carlo Analysis of Arsenic Concentrations in Kenogamisis Lake, Geraldton, Ontario
Client: Greenstone Gold Mines (Ontario), May 2018 – August 2018

Provided technical peer review of a deterministic mass balance model of lake water and sediments. This model was developed to predict future arsenic concentrations in water and sediment adjacent to the historical Hardrock gold mine near Geraldton, Ontario. Review focused on a planned Monte Carlo exercise to further quantify the uncertainty in the modelled predications of lake arsenic concentrations. As part of the ongoing Federal and Provincial Environmental Assessments, Pete attended meetings with Ontario Ministry of the Environment, Conservation and Parks staff to discuss results.

Hydrologist, Grassy Mountain Coal Mine Environmental Assessment Technical Peer Review
Client: Fisheries and Oceans Canada (Alberta), November 2017 – Present

Hydrologist, Whale Tail Expansion Project Review
Client: Fisheries and Oceans Canada (Alberta), May 2020

Hydrologist, Keeyask Generation Project, Review of Impoundment Monitoring and Response Plan
Client: Fisheries and Oceans Canada (Alberta), February 2020 - March 2020

Hydrologist, Alberta Transportation Fish Passage Design Guidelines Review
Client: Fisheries and Oceans Canada (Alberta), December 2019 – April 2020

Hydrologist, Model Assessment and Review of Proposed Quarry Extension
Client: City of Hamilton (Ontario), December 2014 – July 2015

GUIDANCE DOCUMENTS

Co-Author, Low Impact Development Stormwater Management Guidance Manual
Client: Ontario Ministry of the Environment and Climate Change (Ontario), June 2015-October 2017

MOECC is currently updating its 2003 Stormwater Management Manual, with a focus on Low Impact Development (LID) methods. Pete's contributions to the revised manual include the Model Selection Framework and portions of the Modelling chapter text, a Province-wide analysis of precipitation patterns to support the selection of Runoff Volume Control Targets (RVC_T) for Ontario, and commentary related to the analysis of future climate change in urban design modelling.

Modelling Specialist/Co-Author, Ecologically Significant Groundwater Recharge Area Assessment Pilot Study
Client: Lake Simcoe Region Conservation Authority (Ontario), October 2011-May 2012

Pete co-developed a methodology to link ecologically significant features such as wetlands and cold water streams back to recharge areas on a watershed scale. Pete was the lead groundwater modeller on the pilot study delineating Ecologically Significant Groundwater Recharge Area (ESGRAs) in the Lake Simcoe basin. To prove ecological significance, a linkage had to be established between the recharge area and the ecologically significant feature (e.g., a reach of a cold water stream). Particle tracking techniques were used to trace flowpaths through the multiple aquifers with a cluster-analysis technique employed to assess the significance of the particle densities. The ESGRA methodology was documented in a peer-reviewed article published in the Canadian Water Resources Journal (Marchildon et al., 2015) and has been widely applied across southern Ontario.

MINING/RESOURCE EXTRACTION EVALUATIONS

Lead Hydrologic Modeller, Integrated Hydrogeologic and Hydrologic (GSFLOW) Model Development for Detour Lake Mine
Client: Detour Gold Corporation (Ontario), January 2018 – September 2018, February 2020 – Present

GeoProcess undertook an update to the modelling tool employed at the mine site to evaluate groundwater takings, pit shell expansion, and impacts to sensitive receptors. Pete constructed a revised hydrologic submodel based on updated land cover mapping and aerial photographs. The representation of snowpack processes was improved and data from the expanded stream gauge network served to provide additional calibration datasets. The developed integrated surface water-groundwater model directly links the hydrogeologic effects of pit dewatering and footprint expansion to hydrologic system changes in nearby streams, lakes and wetlands.

Senior Hydrologist/Modeller, Integrated Hydrologic/Hydrogeologic Modelling of the Reid Road Quarry

Client: James Dick Construction (Ontario), February 2017-November 2017

The Reid Road property is the location of a discontinued limestone quarry comprising three flooded extraction pits. The proponent plans to undertake the below-water table extraction of bedrock, a relatively new technique in Canada. To assess the impacts of below water table rock extraction, an integrated groundwater/surface water model was developed. Pete lead the model development, constructing the hydrologic submodel and developing the approach to assess the impacts of rock removal on adjacent streams, wetlands, the underlying aquifers, and the existing reservoirs.

Lead Hydrologic Modeller, Phase 2 Review of Potential Cumulative Impacts to Surface Water and Groundwater from In-Situ Oil Sands Operations in the MacKay River Watershed

Client: Cumulative Environmental Management Association (Alberta), November 2014-December 2015

Pete served as the lead hydrologic modeller on a project to assess the impacts of numerous planned Steam Assisted Gravity Drainage (SAGD) oil sand developments on the water resources of the MacKay River watershed in northern Alberta. Pete constructed and calibrated the hydrologic component of an integrated groundwater/surface water model which required the development of a new frozen ground module to simulate the impact of cold climates on recharge and runoff. With the final model, Pete conducted an analysis of the cumulative impacts of the planned GW and SW takings on the instream flow needs of the MacKay Watershed.

Hydrologic Modeller, Thermal Impact Assessment of Below-Water-Table Aggregate Extraction, Hillsburgh, Ontario

Client: Strada Aggregates (Ontario), September 2014 – January 2015

An analysis was undertaken with the USGS MT3D model code to simulate the transient thermal plume migration from a below water table gravel pit. Concerns were raised that continued operations would negatively affect a privately-owned trout hatchery and nearby natural stream receptors. Pete provided the groundwater recharge and climate forcing inputs to drive the analysis. Hydrologic water balance variables were estimated on a daily basis with the USGS PRMS-IV model code calibrated to local streamflow data.

URBAN DEVELOPMENT/INFRASTRUCTURE

Lead Hydrologic Modeller, Integrated Hydrogeologic and Hydrologic Study of a Planned Large-Scale Urban Development

Client: Confidential (Ontario), January 2018 – Present

Current study evaluating the long-term impacts of a large scale (3,000 ha) urban development. GeoProcess has applied the recently developed GSFLOWurban model code, which incorporates new capabilities to represent the hydrologic function of urbanized landscapes, including many types of green infrastructure. This integrated surface water-groundwater model has been used to directly link effects of on-site urbanization to hydrologic system changes in nearby streams, lakes and wetlands. Multiple build-out scenarios have been tested incorporating a variety of LID strategies and compared to current conditions. Results from this assessment will serve to guide ongoing planning and provide input into final detailed site design.

Hydrologist, Haldimand Road 17 Water Balance Assessment

Client: Dougan & Associates (Ontario), August 2018 – December 2018

Conducted a water balance assessment for a small development located near several significant wetland features. Pre- and post-development conditions were considered and a quantitative evaluation of the hydrologic impacts of the development was completed. A series of Low Impact Design (LID) measures and best practices were recommended to maintain existing infiltration rates on the property and limit negative impacts to the hydrologic function of the subject and surrounding lands.

Senior Hydrologist, Analysis of Long Term Hydrogeologic Conditions along the Eglinton Crosstown Line

Client: Crosslinx Transit Solutions (Ontario), May 2016-November 2016

The Eglinton Crosstown is a light rail transit project currently under construction in Toronto, Ontario. To aid in the design of the various underground stations that will service the line, Pete undertook an analysis of the long-term variability of groundwater levels under future climate conditions. The analysis employed an existing regional-scale integrated groundwater/surface water model that was updated for this analysis to better reflect the built urban environment around the planned route. Multiple future climate scenarios derived from Global Climate Models (GCMs) were tested with the model to produce a series of worse-case maximum groundwater levels and annual levels fluctuations around the proposed stations.

FLOODPLAIN MAPPING STUDIES

Hydrologic Modeller, Hydrologic Modelling to Support Wingham and Area Flood Plain Mapping

Client: Maitland Valley Conservation Authority (Ontario), November 2019 – March 2020

GeoProcess was retained by the Maitland Valley Conservation Authority to update the floodplain mapping for the Maitland River and its tributaries in the area around the community of Wingham. To support the hydraulic modelling, Pete developed and calibrated an event-based rainfall-runoff model of the Maitland River watershed upstream of Wingham with the HEC-HMS model code. Transient hydrographs were generated at multiple upstream reaches for input into a 2D hydraulic model of the Maitland River through Wingham.

HYDROMETRICS

Hydrologist, Pearson Airport Hydrometric Monitoring Program

Client: Greater Toronto Airports Authority (Ontario), February 2018 – Present

Designed a monitoring program to capture runoff from lands associated with Toronto Pearson International Airport. Monitoring is ongoing at seven locations on various creeks around the airport. Quarterly reports have been prepared summarizing precipitation patterns observed at the airport, water level observations collected by the monitoring network, the current status of stage-discharge (rating) curves, and the calculated 15-minute discharge at each streamflow station. An event-based rainfall/runoff analysis for the airport lands is completed and documented on an annual basis.

Hydrologist, Detour Lake Mine Site Hydrologic Monitoring Program Support

Client: Detour Gold Corporation (Ontario), January 2018 – Present

Provided technical support to staff during the transition to a new environmental data management system. Worked up historical hydrometric data and provides QC/QA services to the ongoing monitoring program.

Network Applications Specialist, Retrieval and Processing of Historical (1969-1996) Streamflow Data from Achieved Electronic Records

Client: Water Survey Division/Environment Canada, January 2009 – September 2011

Pete was responsible for developing software to process, extract, and QA/QC archived electronic hydrometric data. He managed the retrieval of historical data for the national Water Survey program (3200 stations spanning 25 years) and the development of an instantaneous hydrometric database. These newly available data has been applied in numerous academic and engineering studies on topics such as urbanization, stream morphology, and climate change.

PETER JOHN THOMPSON
HYDROLOGIST/HYDROLOGIC MODELLER

GeoProcess RESEARCH ASSOCIATES

SOURCE WATER PROTECTION STUDIES

Lead Hydrologic Modeller, Region of Durham Groundwater Model Update

Client: Regional Municipality of Durham (Ontario), October 2018 – Present

GeoProcess is currently undertaking a model update for the Regional Municipality of Durham to satisfy the Region's current and ongoing Source Water Protection requirements. Pete constructed and calibrated a distributed hydrologic model with the USGS PRMS-IV code. Climate forcing inputs were processed from local stations with the model parameterization following regional land cover, geology, and soils mapping. Calibration and the subsequent validation of the model was conducted with streamflow data collected from 15 locally gauged catchments. Recharge mapping will serve as an input to a new regional groundwater model which will be used to delineate Wellhead Protection Areas for the Region's 8 municipal wellfields, along with an assessment of Highly Vulnerable Aquifers and Ecologically Significant Groundwater Recharge Areas.

Project Manager/Senior Hydrologist, Whitemans Creek Tier Three Local Area Water Budget and Risk Assessment

Client: Grand River Conservation Authority (Ontario), October 2015-November 2017

Served as the project manager and lead hydrologic modeller on a Tier 3 Water Budget and Risk Assessment of the Whitemans Creek subwatershed. He constructed and calibrated the hydrologic component of an integrated groundwater/surface water model of the study area using the USGS GSFLOW model code. Pete oversaw an analysis of crop types, determined irrigation requirements, and simulated the irrigation demand across the subwatershed. He led the creation of three major project reports and managed the subsequent peer review response process.

Hydraulic Modeller/Model Integration Specialist, Tier 3 Water Budget and Local Area Risk Assessment for the Kelso and Campbellville Groundwater Municipal System

Client: Conservation Halton (Ontario), January 2012- February 2014

Pete developed the hydraulic submodel that was part of an integrated groundwater/surface water model created to analyze the Kelso and Campbellville municipal groundwater systems. The Milton wellfield is adjacent to a flood control reservoir, and matching the well response was dependent on matching the stage in the reservoir by simulating flows from streams and wetlands in the upland area, reservoir operations, and reservoir interaction with the underlying aquifers. All mapped stream tributaries (over 475 km of streams) and 257 shallow wetlands, quarry lakes, and ponds were represented in the model. Pete undertook final calibration of the completed integrated model (which was focused on reservoir/well interactions) and completed the water budget assessment of the wellfield as part of the Tier 3 Source Water Protection study.

Lead Hydrologic Modeller, Wellhead Protection Area Delineation, Vulnerability Scoring and Threats Assessment, Town of Shelburne, Ontario

Client: Grand River Conservation Authority (Ontario), September 2014 – May 2015

Constructed a distributed hydrologic model with the USGS PRMS-IV model code. Long-term water balances were generated with the final calibrated model with groundwater recharge mapping prepared for input to a regional scale MODFLOW model.

PETER JOHN THOMPSON

HYDROLOGIST/HYDROLOGIC MODELLER

GeoProcess RESEARCH ASSOCIATES

SUBWATERSHED STUDIES/ECOLOGICAL ASSESSMENTS

Lead Hydrologic Modeller, Tier 2 Water Budget, Climate Change and Ecologically Significant Groundwater Recharge Area Assessment, Ramara Creeks, Whites Creek and Talbot River Subwatersheds

Client: Lake Simcoe Region Conservation Authority (Ontario), December 2013-October 2014

Pete constructed the hydrologic component of an integrated groundwater/surface water model of several watersheds that drain the north-west side of Lake Simcoe using the USGS GSFLOW code. He calibrated the model with Monte Carlo techniques and evaluated the results with a custom set of tools. Pete managed the application of the model to evaluate droughts and to assess the long-term impacts of future climate change.

Groundwater Modeller, Tier 2 Water Budget Analysis and Water Quantity Stress Assessment for the Oro North and South and Hawkestone Creeks Subwatersheds

Client: Lake Simcoe Region Conservation Authority (Ontario), August 2012-August 2013

Pete was the lead modeller in a study to develop an integrated GW/SW model to simulate the complex recharge pathways from Oro Moraine to adjacent streams, lakes, and wetlands. Pete was responsible for the construction of the groundwater and hydraulic submodels and oversaw calibration of the integrated GSFLOW model. The model was employed to assess the linkages between groundwater recharge areas and ecologically significant surface water features. Municipal takings in the study area were also assessed and complete water budgets were derived for the study watersheds.

PUBLICATIONS AND CONFERENCE PRESENTATIONS

PEER-REVIEWED JOURNAL ARTICLES

O'Brien N. L., Burn D. H., Annable W. K., and **P. J. Thompson**. 2020 (In Review). Trend Detection in the Presence of Positive and Negative Serial Correlation: A Comparison of Block Maxima and Peaks-over-Threshold Data. Submitted to *Water Resources Research* August 2020.

Plumb BD, Annable WK, **Thompson P J**, & Hassan MA. 2017. The impact of urbanization on temporal changes in sediment transport in a gravel bed channel in Southern Ontario, Canada. *Water Resources Research*, 53.

Marchildon MA, **Thompson PJ**, Cuddy SE, Wexler EJ, Howson K. and Kassenaar JD. 2016. A methodology for identifying ecologically significant groundwater recharge areas. *Canadian Water Resources Journal*, 41.4 (2016): 515-527.

Annable WK, Watson CC, **Thompson PJ**. 2010. Quasi-Equilibrium conditions of urban gravel-bed stream channels in Southern Ontario, Canada. *River Research and Applications*, 28: 302–325.

CONFERENCE PRESENTATIONS

Thompson PJ, Takeda MGS, Marchildon MA, and Roul IT, 2019. Application of an Integrated Surface Water-Groundwater Model to Evaluate Low Impact Design Strategies in Southern Ontario. *2019 CWRA National Conference*. Collingwood, ON.

Plumb BD, Hirvonen J, **Thompson PJ**. 2018. A Review of the Impacts of Urbanization on River Morphology: Current Knowledge, Industry Practices, Challenges, and Future Opportunities*, Presented at the 6th International Conference on Natural Channel Systems*, Guelph, Ontario, Canada, May 23-25, 2018.

Takeda MGS., Wexler EJ, **Thompson PJ,** and Kassenaar JDC. 2017. Characterization of Seasonal Thermal Plume Migration from a Below-Water-Table Aggregate Extraction Operation, *'Modflow and More' 2017 Conference*, Golden, Colorado, May 2017.

Wexler EJ, **Thompson PJ**, Kassenaar DC, Takeda MGS. 2016. Applications of Watershed-Scale Integrated Modelling in a Canadian Context. *Proceedings of the XXI International Conference Computational Methods in Water Resources*. June 2016. Toronto, ON.

Kassenaar DC, Wexler EJ, **Thompson PJ**, Takeda MGS. 2016. Incorporating a Dynamic Irrigation Demand Module into an Integrated Surface Water/Groundwater Model to Assess Drought Response. *Toward Sustainable Groundwater in Agriculture – An International Conference Linking Science and Policy*. June 2016. San Francisco, CA, USA.

Kassenaar DC, Wexler EJ, **Thompson PJ**, Takeda MGS. 2016. Assessing Cumulative Effects of SAGD Operations in the Mackay Watershed. *CWRA 69th Conference*. May 2016. Montréal, QC.

Thompson PJ, Wexler EJ, Takeda MGS, Kassenaar DC. 2015. Integrated Surface Water/Groundwater Modelling to Simulate Drought and Climate Change Impacts from the Reach to the Watershed Scale. *2015 conference of the CNC-IAH*. October 2015. Waterloo, ON.

Wexler EJ, Rawl GF, **Thompson PJ**, Kassenaar DC. 2015. Integrated groundwater/surface water modelling to assess urban development and detailed stormwater design – Babcock Ranch Community Development, Lee County, Florida. *2015 conference of the CNC-IAH*. October 2015. Waterloo, ON

Kassenaar DC, Wexler EJ, **Thompson PJ**, Takeda MGS. 2015. Issues and Strategies for Integrated Model Calibration. *'Modflow and More' 2015 Conference*. June 2015. International Groundwater Modeling Center, Golden, CO.

Wexler EJ, **Thompson PJ**, Takeda MGS, Kassenaar DC. 2015. Assessing Sensitivity to Drought and Climate Change with an Integrated Surface Water/Groundwater Model at the Subwatershed Scale. *'Modflow and More' 2015*. June 2015. International Groundwater Modeling Center, Golden, CO.

Takeda MGS, **Thompson PJ**, Kassenaar DC, Wexler EJ. 2014. Dusting Off the Source Water Protection Models: Adaptation and Application of Existing Models to New Projects. *2014 Latornell Conservation Symposium*. November 2014. Alliston, ON.

Thompson PJ and Annable WK. 2014. Characterizing change of high frequency return periods in urbanizing southern Ontario watersheds. *CWRA 2014 Canada Water Resources Congress*. Hamilton, ON.

O'Brien NL, **Thompson PJ**, Burn DH, Annable WK. 2014. A Nonstationary Analysis of Southern Ontario Storm Events Identified from High Resolution Streamflow Data. *CWRA 2014 Canada Water Resources Congress*. Hamilton, ON.

Wexler EJ, **Thompson PJ**, Cuddy SE, Howson KN, Kassenaar JDC. 2014. Simulating Climate Change and Extremes with an Integrated Surface Water- Groundwater Model to Assess Hydrologic Response in the Lake Simcoe Watershed. *CWRA 2014 Canada Water Resources Congress*. Hamilton, ON.

Thompson PJ, Marchildon MA, Wexler EJ, Kassenaar DC. 2013. Applications of Integrated Surface Water/Groundwater Modelling - Techniques and Perspectives. *11th Joint CGS/IAH-CNC Groundwater Conference*, GéoMontréal. October 2013. Montreal, QC.

Marchildon MA, **Thompson PJ**, Cuddy SE, Howson KN, Kassenaar JDC, Wexler EJ. 2013. A new methodology for identifying Ecologically Significant Groundwater Recharge Areas. *11th Joint CGS/IAH-CNC Groundwater Conference*, GéoMontréal. October 2013. Montreal, QC.

Howson K, Cuddy S, Marchildon M, **Thompson PJ**, Kassenaar D, Wexler EJ, Bates S. 2013. Developing Guidance to Maintain Ecologically Significant Groundwater Recharge Areas. *2nd Biennial Lake Simcoe Science Forum*. October 2013. Barrie, ON.

Wexler EJ, Strakowski J, Kassenaar D, Marchildon MA, **Thompson PJ**. 2013. Using GSFLOW to Simulate Wellfield / Reservoir Interaction in a Re-Entrant Valley. *'Modflow and More' 2013*. June 2013. International Groundwater Modeling Center, Golden, CO.

Marchildon MA, Kassenaar DC, Wexler EJ, **Thompson PJ**. 2013. Topography and the Spatial Distribution of Groundwater Recharge and Evapotranspiration: Topography and the Spatial Distribution of Groundwater Recharge and Evapotranspiration. *WaterTech: 2013 Proceedings*. April 2013. Banff, AB.

Kassenaar DC, Wexler EJ, **Thompson PJ**, Marchildon MA. 2013. Integrated Modelling of Groundwater Interaction with Channels, Wetlands and Lakes in GSFLOW. *WaterTech: 2013*. April 2013. Banff, AB.

Thompson PJ and Annable WK. 2013. Characterizing change in baseflow interactions with urbanization through event-based hydrograph separation and analysis. *Proceedings of the 39th International Association of Hydrogeologists Congress*. Niagara Falls, ON.

Thompson PJ and Annable WK. 2011. Tracking changes in groundwater base flow due to urbanization through high resolution stream gauge data. *46th Central Canadian Symposium on Water Quality Research*. February 2011. Burlington, Ontario, Canada.

Annable WK, **Thompson PJ**, Lounder VG. 2010. Quasi-equilibrium characteristics of gravel-bed urban stream channels in southern Ontario, Canada. *Proceedings of the 4th International Conference on Natural Channel Systems*.

PETER JOHN THOMPSON

HYDROLOGIST/HYDROLOGIC MODELLER

EMPLOYMENT HISTORY

GeoProcess Research Associates Inc.
2017 – Present Hydrologist/Hydrologic Modeller

Earthfx Inc.
2011 - 2017 Senior Hydrologist, Project Manager

Water Survey Division, Environment Canada
2009 - 2011 Network Applications Engineer

University of Waterloo
2007 - 2011 Research Assistant, Department of Civil Engineering

TAB 3

Health Canada Santé Canada

HEALTH CANADA'S WRITTEN SUBMISSION TO THE JOINT REVIEW PANEL REGARDING THE GRASSY MOUNTAIN COAL PROJECT PROPOSED BY BENGA MINING LIMITED

September 21, 2020

Signed on behalf of Health Canada:

<Original signed by>

2020-09-03

Chantal Roberge
Director
Environmental Health and Internationally
Protected Persons Programs
Regulatory Operations and Enforcement Branch
Health Canada

Date

Canada

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EXECUTIVE SUMMARY

Health Canada (HC) is participating in the environmental assessment for the Grassy Mountain Coal Project (the Project) as a Federal Authority described in section 20 of the *Canadian Environmental Assessment Act, 2012*.

The following submission provides a summary of key outstanding deficiencies identified by HC within the health-related analyses undertaken by Benga Mining Limited (the Proponent). HC offers comments on areas for which the Department has specialist or expert information or knowledge. In HC's opinion, there remain outstanding uncertainties about the assessment of potential health risks from Project-related changes in air quality, water quality and the acoustical environment (noise). In addition, the overall human health risk assessment did not fully address potential health risks from multi-media exposures (i.e., simultaneous exposure to substances being released into the environment from the coal mining activities and deposited to air, food and water).

HC invites the Joint Review Panel to consider the recommended actions and follow-up measures summarized below. Should the Proponent implement these recommendations, the expected results would be better characterization and identification of Project-related health risks, and corresponding mitigation measures to reduce those risks to human health.

Air Quality Recommendations:

HC Recommendation 1-1:

Characterize the carcinogenicity of diesel particulate matter (DPM), the main carcinogenic component of diesel exhaust (DE), using one of the HC recommended approaches (refer to section 3.1) in order to inform mitigation measures.

HC Recommendation 1-2:

a) Conduct baseline nitrogen dioxide (NO_2) monitoring prior to construction of the Project.

b) Conduct baseline fine particulate matter ($PM_{2.5}$) monitoring prior to construction of the Project.

HC Recommendation 1-3:

a) Investigate additional mitigation measures to be implemented as warranted to minimize the concentration of non-threshold air pollutants, such as NO_2, $PM_{2.5}$ and DPM resulting from Project activities.

b) Continuously monitor NO_2 and $PM_{2.5}$ during all phases of the Project to allow ambient air concentrations to be compared against the 1-hour and 24-hour Canadian Ambient Air Quality Standards (CAAQS) respectively, as well as the annual NO_2 and $PM_{2.5}$ CAAQS. Consider additional mitigation measures if exceedances are measured.

Drinking Water Quality Recommendations:

HC Recommendation 2-1:

a) Provide a plan to evaluate potential risks to human health via the end-pit late (EPL) drinking water exposure pathway during the mine closure and decommissioning phase.

b) Provide details on how the plan will be modified to accommodate for flexibility in the frequency of monitoring based on comparison of measured results against the most up-to-date Guidelines for Canadian Drinking Water Quality (GCDWQ).

c) Use the most up-to-date drinking water guidelines to characterize human health effects.

d) Develop a risk communication plan to deter people from swimming or fishing in the EPL.

Human Health Risk Assessment – Analysis, Monitoring and Adaptive Management Recommendations:

HC Recommendation 3-1:

a) Use site-specific analyses to characterize the contaminants of potential concern (COPCs) associated with the sources of dust generated by the Project, or provide site-specific coal analysis data to demonstrate the appropriateness of the surrogate data used to date. Use the site-specific analysis of COPCs as the basis of the modelling inputs into the human health risk assessment (HHRA).

b) Develop a comprehensive environmental monitoring program to verify the HHRA predictions based on site-specific concentrations of COPCs in suspended dust (as per (a) above). It is recommended that this monitoring program also include relevant environmental media impacted by dust (i.e., surface water, soil and sediment) during all Project phases. HC is available to review the monitoring program, upon request.

c) Provide details on how the results of the monitoring program (as per (b) above) will inform adaptive management measures in all phases of the Project.

d) If monitored COPC concentrations (as per (b) above) exhibit an increasing trend, concentrations exceed applicable guidelines and/or are at levels expected to produce potential risks (e.g., exceed site-specific target levels, where applicable), consider updating the HHRA. If monitored COPC concentrations (as per (b) above) show an increasing trend in environmental media (e.g., surface water, soil or sediment), measured COPC concentrations in relevant traditional foods that are harvested and consumed should be collected and an updated HHRA considered.

Noise Recommendations:

HC Recommendation 4-1:

a) Implement a formal noise-complaint resolution process in consultation with Indigenous groups and local community members who may be impacted by noise due to Project activities.

b) Proactively inform the local community and potentially impacted Indigenous groups about the noise-complaint resolution process.

c) Implement a community engagement plan in order to mitigate noise issues, which would include an evaluation of the effectiveness of the plan.

d) Include the effectiveness of the community engagement plan in the annual reporting to applicable federal and provincial agencies.

HC Recommendation 4-2:

a) Provide an assessment of the magnitude and frequency of occurrence of highly impulsive noise events (e.g. shunting/coupling of trains) or high-energy impulsive noises (e.g. blasting) during construction and/or operations phases (as applicable) on nearby individuals and communities (or receptors).

b) If highly impulsive noises (e.g. shunting/coupling of trains) or high energy impulsive noises (e.g. blasting) during construction and/or operations phases (as applicable) are greater than predicted and/or result in public complaints, consider additional monitoring and mitigation. In addition, provide advance notice to nearby individuals or communities (or receptors) prior to the generation of any impulsive, highly impulsive or high energy impulsive sounds.

SECTION 1.0 INTRODUCTION

Benga Mining Limited, a wholly owned subsidiary of Riversdale Resources Limited (the Proponent), is proposing to construct and operate an open-pit metallurgical coal mine near the Crowsnest Pass, approximately seven kilometres north of the community of Blairmore, in southwest Alberta. As proposed, the production capacity of the Project would be a maximum of 4.5 million tonnes of clean coal per year, over a mine-life of about 25 years.

Health Canada (HC) is providing this written submission to the Joint Review Panel (the Panel) for its consideration at the hearing. It contains HC's comments on key outstanding human health related deficiencies and/or considerations with respect to the analyses conducted by the Proponent. Further, it offers recommendations for consideration by the Panel that, if put in place, may help to further identify and/or reduce potential risks to human health from the Project. HC's observations and recommendations are limited to issues for which the Department possesses specialist or expert information or knowledge. A list of references associated with this submission is included in Annex 1. Summaries of qualifications and experience of HC experts who have participated in this review are included in Annex 2.

SECTION 2.0 HEALTH CANADA ROLES AND RESPONSIBILITIES

The Panel for the proposed Project has been convened pursuant to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012). HC is the federal department responsible for helping Canadians maintain and improve their health and is participating in these proceedings as requested by the Panel on November 2, 2018. HC is a Federal Authority (FA) participating under Section 20 of CEAA 2012. With respect to subparagraph 5(1)(c)(i) of CEAA 2012, HC focuses on the environmental impacts of the proposed Project that may adversely affect the health of Aboriginal peoples. With respect to subparagraph 5(2)(b)(i) of CEAA 2012, HC evaluates the Project's environmental impacts on the health of non-Aboriginal peoples as well. As a FA, HC's role is to assist the Panel with its evaluation of the potential human health impacts of the proposed Project by providing to the Panel any specialist or expert information or knowledge in HC's possession regarding the potential impacts of the proposed Project on human health.

For the Project, HC provides comments related to the specialist or expert information or knowledge in its possession, which includes air quality, drinking and recreational water quality, and multi-media human health risk assessment (which incorporates potential exposures from all Project relevant environmental media including, air, groundwater, surface water, soil, sediment and traditional foods), and the acoustic environment (noise). Specific to this submission, HC's recommendations to the Panel seek to address key deficiencies and other considerations with respect to potential impacts resulting from changes to air quality, drinking and recreational water quality and noise. In addition, HC's recommendations address limitations with the overall human health risk assessment (HHRA), that does not fully address potential health risks associated with multi-media exposures.

HC's comments focus on the accuracy, scientific validity and completeness of assessments concerning human health effects. HC will not issue any approvals or make any regulatory decisions with respect to this Project.

SECTION 3.0 HEALTH CANADA REVIEW

Through the Department's participation in the environmental assessment of this Project, HC has reviewed the following Project documentation as it relates to its mandate, and the specialist or expert information or knowledge in HC's possession:

- Environmental Impact Statement (EIS)
- Information requests (IRs) and responses
- Submissions from Indigenous communities
- Submissions from the public and other jurisdictions
- Other supporting documents up to August 25, 2020

HC has submitted comments during the conformity, technical and sufficiency review phases of this Project, which have been contained in the following documents: Canadian Impact Assessment Registry (CIAR) 19, 39, 47, 76, 77, 167, 283 and 347. In this written submission, HC presents key outstanding human health related deficiencies and/or considerations based on the information available up to August 25, 2020 and provides recommendations to the Panel. Only issues relevant to the proposed Project for which HC is in possession of specialist or expert information or knowledge have been discussed in the Department's comments.

HC does not possess specialist or expert information or knowledge with which to express an opinion concerning the adequacy of the results of the environmental fate modeling conducted by the Proponent. HC's conclusions are dependent on the validity of the Proponent's predictions, which are reviewed and commented on by other parties to this process (e.g., Environment and Climate Change Canada). If there are significant changes to the Proponent's predictions, or if there are any changes to the design, construction or operation of the proposed Project that would alter the conclusions of the HHRA and supporting documentation, it may be prudent for the Proponent to update the HHRA. HC is available to review any updates upon request from a Responsible Authority.

3.1 AIR QUALITY

Background

There is consensus amongst international and national organizations (e.g., HC, World Health Organization (WHO), United States Environmental Protection Agency (US EPA), European Union, International Agency for Research on Cancer (IARC)) that air pollution adversely impacts public health (e.g., increased mortality and hospitalizations, respiratory symptoms, and cardiovascular effects) (HC, 2016a). Changes in air quality due to emissions of gases, particulate matter and other chemicals in relation to a project are often included in environmental assessments to address the potential for these substances to affect human health.

HC's approach is to review the risks to human health resulting from exposure to air pollutants using health-based evaluation tools, guidelines, standards and toxicological reference values (TRVs). The information reviewed by HC includes baseline conditions and predicted Project-related air pollutant concentrations for different assessment scenarios at locations where human receptors may be affected. HC does not currently possess expertise on the assessment or evaluation of odours, the environmental fate of airborne contaminants, or socio-economic effects related to changes in air quality. As well, HC does not possess the specialist or expert information

or knowledge necessary to verify air quality modelling results and assumes that correct, accepted and/or validated methods were used.

Under the auspices of the Canadian Council of Ministers of the Environment (CCME), HC and Environment and Climate Change Canada (ECCC) have worked with provincial/territorial governments and non-governmental stakeholders to develop the Air Quality Management System (AQMS) — a comprehensive and national approach to improving air quality in Canada. A key element of the AQMS is the health and environment-based Canadian Ambient Air Quality Standards (CAAQS), which provide the benchmark against which air quality management is evaluated across the country. The federal government published CAAQS for fine particulate matter ($PM_{2.5}$) and ozone in 2012, sulphur dioxide (SO_2) in 2016, and nitrogen dioxide (NO_2) in 2017 (CCME, 2012, 2014, 2016b, 2016c). Provinces and territories use the CAAQS in air quality management decision-making aimed at improving poor outdoor air quality and maintaining good outdoor air quality.

The air quality assessment indicates that potential sources of the criteria air pollutants SO_2, nitrogen oxides (NO_x) and carbon monoxide from the Project include diesel-fired equipment emissions (diesel exhaust (DE)), and ammonium nitrate and fuel oil used in overburden blasting. The assessment indicates that DE is one of the major sources of emissions from the Project. NO_2 and diesel particulate matter (DPM) are the predominant substances of concern associated with DE emissions. The air quality assessment also indicates that potential particulate sources ($PM_{2.5}$, particulate matter less than 10 microns in diameter (PM_{10}) and total suspended particulate (TSP)) include fugitive dust emissions from wheel entrainment, mining and coal processing facility operations, and soil/overburden/waste rock and ore/coal handling activities.

For human receptors and for children in particular, long-term exposure to ambient NO_2 has been associated with adverse respiratory effects, including reduced measures of lung function and reduced lung function growth. Several studies in children have also shown relationships between long-term exposure to NO_2 and the development of asthma and/or allergic responses (HC, 2016b). Short-term NO_2 exposure has also been associated with a range of adverse respiratory effects, including decreased lung function, increased airway hyper-responsiveness and airway inflammation. Those with a pre-existing respiratory condition are regarded as being susceptible to the effects of NO_2 and other air pollutants. Children, due to the greater prevalence of asthmatic conditions in this age group and their greater levels of activity, are regarded as susceptible to the effects of air pollution since they are more likely to encounter such pollution for prolonged periods of time. Air pollution, including $PM_{2.5}$, is carcinogenic (i.e., cancer causing) as recognized by the IARC (IARC, 2013). Additional health effects from exposure to $PM_{2.5}$ include increased hospitalizations, cardiovascular and respiratory effects, and even premature mortality (HC, 2016a). Diesel exhaust is widely recognized as carcinogenic to humans, including by HC and the IARC (HC, 2016c; IARC, 2014).

A multi-media perspective to assess overall human exposure to project-related contaminants is required when there are multiple exposure pathways for a given contaminant (see Section 3.3). For example, contaminants in air (e.g., from fugitive dust emissions) may contribute to contaminant levels in other media, such as drinking/recreational water (see Section 3.2) and traditional foods (see Section 3.3), all of which contribute to the overall exposure to that contaminant.

Health Canada Analysis and Recommendations

HC submitted a number of supplemental IRs and comments regarding air quality during the review of the Project. The comments provided by the Department included, but were not limited to the following:

-the carcinogenicity of DPM;
-baseline NO_2 concentrations;
-updated $PM_{2.5}$ risk quotients for receptors in the HHRA based on updated air quality model predictions;
-recommended mitigation and air quality monitoring; and,
-adaptive management as part of follow-up activities.

HC's comments resulted in the following recommendations:

Carcinogenicity of Diesel Particulate Matter

HC Recommendation 1-1:

HC suggests that the Panel recommend that the Proponent:

- Characterize the carcinogenicity of DPM, the main carcinogenic component of DE, using one of the HC recommended approaches in order to inform mitigation measures.

HC Analysis: The proponent has not sufficiently characterized the health risks associated with exposure to the carcinogenic components of DE.

DPM and NO_2 are the predominant contaminants of concern associated with DE. The proponent indicated that the potential carcinogenic risk of diesel emissions was assessed in the HHRA. The HHRA assessed individual contaminants of potential concern (COPCs) known to be emitted from diesel-powered engines, including heavy metals, benzene and polycyclic aromatic hydrocarbons (PAHs). The assessment found exceedances of hazard quotients (HQs) and incremental lifetime cancer risk for some of these contaminants but concluded that the Project was not predicted to pose a risk to human health at publically accessible locations (CIAR 251, p 443-556; CIAR 313, p1274). In the HHRA, the proponent states that there is no available unit risk and slope factor for DPM (CIAR 89, p 109-112).

The proponent states that the California Environmental Protection Agency (Cal EPA) unit risk and slope factor lack scientific justification in their derivation, and current epidemiological studies (HEI 2015a; HEI 2015b as cited in CIAR 89, p 111) are not representative of emissions from newer diesel engines (CIAR 191, p13-14 and 89, p 109-112). Thus, a carcinogenic assessment of DPM using the Cal EPA unit risk was considered inappropriate and therefore not conducted. Instead, the Proponent used the deterministic reference concentration of 5 $\mu g/m^3$ (as referenced in HC 2016c), which they considered the most appropriate guidance value to assess chronic non-carcinogenic respiratory effects of future emissions (CIAR 89, p 109-112).

HC is of an opinion that a quantitative assessment of risk is warranted, making use of the associated unit risk value published by the Cal EPA (Cal EPA 1998). While HC does not specifically endorse the Cal EPA unit risk value and recognizes its limitations, this approach

provides insight as to the potential impacts the Project would have in relation to risk associated with the diesel emissions. If this is not conducted, HC recommends providing a robust qualitative assessment of the carcinogenic risk of DE associated with the Project. This should include different elements to support transparency: i) identification of the main sources of diesel exhaust for the Project and recognition of the relative importance of DE as a source of air pollution for the Project; ii) recognition that DE has been declared a human carcinogen by international agencies including HC, WHO (IARC), the US EPA and the Cal EPA; and, iii) the rationale for not undertaking a quantitative analysis of DE carcinogenic risk for the Project.

Sources of Information:

- Proponent responses to sufficiency (CIAR 291)
- Proponent reply to sufficiency of comments of non-Indigenous parties (CIAR 191)
- Proponent response to HC's IRs – Eight Addendum (CIAR 89)
- Proponent response to HC's IRs – Sixth Addendum (CIAR 70)
- Tenth Addendum Package 4: Indigenous Rights, Land Use and Culture and Human Health (CIAR 251)
- Eleventh Addendum to the Environmental Impact Assessment (CIAR 313)
- EIS – Consultant Report 1: Air Quality (CIAR 42)

Baseline Nitrogen Dioxide Levels

HC Recommendation 1-2:

HC suggests that the Panel recommend that the Proponent:

a) Conduct baseline NO_2 monitoring prior to construction of the Project.

b) Conduct baseline $PM_{2.5}$ monitoring prior to construction of the Project.

HC Analysis: Baseline monitoring data from a representative location is lacking and may result in the underestimation of the Project's contribution to air pollutant levels.

The air quality assessment, and subsequently the HHRA, relied on monitoring data from the City of Lethbridge to collect baseline NO_2 values (CIAR 42, p 26-31; CIAR 251 p 72-76). According to the air quality assessment, these data were used to verify that predicted NO_2 concentrations from the Project would not be underestimated (CIAR 191, p 26). Thus, the Proponent asserts that use of the Lethbridge monitoring data is conservative, as it over-estimated baseline concentrations when combined with modelled results. HC has indicated that use of data from the Lethbridge monitoring station may lead to a misleading result, as it is a community with greater emissions than the Project area. There are concerns that exceedances of the CAAQS may be rationalized by the Proponent by noting the conservatism of using baseline information from a more populated area, thus potentially masking the actual impacts due to the Project. HC recommends the use of monitoring data to establish NO_2 and $PM_{2.5}$ background concentrations that would be more representative of the Project area. This may provide a more accurate picture of the Project's contribution to the NO_2 and $PM_{2.5}$ ambient air concentrations in the area near the Project. It is preferable that a baseline monitoring program be conducted for a duration of at least one year that would allow ambient concentrations to be comparable against the CAAQS and to account for seasonal variability. CAAQS values should not be used as trigger conditions for additional

mitigation as the values are not limits to not be exceeded but air management tools. Observable health effects may occur below the CAAQS for non-threshold air pollutants. HC recommends using technologically and economically feasible mitigation measures for reducing air pollutants emitted by the Project.

Sources of Information:

- Proponent reply to sufficiency of comments of non-Indigenous parties (CIAR 191)
- Tenth Addendum Package 4: Indigenous Rights, Land Use and Culture and Human Health (CIAR 251)
- EIS – Consultant Report 1: Air Quality and Noise (CIAR 42)

Air Quality Mitigation, Monitoring and Adaptive Management

HC Recommendation 1-3:

HC suggests that the Panel recommend that the Proponent:

a) Investigate additional mitigation measures to be implemented as warranted to minimize the concentration of non-threshold air pollutants, such as NO_2, $PM_{2.5}$ and DPM resulting from Project activities.

b) Continuously monitor NO_2 and $PM_{2.5}$ during all phases of the Project to allow ambient air concentrations to be compared against the 1-hour and 24-hour CAAQS respectively, as well as the annual NO_2 and $PM_{2.5}$ CAAQS. Consider additional mitigation measures if exceedances are measured.

HC Analysis: Health effects occur at all levels of exposure to NO_2, $PM_{2.5}$ and DPM, and additional mitigation measures would reduce the associated health risks of these pollutants.

HC considers NO_2 (along with $PM_{2.5}$) to be "non-threshold" air pollutants; meaning that health effects may occur at low levels of exposure to these substances, even those below the applicable CAAQS (HC, 2016a; HC, 2016b; WHO, 2003). For carcinogens such as PAHs and DPM, incremental lifetime cancer risk (ILCR) is used to characterize the potential human health risk associated with that exposure (i.e., incremental risk above the typical background risk that exists). An ILCR of less than 1 extra case of cancer per 100 000 people, HC considers essentially negligible (HC, 2019c). For common air pollutants (e.g., NO_2), effects are continuous and cannot be compared to the same benchmarks as carcinogens. The CAAQS are benchmarks for comparison of common air pollutants, though they do not represent an absence of adverse health effects. Proposed mitigation measures should not be restricted to meeting the CAAQS, but should work towards reducing overall population exposure to non-threshold air pollutants associated with the Project.

Predicted 1-hour NO_2 concentrations exceeded the 2025 CAAQS at 11 out of the 15 locations described in the HHRA (CIAR 251, p495). The Proponent states that Project activities are the only source leading to NO_2 exceedances for locations that are found within the Mine Permit Boundary (MPB), which will be closed off to the general public (CIAR 251, p 496-497). In contrast, the Proponent states that elevated NO_2 exceedances at publicly accessible locations (i.e., south

of the MPB) are not due to the Project. These two locations include a traditional land use site and a trapper cabin. Based on time series data, the Proponent concludes that annual exceedances of the "CAAQS toxicological reference value (TRV)" are low and that for most receptor locations, the TRV is exceeded less than 2.85% of the time (CIAR 251, p 497). HC notes that the CAAQS should not be considered as TRVs, but are instead achievable air quality management targets for which there can be adverse health effects even below the selected target value. The results indicate that there is an existing NO_2 air pollution issue in the Project area, thus HC recommends that special attention be directed to reducing NO_2 concentrations during the construction and operation phases of the Project. Since NO_2-related health effects may occur at any level of exposure, any incremental reduction in ambient NO_2 concentrations will directly lead to reduced risks of health effects inside the areas impacted by the Project.

Predicted 24-hour $PM_{2.5}$ concentrations slightly exceed the CAAQS at the Regional Study Area – Maximum Point of Impingement (RSA-MPOI), a location found within the Project footprint and which will be inaccessible by the general public (CIAR 251, p 499). Predicted additive acute inhalation HQ results for the respiratory irritants group (which includes NO_2 and $PM_{2.5}$) show exceedances of the target HQ of 0.2 at most receptor locations, which HC acknowledges may be conservative. An HQ of 1.0 may be appropriate for air contaminants for which inhalation is the only exposure pathway (CIAR 251, p 507). Exceedances of an HQ of 1.0 are still found at the maximum points of impingement and the Blairmore North location. Similarly, acute inhalation of DPM exceeds the target HQ of 0.2 at most receptor locations, which the proponent notes are primarily due to baseline for some receptors (CIAR 251, p 505-506). Given that $PM_{2.5}$ is a non-threshold air pollutant and CAAQS are not considered pollute-up-to levels, HC recommends a detailed assessment of the carcinogenic effects of DPM associated with DE (see recommendation 1-1). HC also recommends that additional mitigation be considered to reduce emissions of $PM_{2.5}$ and therefore minimize exposure in order for health effects to be minimized.

HC acknowledges that the Proponent has provided a list of mitigation measures that they will commit to implement. Some of the mitigation measures related to air emissions include those that may reduce DE emissions, such as the Proponent's commitment to use Tier IV vehicles at the start of operations (CIAR 291, p 4). Although these mitigation measures may prove to reduce DE emissions, HC recommends additional technologically and economically feasible mitigation measures be considered to further reduce non-threshold air pollutants associated with DE.

The Proponent has indicated it will continually monitor for NO_2, $PM_{2.5}$ and PM_{10} at two sites and that it will allow for a direct comparison of measurements to both the Alberta Ambient Air Quality Objectives (AAAQOs) and the CAAQS. The air monitoring program will be used to confirm that the ambient concentrations in areas accessible to the general public do not exceed the levels predicted by the air dispersion modelling (CIAR 360, p 112). HC supports this approach and recommends that air quality monitoring be conducted during all phases of the Project. HC would also recommend that the placement of monitors reflect locations where populations and individuals are likely to be exposed (both under current and future use scenarios). Monitoring will determine the accuracy of predictions, verify whether air quality standards/objectives are being met and assist in the implementation and/or modification of mitigation measures if exceedances are reported, and identify if monitored levels are higher than predicted. HC is available to review the detailed air quality monitoring plan and follow-up results upon request from the Responsible Authority.

Sources of Information:

- Response Package to JRP Package IR 7 - Twelfth Addendum (CIAR 360)
- Proponent responses to sufficiency (CIAR 291)

- Appendix 1.3-1: Draft Air Quality Monitoring and Adaptive Management Plan – Tenth Addendum (CIAR 251)
- Tenth Addendum Package 4: Indigenous Rights, Land Use and Culture and Human Health (CIAR 251)
- Proponent response to HC's IRs – Eight Addendum (CIAR 89)
- EIS – Consultant Report 1: Air Quality and Noise (CIAR 42)

3.2 DRINKING WATER QUALITY

Background

Coal mining Project activities have the potential to affect water quality in nearby drinking water sources through changes in surface and groundwater flows, seepage from tailings, and discharges to bodies of water. When these water sources are used for drinking water, it is important to assess potential impacts on health and to confirm that drinking water treatment facilities (existing or planned) will still be adequate for treating the water subsequent to any potential changes in the quality of the source water. Potential health impacts can also occur through incidental surface water ingestion or dermal contact with surface water during recreational activities.

HC does not have a role in the regulation of drinking water for on-site workers for this Project, nor does it have expertise in the odour or subjective taste of drinking water. HC does not recommend the consumption of untreated water.

A multi-media perspective to assess overall human exposure to project-related contaminants is required when there are multiple exposure pathways for a given contaminant (see Section 3.3). For example, contaminants in drinking/recreational water may be linked to contaminant levels in other media, such as air (see Section 3.1) and traditional foods (see Section 3.3), all of which contribute to the overall exposure to that contaminant.

Health Canada Analysis and Recommendations

HC submitted a number of supplemental IRs and comments regarding drinking and recreational water quality during the EIS Sufficiency Review phase of the Project. The comments provided by the Department included, but were not limited to the following:

- inclusion of a water consumption pathway from groundwater and surface water in the HHRA;
- potential health impacts resulting from consumption of surface water from the end-pit lake (EPL);
- inclusion of the surface drinking water pathway in the HHRA; and,
- recommended EPL monitoring and adaptive management as part of follow-up activities.

HC comments resulted in the following recommendations:

HC Recommendation 2-1:

HC suggests that the Panel recommend that the Proponent:

a) Provide a plan to evaluate potential risks to human health via the EPL drinking water exposure pathway during the mine closure and decommissioning phase.

b) Provide details on how the plan will be modified to accommodate for flexibility in the frequency of monitoring based on comparison of measured results against the most up-to-date Guidelines for Canadian Drinking Water Quality (GCDWQ).

c) Use the most up-to-date drinking water guidelines to characterize human health effects.

d) Develop a risk communication plan to deter people from swimming or fishing in the EPL.

HC Analysis: Details are missing on how contaminant concentrations in the EPL will be monitored and how potential risks to human health from drinking water will be evaluated during mine closure and decommissioning.

In the twelfth addendum (CIAR 360, p 6-18), revised ILCR values for fluoranthene and arsenic indicate that there is low risk of potential adverse health effects associated with lifetime exposure to the predicted surface water in Blairmore and Gold Creeks. However, the risks for the EPL indicate that the predicted concentrations are approaching or exceed the GCDWQ (HC, 2019a) for arsenic and thus represent a higher potential for adverse health effects assuming long-term exposures. In the eleventh addendum (CIAR 313, p 1275), the Proponent acknowledges that management considerations of the EPL are warranted and that actual measured concentrations at the time of the EPL creation should be used to revisit the HHRA. Additionally, the Proponent notes that surface water concentrations of the EPL should be assessed and monitored as a component of the mine closure strategy to assure that measured concentrations are not a human health concern.

HC provides the following recommendations with respect to monitoring of the EPL. In the context of the GCDWQ, HC recommends that during the mine closure phase, source water of the EPL be characterized in order to determine the frequency of monitoring and the specific COPCs to be monitored. From a human health perspective, the frequency of monitoring should increase when COPCs are found at concentrations approaching or exceeding federal drinking water guidelines or provincial drinking water standards. In some cases, environmental benchmarks that are more conservative may be used (e.g., for protection of aquatic life). If the drinking water maximum acceptable concentrations (MAC) are the appropriate benchmark for monitoring the EPL, HC recommends that the current guidance found in the most up-to-date version of the GCDWQ for individual parameters of interest be followed. At a minimum, this may result in monitoring at a frequency of at least once per year for the EPL mine-closure phase. More frequent monitoring may be recommended based on the water quality characterization of the EPL.

HC also notes that the GCDWQ for arsenic (MAC of 10 µg/L) is a risk-managed value based on the drinking water treatment achievability at the time of developing the guideline. The health-based value, which represents essentially negligible risk of cancer, is 0.3 µg/L, (HC, 2006). Thus

from a drinking water perspective, it is recommended that levels of arsenic be as low as reasonably achievable. This further supports monitoring of the EPL since predicted arsenic levels in the EPL are predicted to exceed the health-based value.

HC also suggests the use of the most up-to-date guideline for aluminum in drinking water to characterize human health effects (MAC of 2.9 mg/L for total aluminum in drinking water, based on neurological effects (HC, 2019b)). This updated guideline should be considered for all drinking water quality monitoring programs, including the EPL.

Furthermore, the Proponent states that contact with the EPL while swimming is not expected as the lake will be for visual appeal only and that fish consumption is not expected to occur as local fish species do not thrive in benthic environments (CIAR 251, p 473-474). The information provided is not clear as to what reclamation for "visual appeal" will entail with respect to the protection of human health. HC recommends that risk communication measures be developed to prevent people from using the EPL for swimming or fishing.

Sources of Information:

- Twelfth Addendum to the Environmental Impact Assessment (CIAR 360)
- Eleventh Addendum to the Environmental Impact Assessment (CIAR 313)
- Tenth Addendum Package 4: Indigenous Rights, Land Use and Culture and Human Health (CIAR 251)
- EIS – CR12: HHRA (CIAR 42)
- EIS – CR1: Water Quality (CIAR 42)

3.3 HUMAN HEALTH RISK ASSESSMENT – ANALYSIS, MONITORING AND ADAPTIVE MANAGEMENT

Background

Human health risk assessments (HHRA) provide a critical analysis of the potential health risks of a Project. An HHRA can be defined as the process that is used to estimate the nature and probability of adverse health effects in humans who may be exposed to contaminants through different exposure pathways (i.e., ingestion, inhalation and dermal contact) in specific environmental media (i.e., air, soil, water and traditional foods). HC typically suggests that proponents complete a traditional foods impact assessment if there is the potential risk to human health as a result of contamination of traditional foods. Traditional foods (also known as country foods) are foods that are trapped, fished, hunted, harvested or grown for subsistence or medicinal purposes or obtained from recreational activities such as sport fishing and/or game hunting and trapping. Traditional foods do not include foods produced in commercial operations (e.g., large farms or greenhouses for commercial sale) and offered for sale. HC's expertise lies in the conduct of HHRAs of chemical contaminants in food when empirical data are provided.

The findings of an HHRA are useful for determining the significance of potential health effects and establishing appropriate mitigation measures, follow-up programs and plans for monitoring potential residual effects. The results of a well-documented HHRA can provide increased scientific support for the conclusions of an assessment.

HC has published scientific guidance available on conducting multi-media HHRAs in the context of environmental assessments, where concentrations of chemicals in various environmental media are estimated rather than measured as actual contamination has not yet occurred (HC,

2019c). The purpose of an HHRA in this case is to provide an estimate of the potential risks to human health from all Project phases and to respond to government and public concerns related to those projected effects. In this context, HC expresses an opinion on whether the HHRA was performed according to current practices, is scientifically defensible, and represents a reasonable worst-case scenario for potential future human health risks.

HC considers the following aspects in its review:

- The appropriateness of methodologies used;
- The predicted human health effects and any comparisons to health-based guidelines and standards;
- The identification of any potential human health effects as a result of predicted changes to the environment;
- The conclusions made concerning potential human health effects, including the uncertainties identified in the assessment and the accompanying rationale or justifications;
- The evidence provided to justify the conclusions and the scientific defensibility of the rationale regarding potential effects to human health; and,
- The adequacy and duration of monitoring and/or follow-up programs, risk mitigation strategies, and risk management approaches.

Health Canada Analysis and Recommendations

HC has submitted a number of supplemental IRs and comments during the EIS sufficiency review phase of the federal review of the Project related to HHRA and monitoring recommendations or concerns.

Comments and IRs from the Department included but were not limited to the following:

- HHRA methodology;
- the use of an HHRA multi-media approach;
- potential for leachate from storage areas;
- mitigation measures to address potential health risks;
- coal dust constituents at the Project site and inclusion of coal dust as a COPC;
- potential for silica dust from the Project to impact human health;
- inclusion of a water-based exposure pathway in the HHRA;
- site-specific consumption patterns and rates for traditional foods;
- background levels of COPCs in traditional foods; and,
- dietary exposure to methylmercury.

HC's comments have resulted in the following recommendations:

HC Recommendation 3-1:

HC suggests that the Panel recommend that the Proponent:

a) Use site-specific analyses to characterize the COPCs associated with the sources of dust generated by the Project, or provide site-specific coal analysis data to demonstrate the appropriateness of the surrogate data used to date. Use the site-specific analysis of COPCs as the basis of the modelling inputs into the HHRA.

b) Develop a comprehensive environmental monitoring program to verify the HHRA predictions based on site-specific concentrations of COPCs in suspended dust (as per (a) above). It is recommended that this monitoring program also include relevant environmental media impacted by dust (i.e., surface water, soil and sediment) during all Project phases. HC is available to review the monitoring program, upon request.

c) Provide details on how the results of the monitoring program (as per (b) above) will inform adaptive management measures in all phases of the Project.

d) If monitored COPC concentrations (as per (b) above) exhibit an increasing trend, concentrations exceed applicable guidelines and/or are at levels expected to produce potential risks (e.g., exceed site-specific target levels, where applicable), consider updating the HHRA. If monitored COPC concentrations (as per (b) above) shows an increasing trend in environmental media (e.g., surface water, soil or sediment), empirical data of COPC concentrations in relevant traditional foods that are harvested and consumed should be collected and an updated HHRA considered.

HC Analysis: Site-specific analyses were not used to inform the HHRA. Surrogate data was used to identify COPCs for the HHRA without sufficient justification that it is representative of site-specific conditions. This introduces uncertainty into the validity of the HHRA and the potential health risks.

During the environmental assessment process, some of HC's comments on the HHRA have been addressed; however, there remain outstanding concerns about the reliability of the predictions in the HHRA. HC suggest monitoring of environmental media to verify predictions in the environmental assessment and to address the uncertainties of the HHRA's conclusions.

Coal dust can serve as a vector for metals and PAHs to enter deep into the lungs and into the blood circulation. Hence, chemicals like PAHs that are attached to these coal dust particles can then be delivered to organs and tissues causing deleterious effects. Exposure to coal dust may represent a serious health risk given its chemical complexity. The assessment of the potential bioavailability of attached constituents to coal dust was not adequately characterized by the Proponent. Additionally, there was no analysis of the type of coal that would be extracted from the Grassy Mountain Coal Mine Project site, or how the dust mixture and heterogenous exposure source may vary during extraction and processing. Instead, surrogate values from thermal coal used at three other mines were used (CIAR 251, p 90), but the report did not provide evidence as to whether the chemical constituents associated with thermal coal dust may be different from metallurgical coal dust, which will be the type of coal mined in this Project. Therefore, the surrogate values that would be used for assessing the toxicity of coal dust for this Project may not be appropriate and/or applicable for use in the HHRA. It is recommended that the Proponent provide site-specific coal analysis data to demonstrate the appropriateness for using surrogate data, or re-assess risks using actual site-specific coal composition data. This site-specific information is necessary to identify the COPCs created at the pit (e.g., from raw ore, coal dust and other waste rock dust), in processing areas, at the train-loadout area (located within the town of Blairmore) and arising from the rail cars used for shipping the coal.

HC notes the use of a default average airborne concentration of respirable particulate matter (i.e., PM_{10}) of 0.76 $\mu g/m^3$ in the sample calculation for concentration in airborne dust (CIAR 251, Package 4, p 916) which is a typical assumption for fugitive dust generated from windblown dust of soils at contaminated sites (HC, 2012). However, the Project activities are not consistent with

the default value of 0.76 µg/m^3, and this concentration of airborne particulate matter likely underestimates the potential dust generation associated with the exposure scenarios identified for the various Project activities. The use of dust concentrations that may underestimate potential exposure associated with inhalation of particulates from Project activities as well as deposition of particulate matter onto soil, sediment, water and foods as presented in the HHRA may result in an underestimate of human health risk.

Due to these uncertainties, HC recommends monitoring to verify whether the HHRA assumptions used are appropriate and ultimately assist with the implementation or modification of mitigation measures (i.e., adaptive management). HC is available to review any stage of a future monitoring program, as appropriate. HC recommends monitoring site-specific COPCs during all Project phases to confirm the predictions of the HHRA and keep risks to human health as low as possible. Environmental media to be monitored include air, dust, water, soil and sediment. If concentrations of these key contaminants in environmental media show an increasing trend, concentrations exceed applicable guidelines in environmental media, and/or are at levels expected to produce potential risks (e.g., exceed site specific target levels, where applicable), consider updating the HHRA to re-assess the potential risk to human health. If COPC concentrations exhibit an increasing trend in environmental media, empirical data of COPC concentrations in relevant traditional foods that are harvested and consumed should be collected and updated HHRA considered. Additional mitigation and monitoring activities may be recommended and become part of a follow-up program to validate that the updated predictions accurately represent activities at the site for all phases of the Project and to determine the effectiveness of the proposed mitigation measures.

Sources of Information:

- Twelfth Addendum to the Environmental Impact Assessment (CIAR 360)
- Eleventh Addendum to the Environmental Impact Assessment (CIAR 350)
- Tenth Addendum to the Environmental Impact Assessment Package 4: Indigenous Rights, Land Use and Culture and Human Health Information Request 4.10 (CIAR 251)
- Eighth Addendum to the Environmental Impact Assessment (CIAR 89)
- EIS – Consultant Report 12: Human Health and Wildlife Screening Risk Assessment (CIAR 42)

3.4 ACOUSTICAL ENVIRONMENT (NOISE)

Background

Human exposure to noise can cause annoyance, disturb sleep, impact communication, and has also been associated with cardiovascular reactions. Brief exposures to very high levels of noise or prolonged exposures to high noise levels can cause permanent hearing loss and/or tinnitus (i.e., ringing in the ear) (HC, 2017). With respect to noise-related health impacts, HC possesses expertise in the following areas:

a) Evaluating the modelled changes between existing and predicted daytime and nighttime sound levels at locations presently and/or reasonably foreseeably to be occupied by humans; and,
b) Evaluating the human response to noise based on source type, characteristics (e.g. impulsive or tonal), time of day, and type of community (e.g., urban, quiet rural).

HC does not possess specialist or expert information or knowledge on the impacts of noise on wildlife or ecosystems. HC's advice also does not extend to occupational settings as occupational noise is under the jurisdiction of provincial and/or federal workplace legislation.

Health Canada Analysis and Recommendations

HC submitted a number of supplemental IRs and comments regarding noise during the EIS Sufficiency Review phase of the Project.
The comments provided by the Department included the following:

- low frequency noise concerns;
- potential for sleep disturbances;
- blasting noise;
- complaint resolution process;
- use of percentage highly annoyed (%HA); and,
- highly impulsive noise.

HC's comments resulted in the following recommendations:

Noise Complaint Resolution Process

HC Recommendation 4-1:

HC suggests that the Panel recommend that the Proponent:

a) Implement a formal noise-complaint resolution process in consultation with Indigenous groups and local community members who may be impacted by noise due to Project activities.

b) Proactively inform the local community and potentially impacted Indigenous groups about the noise-complaint resolution process.

c) Implement a community engagement plan in order to mitigate noise issues, which would include an evaluation of the effectiveness of the plan.

d) Include the effectiveness of the community engagement plan in the annual reporting to applicable federal and provincial agencies.

HC Analysis: A community engagement plan and a noise complaint-response protocol to identify/mitigate noise issues and associated risks to human health are lacking.

Community engagement has been shown to be beneficial in reducing the number of complaints (HC, 2017). As such, if a community engagement plan is implemented, this may influence/target monitoring and/or mitigation in order to reduce annoyance and/or sleep disturbance at the nearby receptor locations. Regular reporting is important to support the effectiveness of this community engagement plan and to identify whether additional engagement and/or mitigation may be required.

In HC's opinion, it is recommended that a complaint-response protocol be implemented, which includes a formalised means of receiving and responding to complaints in a timely fashion with

additional monitoring and mitigation measures defined in the event of noise-related complaints. In addition, it is recommended the proponent inform all people (Indigenous and non-Indigenous) who may be affected by Project-related noise, in advance of any notable changes in sound levels (e.g., blasting), as this type of communication may identify/mitigate many concerns related to noise. Multiple methods of communication (e.g., telephone, mail, signage, websites) can support effective and efficient communication between the Proponent and community.

The proponent has predicted that %HA will be below 6.5% at noise receptors. As referenced in HC (2017), the U.S. Federal Transit Administration describes a long-term increase of more than 6.5%HA as representing a severe Project-related noise impact (U.S. FTA, 2006) (CIAR 55, p49-58; CIAR 70, p181-184). The proponent has stated that their noise predictions suggest no effects on sleep will occur, and they have noted: "*If, during Project operations, any noise complaint is filed, the Alberta Energy Regulator Directive 038 (AER 2007; amended in 2013) noise complaint investigation procedures will be followed*."(CIAR 89, p154-155). HC accepts this approach. The proponent has stated they will be developing a complaint resolution communication process with Piikani First Nation, the nearest Indigenous community. HC is of the opinion that any communications be extended to the local community and other Indigenous groups that may use the land for traditional activities.

Sources of Information:

- Proponent response Fourth Addendum (CIAR 55)
- Proponent response Eighth Addendum (CIAR 89)
- Proponent response Sixth Addendum (CIAR 70)
- EIS – Consultant Report 2A: Environmental Noise Impact Assessment (CIAR 42)

Potential for Highly Impulsive and High Energy Impulsive Noise

HC Recommendation 4-2:

HC suggests that the Panel recommend that the Proponent:

a) Provide an assessment of the magnitude and frequency of occurrence of highly impulsive noise events (e.g. shunting/coupling of trains) or high energy impulsive noises (e.g. blasting) during construction and/or operations phases (as applicable) on nearby receptors.

b) If highly impulsive noises (e.g. shunting/coupling of trains) or high energy impulsive noises (e.g. blasting) during construction and/or operations phases (as applicable) are greater than predicted and/or result in public complaints, consider additional monitoring and mitigation. In addition, provide advance notice to nearby receptors prior to the generation of any impulsive, highly impulsive or high energy impulsive sounds.

HC Analysis: Information on the occurrence of highly impulsive noise events (e.g. shunting/coupling of trains) or high energy impulsive noises (e.g. blasting) on nearby receptors is lacking.

The proponent has stated that there may be blasting during the construction and early operations phases. The proponent also indicated that there will not likely be regular railcar shunting/coupling at the rail load-out location (CIAR 89, p144; CIAR 251, Package 1, p 47). However, HC is

concerned about any highly impulsive noises (such as shunting/coupling of rail cars), and any high energy impulsive sounds (such as blasting), as these may cause a disproportionate increase in annoyance and/or sleep disturbances. In calculating %HA, it is recommended all highly impulsive sounds include a highly impulsive noise characteristic adjustment of +12 decibels (dB) as per ISO 1996-1:2016. High energy impulsive sounds require their own assessment when calculating %HA, as per ISO 1996-1:2016 (ISO, 2016) or HC (HC, 2017). Potential impacts on sleep can be managed through an effective community engagement plan. An assessment of the magnitude and frequency of occurrence of highly impulsive and high energy impulsive noise effects events should be conducted and potential mitigation proposed if any of these noises affect nearby receptors. Furthermore, noise monitoring may be an effective means of identifying situations where these types of noises may be a source of noise complaints.

Sources of Information:

- Tenth Addendum Package 1: Air Quality and Noise, Information Request 1.9 (CIAR 251)
- Proponent response Eighth Addendum (CIAR 89)

SECTION 4.0 SUMMARY OF RECOMMENDATIONS

HC promotes a precautionary approach, including monitoring to verify impact predictions and adaptive management initiatives. The following summarizes HC's recommendations to the Panel on actions that the Proponent can take to reduce risks to human health from the Project:

HC recommendation 1-1:

Characterize the carcinogenicity of DPM, the main carcinogenic component of DE, using one of the HC recommended approaches in order to inform mitigation measures.

HC recommendation 1-2:

a) Conduct baseline NO_2 monitoring prior to construction of the Project.

b) Conduct baseline $PM_{2.5}$ monitoring prior to construction of the Project.

HC Recommendation 1-3:

a) Investigate additional mitigation measures to be implemented as warranted to minimize the concentration of non-threshold air pollutants, such as NO_2, $PM_{2.5}$ and DPM resulting from Project activities.

b) Continuously monitor NO_2 and $PM_{2.5}$ during all phases of the Project to allow ambient air concentrations to be compared against the 1-hour and 24-hour CAAQS respectively, as well as the annual NO_2 and $PM_{2.5}$ CAAQS. Consider additional mitigation measures if exceedances are measured

HC Recommendation 2-1:

a) Provide a plan to evaluate potential risks to human health via the EPL drinking water exposure pathway during the mine closure and decommissioning phase.

b) Provide details on how the plan will be modified to accommodate for flexibility in the frequency of monitoring based on comparison of measured results against the most up-to-date Guidelines for Canadian Drinking Water Quality (GCDWQ).

c) Use the most up-to-date drinking water guidelines to characterize human health effects.

d) Develop risk communication plan to deter people from swimming or fishing in the EPL.

HC Recommendation 3-1:

a) Use site-specific analyses to characterize the COPCs associated with the sources of dust generated by the Project, or provide site-specific coal analysis data to demonstrate the appropriateness of the surrogate data used to date. Use the site-specific analysis of COPCs as the basis of the modelling inputs into the HHRA.

b) Develop a comprehensive environmental monitoring program to verify the HHRA predictions based on site-specific concentrations of COPCs in suspended dust (as per (a) above). It is recommended that this monitoring program also include relevant

environmental media impacted by dust (i.e., surface water, soil and sediment) during all Project phases. HC is available to review the monitoring program, upon request.

c) Provide details on how the results of the monitoring program (as per (b) above) will inform adaptive management measures in all phases of the Project.

d) If monitored COPC concentrations (as per (b) above) exhibit an increasing trend, concentrations exceed applicable guidelines and/or are at levels expected to produce potential risks (e.g., exceed site-specific target levels, where applicable), consider updating the HHRA. If monitored COPC concentrations (as per (b) above) shows an increasing trend in environmental media (e.g., surface water, soil or sediment), empirical data of COPC concentrations in relevant traditional foods that are harvested and consumed should be collected and an updated HHRA considered.

HC Recommendation 4-1:

a) Implement a formal noise-complaint resolution process in consultation with Indigenous groups and local community members who may be impacted by noise due to Project activities.

b) Proactively inform the local community and potentially impacted Indigenous groups about the noise-complaint resolution process.

c) Implement a community engagement plan in order to mitigate noise issues, which would include an evaluation of the effectiveness of the plan.

d) Include the effectiveness of the community engagement plan in the annual reporting to applicable federal and provincial agencies.

HC Recommendation 4-2:

a) Provide an assessment of the magnitude and frequency of occurrence of highly impulsive noise events (e.g. shunting/coupling of trains) or high energy impulsive noises (e.g. blasting) during construction and/or operations phases (as applicable) on nearby receptors.

b) If highly impulsive noises (e.g. shunting/coupling of trains) or high energy impulsive noises (e.g. blasting) during construction and/or operations phases (as applicable) are greater than predicted and/or result in public complaints, consider additional monitoring and mitigation. In addition, provide advance notice to nearby receptors prior to the generation of any impulsive, highly impulsive or high energy impulsive sounds.

SECTION 5.0 CLOSING REMARKS

HC is pleased to participate in the Panel's review of the Project as part of the Department's role in helping Canadians maintain and improve their health. HC appreciates the opportunity to provide the Panel with the specialist or expert information or knowledge that is in its possession in accordance with *CEAA, 2012.*

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ANNEX 2 EXPERT SUMMARY OF QUALIFICATIONS AND EXPERIENCE

Melissa Gorman, MPH
Environmental Assessment Specialist / Regulatory Operations and Regions Branch
Health Canada
Suite 910, 9700 Jasper Avenue
Edmonton, Alberta T5J 4G3

Curriculum Vitae

SUMMARY

Ms. Gorman is an Environmental Assessment Specialist in the Regulatory Operations and Enforcement Branch at Health Canada. She participates in the review of potential developmental projects in Alberta, Yukon and the Northwest Territories for potential human health impacts and coordinates Health Canada's participation as a federal authority under the *Canadian Environmental Assessment Act, 2012* and the *Impact Assessment Act, 2019*. Ms. Gorman also represents Health Canada at consultations and meetings with other government departments and agencies, Indigenous groups and industry.

EXPERIENCE

Environmental Assessment Specialist, Environmental Health Program, Regulatory Operations and Enforcement Branch, Health Canada
2014 – Present

- Coordinate Health Canada's participation in the review of potential development projects in Alberta, Yukon and the Northwest Territories.
- Participate in the review of environmental impact statements for potential human health impacts.
- Participate in departmental and interdepartmental working groups in the review of proposed development projects.
- Represent Health Canada at multi-departmental consultations and panel hearings.
- Support the development of internal and external guidance documents and tools.

Evaluator, Science and Technology Branch, Ecological Assessment Division, Environment and Climate Change Canada (ECCC)
2009 – 2014

- Conducted screening risk assessments on priority petroleum chemicals under the Chemicals Management Plan's Petroleum Sector Stream Approach in collaboration with Health Canada.
- Collaborated with other evaluators in ECCC and Health Canada, internal science advisors, external reviewers and management.
- Conducted literature searches, analyzed existing research and used modelling software.
- Provided analyses of results, advice and recommendations to management.

Health and Environment Officer, Former Safe Environments Program, Health Canada
2008 – 2009

- Co-wrote two industry analysis reports for Alberta and the Northwest Territories to help guide national risk management strategies under the Chemicals Management Plan.
- Created an industry-specific stakeholders list for the region for engagement purposes.
- Created an inventory of human biomonitoring studies in the region to identify potential gaps in research for funding requests.

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EDUCATION

Master of Public Health (M.P.H.) Degree in Environmental and Occupational Health
School of Public Health, University of Alberta, Edmonton, 2009

Bachelor of Science (B.Sc.) Degree in Biology and Chemistry
University of Alberta, Edmonton, 2006

PROFESSIONAL DEVELOPMENT

- International Association for Impact Assessment Conference (2019)
- Health Impact Assessment Training, Health Canada (2018)
- Western Indigenous Consultation and Engagement Conference (2018)
- Legal Duty to Consult, former Indian and Northern Affairs Canada (2015, 2017)
- Human Health Risk Assessment Training, Health Canada (2017)
- Training on Consultation and Accommodation, former Indian and Northern Affairs Canada (2015)
- Introduction to the *Canadian Environmental Assessment Act, 2012*, former Canadian Environmental Assessment Agency (CEAA) (2014)
- Aboriginal Groups: Environmental Assessment, former CEAA (2014)

Graham Irvine
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Curriculum Vitae

SUMMARY

Graham Irvine is an Environmental Assessment Specialist in the Regulatory Operations and Enforcement Branch at Health Canada. Graham participates in the review of potential developmental projects in Alberta, Yukon, and Northwest Territories for potential human health impacts and coordinates Health Canada's participation as a federal authority under the *Canadian Environmental Assessment Act, 2012*. Graham also represents Health Canada at consultations and meetings with other government departments and agencies, Indigenous groups and industry.

EXPERIENCE

Environmental Assessment Specialist, Environmental Health Program, Regulatory Operations and Enforcement Branch, Health Canada

2015 – Present

- Coordinate Health Canada's participation in the review of potential development projects in Alberta, Yukon, and Northwest Territories.
- Participate in the review of environmental impact statements for potential impacts to Indigenous health.
- Participate in departmental and interdepartmental working groups in the review of proposed development projects.
- Represent Health Canada at multi-departmental Indigenous consultations.
- Support the development of internal and external guidance documents and tools.

Research Technologist, CanmetENERGY, Natural Resources Canada

2013 – 2015

- Developed lab-scale methods for measurement of bitumen-water emulsions and adhesion
- Acquired equipment and materials necessary for the setup of a wave tank to determine effects of bitumen spilled on water
- Ran wave tank tests and sampled water, oil, and headspace vapours for determination of effects of bitumen spilled on water
- Separated bitumen into component parts with column chromatography

Graham Irvine
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Curriculum Vitae

EDUCATION

M.SC, BIOLOGY: SPECIALIZATION IN CHEMICAL AND ENVIRONMENTAL TOXICOLOGY 2013
University of Ottawa Ottawa, ON

Thesis: *Soil Ingestion Rate and Excess Lifetime Cancer Risk in First Nations' People Exposed to Polycyclic Aromatic Hydrocarbons Near In-situ Bitumen Extraction in Cold Lake, Alberta*.

B.SC., ENVIRONMENTAL RESOURCE SCIENCE 2011
Trent University Peterborough, ON

PUBLICATIONS

- Irvine G, Blais JM, Doyle JR, Kimpe LE, White PA. 2014. Cancer Risk to First Nations' People From Exposure to Polycyclic Aromatic Hydrocarbons Near in-situ Bitumen Extraction in Cold Lake, Alberta. In Revision to *Environmental Health*, **13**:7.
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PROFESSIONAL DEVELOPMENT

- Fundamentals of Acoustics and Noise Control (2018)
- Legal Duty to Consult, former Indian and Northern Affairs Canada (2017)
- Human Health Risk Assessment Training, Health Canada (2017)
- Media Training, Health Canada (2016)

Luigi Lorusso, M.Eng., P.Eng.
Health Canada – Supervisor/Unit Head, Contaminated Sites Division

Curriculum Vitae

Chemical and Environmental Health Management Bureau
Healthy Environments and Consumer Safety Branch
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269 Laurier Avenue West
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SUMMARY

Luigi Lorusso has over 25 years of combined work experience, in both the private and public sectors, in the assessment (including human health risk assessment), remediation and management of contaminated sites. He also has experience in providing human health related advice on environmental assessment projects within Canada. As part of his work experience, he supported the development of human health based soil quality guidelines and screening values for various chemicals, and also supported the development of various human health risk assessment related guidance documents for use at federal contaminated sites. Luigi currently works in the Contaminated Sites Division at Health Canada, and in his current role, he provides senior advice related to human health risk assessment of contaminated sites and relevant aspects of environmental assessments within Canada.

EXPERIENCE

Health Canada Contaminated Sites Division (CSD)
Unit Head - Supervisor and Periodic Acting Division Manager (May 2006 to Present)

- Senior Review of Health Canada (HC)'s CSD advice provided to Federal Custodians to ensure national consistency in the advice provided as well as ensuring advice is consistent with current HC policy. Where necessary, engagement of other HC programs to discuss potential inconsistency in advice being provided in an effort to resolve such issues.
- Senior Technical Review of CSD's expert review of human health risks associated with environmental impact assessments and remedial action plans for CEAA triggered projects
- Provide human health related guidance, training and advice to federal custodian departments dealing with the management of federal contaminated sites
- Manage human health risk assessment related consulting and research contracts to support Health Canada Contaminated Sites guidance development and provision of advise
- Support in the development of human health risk assessment guidelines and soil quality guidelines
- Provide Senior management strategic advice and recommendations on CSD's program activities and high profile departmental cross cutting issues (e.g. off-site contamination of drinking water by PFAS chemicals from various Federal contaminated sites and off-site contamination of Arsenic in various environmental media and country foods)
- Developing contracts, research agreements, and Request for Standing Offers (RFSO) for providing CSD with human health risk assessment related services
- Liaison activities with other government departments in FCSAP, as well as liaison with Provincial and Territorial governments in relation of chemicals of concern on federal lands and those migrating off federal lands onto provincial/territorial lands.
- Lead multidisciplinary teams in addressing various HC program wide scientific and policy issues (e.g. PFASs at firefighting training areas, Arsenic in environmental media and country foods, UXOs at DND firing ranges, benefits of risk assessment in managing contaminated sites to ensure funds are appropriately resourced to priority sites etc.)
- Member of the departmental Task Force for Scientific Risk Assessment where I represent CSD as one of HC's experts in human health risk assessment. This includes leading the evaluation and preparation of guidance on 2 departmental wide cross cutting issues, (i) Body Weight and (ii) Uncertainty in Human Health Risk Assessment
- Support in the general management of CSD Workplan development and Financial Management

Luigi Lorusso, M.Eng., P.Eng.
Health Canada – Supervisor/Unit Head, Contaminated Sites Division

Curriculum Vitae

Heath Canada, Environmental Assessment Division
Acting Manager (January 2012 to March 2012, April to November 2012)

- Managing the day to day operations (including all HR and Financial matters for the division)
- Briefing (written and oral) senior management (including Director of EHB and Director General SED) on implications of new CEA Act, CEAA Project Panels and EA projects (e.g. Major energy projects including, Northern Gateway Pipeline Project, Oil Sands Development Projects, Hydroelectric projects, mining projects etc.)
- Providing senior level oversight and approval in comments being provided to proponents of the above noted major energy projects under the CEA Act (old and new 2012 Act).
- Analysis of new 2012 CEA Act and implications to Health Canada
- Setting National priorities under new CEA Act
- Coordinating the signing of 2 Government of Canada Response MCs by the Health Minister
- Participating and representing HC in various interdepartmental meetings and committees (including DG level Committees, and interdepartmental for MC approvals)
- Providing senior level oversight and approval in the development of various guidance documents and standard advice documents

Health Canada, PMRA, ASRAD, Office of Policy and Strategic Advice
Project Manager (BI 4) and Acting Section Head (BI 5 - on a rotating basis)

- Briefing and providing strategic advice and recommendations to senior management in PMRA (including Directors, Executive Director, Deputy Minister, and Minister of Health) related to ASRAD work
- Developing workplans, allocating resources and tracking of project activities to ensure the scheduled completion of various Business Line activities
- Preparing and Co-ordinating the timely completion of Agency Responses to the Office of the Auditor General, Commissioner of the Environment and Sustainable Development, House of Commons and Parliamentary Standing Committees, and Environmental Petitions
- Developing Policies, MOUs and other agreements with various government departments and agencies on various emerging and cross-cutting issues

GPEC INTERNATIONAL LTD.
Senior Project Manager and Lead Project Engineer with GPEC (Sept. 1995 to March 2003)

- Managing of large and small capital projects, both domestic and international (estimated combined contract values in the millions of dollars)
- Leading multidisciplinary project teams and focus groups
- Planning, scheduling and coordinating the execution and completion of project activities
- Conducting environmental site assessments of contaminated sites, and environmental impact assessments for various small and large scale projects (e.g. development of waste management facilities, remediation of contaminated sites, etc.)
- Conducting risk assessments (including occupational, and residential exposure assessments) of contaminated sites (including stochastic and deterministic modelling) and developing risk management strategies
- Providing clients with scientific (including human health) and regulatory advice based on the findings of our environmental assessments, risk assessment, and environmental impact assessments
- Reviewing, Evaluating, and interpreting project related national and international legislation, regulations, policies, and guidelines
- Assisting foreign states (i.e. developing countries) in the privatization of hazardous waste management systems with the utilization of co-gen systems
- Evaluating risks and liabilities associated with various substances, project activities and developing and implementing strategies to minimize these risks
- Developing and implementing health and safety procedures

- Evaluating and designing various treatment technologies/processes and sizing and procuring equipment (as needed)
- Performing client liaison activities (including foreign governments)
- Permitting, commissioning, and licensing of GPEC's various remediation technologies
- Conducting community information sessions
- Developing and Implementing Company Policies and Project Management methodologies
- Heading research at GPEC - Designing and performing bench and pilot scale research and scaling-up activities

ENVIRONMENT CANADA:
Engineer in Training (3 Separate Co-op work terms, 1992 to 1994)

- Conducting treatability and feasibility studies of various remediation technologies
- Writing technical summary sheets for the DESRT (Development and Demonstration of Site Remediation Technologies) program
- Developing and performing bench and pilot scale experiments
- Optimization of remediation processes (soil and water)

UNIVERSITY OF OTTAWA:
Biochemist (1993-1994 school term)

- Conducting a treatability study investigating the use of bacteria for the removal of selenium from waste water.

HEALTH CANADA:
Biochemist (2 Summer work terms, 1990 and 1991)

- Developing a methodology to separate enantiomeric isomers of the drug Metoprolol (with the Health and Welfare Canada's Biopharmaceutics and Pharmacodynamics division (BPD)) and subsequently performing bench scale experiments
- Implementing Workplace Hazardous Materials Information System (WHMIS) into the laboratory environment
- Investigating the effects of Indomethacin on the enzymatic activity of Phospholipases (with the Bureau of Human Prescription Drugs)
- Performing in-vitro and in-vivo biochemical experiments using radioisotope tracers

EDUCATION

B.Sc. Biochemistry, University of Ottawa (May 1991)
B.A.Sc. Chemical Engineering, Co-op, University of Ottawa (May 1995)
M.Eng. Chemical Engineering (Specialization: Environmental Engineering), University of Ottawa (May 1999)

Brenda Woo
Alberta Regional Manager, Environmental Heath Program
Regulatory Operations and Enforcement Branch
Health Canada
Suite 910, 9700 Jasper Avenue
Edmonton, Alberta T5J 4G3

Curriculum Vitae

SUMMARY

Ms. Brenda Woo is a Regional Manager of the Environmental Health Program in the Regulatory Operations and Enforcement Branch at Health Canada. As the Alberta Regional Manager, she is responsible for delivering the operational Environmental Assessment program in Alberta, Yukon and Northwest Territories. She works in close partnership with her Environmental Assessment Specialists and colleagues in the Healthy Environments and Consumer Safety Branch to ensure that Health Canada provides quality and timely expertise. Ms. Woo will represent Health Canada at the Grassy Mountain Coal Project hearing to address mandate and policy related questions directed to Health Canada.

EXPERIENCE

Alberta Regional Manager, Environmental Health Program, Regulatory Operations and Enforcement Branch, Health Canada
October 2010 – Present
September 2007 – January 2010

- Manage the Regional Environmental Health Program for Alberta and the North which is comprised of 5 core program areas: Environmental/Impact Assessment, Federal Contaminated Sites Action Plan, Air Quality, Radon, and Chemicals Management Plan.
- Ensure the effective and efficient management of the program's financial and human resources.
- Work collaboratively with colleagues in the national program and our partners in the Healthy Environments and Consumer Safety Branch.
- Develop and maintain collaborative relationships and linkages with other federal government departments, provincial and territorial governments, and other regional partners and stakeholders.
- Provide strategic advice and briefings to senior management

Senior Environmental Health Specialist, Safe Environments Program, Healthy Environments and Consumer Safety Branch, Health Canada
May 2004 – September 2007

- Provided policy and planning advice and support to the Regional Manager.
- Provided technical expertise on regional environmental health issues.
- Participated on regional multi-stakeholder working groups.
- Established and fostered cooperative relationships with regional stakeholders.

Brenda Woo
Alberta Regional Manager, Environmental Heath Program
Regulatory Operations and Enforcement Branch
Health Canada
Suite 910, 9700 Jasper Avenue
Edmonton, Alberta T5J 4G3

Curriculum Vitae

Environmental Health Officer, Environmental Health Services, First Nations and Inuit Health Branch, Health Canada

March 1999 – April 2004

- Developed, implemented, evaluated and delivered environmental public health programs and services to First Nations communities in Alberta.
- Conducted inspections for compliance to public health legislation
- Investigated and provided health promotion/education in the areas of communicable disease, emergency response, environmental contaminants, food safety, housing, occupational health and safety, waste management, transportation of dangerous goods and water quality.
- Coordinated Health Canada's scientific advice on human health implications of proposed development projects under the *Canadian Environmental Assessment Act* for projects in Alberta, Saskatchewan and Northwest Territories.

Environmental Health Officer Trainee, Environmental Health Services, First Nations and Inuit Health Branch, Health Canada

June 1998 – February 1999

- Developed practical and technical skills on conducting inspections, investigations and monitoring activities associated with the delivery of environmental health services to First Nations communities.
- Conducted investigation of enteric disease outbreaks, including inspection of private and public facilities; development of questionnaires and educational materials; interviewing of cases and contacts; epidemiological analysis; working with community health teams.
- Developed and delivered education and awareness sessions to community members and stakeholders.

EDUCATION

Certificate in Public Health Inspection (Canada)
Canadian Institute of Public Health Inspectors, 1999

Bachelor of Applied Science (B.A.Sc.) Degree in Environmental Health
Ryerson Polytechnic University, Toronto, Ontario, 1998

Bachelor of Science (B.Sc.) Degree in Human Biology
University of Toronto, Ontario, 1996

Margaret Yole, DVM, MSc, PhD (Toxicology)
Health Risk Assessment and Toxicology Specialist
Environmental Health Program. MB/SK Region
Regulatory Operations and Enforcement Bureau
Health Canada
391 York Ave
Winnipeg, MB
R3C 4W1

Curriculum Vitae

SUMMARY

Dr. Margaret Yole is a Health Risk Assessment and Toxicology Specialist within the Contaminated Sites Division at Health Canada's MB/SK Regional office in Winnipeg, MB. Since joining Health Canada in 2006, she has provided expert advice for multiple assessment and remediation projects in the western provinces, providing in input regarding site investigations, human health risk assessments and remedial action plans for federal contaminated sites, and the potential toxicological impacts of proposed project under federal environmental assessment process. She is also involved in the development of guidance for use at federal contaminated sites.

In her previous roles, Dr. Yole has been a university instructor in veterinary toxicology and pharmacology, supervised a veterinary diagnostic toxicology laboratory and been a clinician in private veterinary practice. Dr. Yole also currently freelances as a technical editor of scientific publications for scientists who are not native English speakers.

EXPERIENCE

2006 TO PRESENT

TOXICOLOGIST/HUMAN HEALTH RISK ASSESSOR

Health Canada, Winnipeg, MB

As part of the regional Environmental Health Program,

- prepare or review toxicological assessments of priority chemicals in order to develop exposure guidelines (*e.g.,* benzo-a-pyrene, mercury, trichloroethylene, nickel, chromium, n-hexane, 1,4-dioxane, energetic compounds and others);
- provide expert advice to federal custodial departments and prepare regulatory guidance with regard to federal contaminated sites under the FCSAP program;
- assess the toxicological impact of proposed major projects (*e.g.*, uranium and other mines, closures of abandoned mines, hydroelectric dams, *etc.*); and
- coordinate with other levels of government to assess and manage provincial/municipal contaminated sites (*e.g.*, Flin Flon Soils Study, Lead in Winnipeg Soils) or proposed projects (*e.g.*, Red River Floodway Expansion).

On term assignments at Health Canada,

- prepared the very challenging reviews of the toxicology of naphthalene and nitrogen dioxide, which were used as supporting documentation for indoor exposure guidelines for these priority chemicals; and
- prepared tools to assess national chemical emergencies for the Chemical Emergency Preparedness Unit (CEPRU) and to address mandatory reporting under the WHO International Health Regulations, and reviewed guidance for health professionals confronting major crude oil spills.

Margaret Yole, DVM, MSc, PhD
Health Risk Assessment and Toxicology Specialist
Environmental Health Program
Regulatory Operations and Enforcement Bureau
Health Canada

Curriculum Vitae

2018 TO PRESENT
SCIENTIFIC/TECHNICAL EDITOR (FREELANCE REMOTE)
E-WORLD EDITING, PORTLAND OR

- Edit research articles (100+ to date) written by Korean researchers for publication in English-language journals.

2003-2004
TERM ASSISTANT PROFESSOR, VETERINARY TOXICOLOGY
Dept. Vet. Biomedical Sciences, University of Saskatchewan,Saskatoon, SK

- As a primary instructor, redesigned the veterinary toxicology course, emphasising food safety, basic, clinical and environmental toxicology.
- Also delivered a guest undergraduate lecture on toxicant damage to DNA; and acted as group leader for problem-based learning in anatomy/physiology.

1997-2001
ADJUNCT INSTRUCTOR/PH.D. CANDIDATE, PHARMACOLOGY/TOXICOLOGY
Dept. of Molecular Biosciences, University of California, Davis, CA

- As an adjunct instructor, initiated weekly review sessions, provided “Breakfast Club” group or individual tutoring for students in difficulty, developed study guides, maintained e-mail questions/answers, led research discussion groups, co-ordinated, proctored and graded all exams for 120 DVM students.
- Also delivered lectures on opioid pharmacology to veterinary students and on autonomic pharmacology and immunotoxicology to graduate students.

FALL 1995
SENIOR LECTURER, VETERINARY TOXICOLOGY
Dept. Veterinary Biomedical Sciences, Univ. of PEI , Charlottetown, PEI

- As a sabbatical replacement, was asked to revise the Veterinary Toxicology course, and created a new syllabus, using lectures accompanied by problem-based learning tutorial periods.

2003-2004
CO-SUPERVISOR, DIAGNOSTIC VETERINARY TOXICOLOGY LAB
Dept. Vet. Biomedical Sciences, U. of Saskatchewan Saskatoon, SK

- Assessed analytical results from suspected toxicoses, and consuled with clients and veterinarians regarding domestic animal and wildlife toxicology cases, and consulted with the global Food Animal Residue Avoidance Databank (gFARAD) on withdrawal times for food animals following toxicant exposures.

Margaret Yole, DVM, MSc, PhD
Health Risk Assessment and Toxicology Specialist
Environmental Health Program
Regulatory Operations and Enforcement Bureau
Health Canada

Curriculum Vitae

1991-1993
ASSOCIATE VETERINARIAN
Fairlea Veterinary Hospital, Picton, ON

- Provided medical, surgical, ambulatory and emergency care for a two-person small animal/equine practice in rural Ontario.

EDUCATION

PH.D., IMMUNOTOXICOLOGY 2007
University of Saskatchewan Saskatoon, SK

Thesis: *Alterations in lymphocyte signalling produced by exposure to mercury.* Independent project investigating mercury-induced alterations in cell signalling at the immunological synapse.

M.SC., IMMUNOTOXICOLOGY 1997
University of Saskatchewan Saskatoon, SK

Thesis: *Evaluation of immune system effects of 5-hydroxymethyl-2'-deoxyuridine.* Evaluation of potential therapeutically-limiting immune system toxicity of a novel anti-retroviral/-leukemia nucleoside.

- Interprovincial and U of S graduate student scholarships

DOCTOR OF VETERINARY MEDICINE (D.V.M.) 1991
Atlantic Veterinary College, University of PEI Charlottetown, PEI

- Dean's list (1988) and AVC merit scholarship (1989 and 1990)
- R.G. Thomson award, highest 4-yr aggregate GPA (1991)

B.SC., BIOLOGY 1985
Dalhousie University Halifax, NS

TECHNICAL AND OTHER TRAINING:

Risk Assessment; Dose-Response Assessment; Contaminated Site Management; Environmental Site Assessment; Vapour Intrusion; Emergency Operations Centre 100/200/300; Technical Writing; Public Outreach/Risk Communication; Media Training; Aboriginal Involvement

PUBLICATIONS

Haber, LT, B Meek, A Li-Muller, M Yole, AK Mohapatra, and S Petrovic A Framework for Risk Assessment for Less-Than-Chronic and Intermittent Exposures to Chemicals (Noncancer Endpoints). Poster #1819: Society of Toxicology Annual Meeting, Mar 26, 2014, Phoenix AZ

National Federal Contaminated Sites Workshops:

Margaret Yole, DVM, MSc, PhD
Health Risk Assessment and Toxicology Specialist
Environmental Health Program
Regulatory Operations and Enforcement Bureau
Health Canada

Curriculum Vitae

2012 Presentation: Li-Muller, A (presenter), Healey, N, Yole, M, Petrovic, S: Health Canada Interim Position on Human Health Risk Assessment for Short-Term Exposure to Carcinogens at Contaminated Sites

2010 Poster: Mitchell, I, Yole, M and Wright, P: Derivation of Toxicity Reference Values for 1,4-Dioxane

2008 Poster: Mitchell, I, Knafla, A, Carey, J, Williams, D, Yole, M and Smith, L: Development of a Human Health Soil Quality Guideline for n-Hexane

2008 Presentation: Muller, A (presenter), Healey, N, Yole, M, and Petrovic, S: Human Health Cancer Risk Assessment for Less-than-lifetime Exposure at Contaminated Sites

Yole, M, Wickstrom, M, and Blakley, B. Cell death and cytotoxic effects in YAC-1 lymphoma cells following exposure to various forms of mercury. Toxicology. 2007 Feb 28;231(1):40-57.

Blakley BR and Yole MJ: Species differences in normal brain cholinesterase activities of animals and birds. Vet Hum Toxicol 44:129-32,
2002.

Blakley BR, Yole MJ, Brousseau P, Boermans H, Fournier M: Effect of Chlorpyrifos on Immune Function in Rats. Vet HumToxicol 41:140-144, 1999.

Blakley BR, Yole MJ, Brousseau P, Boermans H, Fournier M: Effect of pentachlorophenol on immune function. Toxicol 125:141-148, 1998.

Blakley BR, Yole MJ, Brousseau P, Boermans H, Fournier M: Effect of 2,4-dichlorophenoxyacetic acid, trifluralin and triallate herbicides on immune function. Vet Hum Toxicol 40:5-10, 1998.

Yole MJ, Gupta SV, Kumar SVP and Blakley BR: Immune alterations associated with 5-hydroxymethyl-2'-deoxyuridine. Presented at: Canadian Network of Toxicology Centres (CNTC) Annual Research Symposium, Toronto, Ontario, May 2-3, 1995.

Tasker RAR, Connell BJ, Yole MJ: Systemic injections of alpha-1 adrenergic agonists produce antinociception in the formalin test. Pain 49:383-391, 1992.

TAB 4

Natural Resources Canada | Ressources naturelles Canada

Natural Resources Canada's Final Submission to the Joint Review Panel regarding the Grassy Mountain Coal Project proposed by Benga Mining Limited, a subsidiary of Riversdale Resources Limited

September 21, 2020

Signed on behalf of Natural Resources Canada

<Origin[redacted]

September 21, 2020

John Clarke
Director
Office of the Chief Scientist
Natural Resources Canada

Date Signed

Natural Resources Canada | Ressources naturelles Canada

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Natural Resources Canada | Ressources naturelles Canada

Abbreviations

AER	Alberta Energy Regulator
CCMEO	Canada Centre for Mapping and Earth Observation
EIA	Environmental Impact Assessment
FAAR	Federal Authority Advice Record
GSC	Geological Survey of Canada
The Agency	Impact Assessment Agency of Canada
IR	Information Request
JRP	Joint Review Panel
LMS	Lands and Minerals Sector
NBCC	National Building Code of Canada
NRCan	Natural Resources Canada

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Chapter 1 – Context

1.1 – Departmental Mandate and Responsibilities

1. Established under the *Department of Natural Resources Act* (1994), NRCan seeks to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resources products. NRCan is an established leader in science and technology in the fields of energy, forests, minerals and metals, and uses its expertise in geosciences to build and maintain an up-to-date knowledge base of our landmass. NRCan supports the environmental, social and economic priorities of the federal government by focusing our science and technology programs on innovative, sustainable development projects that improve the quality of life of Canadians.

2. Scientists and technical experts from NRCan's Lands and Minerals Sector (LMS) were involved in the environmental assessment of the proposed Grassy Mountain Coal project. The Geological Survey of Canada (GSC), is part of LMS and is Canada's oldest scientific agency for geoscientific information and research. Its world-class expertise focuses on the sustainable development of Canada's mineral, energy and water resources; stewardship of Canada's environment; management of natural geological and related hazards; and technology innovation. It provides Canadians with timely, reliable, scientific, economic, environmental and governance knowledge and expertise required to support the sustainable development of Canada's land resources. Within LMS, the Explosives Security and Safety Branch is responsible for administering the federal *Explosives Act* and its regulations.

1.2 – NRCan's Participation in the Joint Review Panel Environmental Assessment

3. Natural Resources Canada (NRCan) is participating as a Federal Authority in the environmental assessment by Review Panel of the Benga Mining Limited's (the Proponent's) proposed Grassy Mountain Coal Project (the Project), providing specialist or expert information or knowledge pursuant to Section 20 of the *Canadian Environmental Assessment Act*, 2012. NRCan's participation in the environmental assessment involved the provision of scientific and technical expertise in areas within our mandate relevant to the project. In addition, based on the information provided by the Proponent to date, NRCan has identified that it may be required to issue a permit or licence pursuant to Section 7.1(a) of the *Explosives Act* to allow the Project to proceed.

4. This submission responds to the JRP's June 29, 2020 Letter of Request (CIAR #380) to participate in the public hearing. The JRP requested that NRCan provide a technical written submission on the potential environmental effects of the Project as they relate to the department's mandate and areas of expertise.

5. To date, NRCan has provided advice to the Impact Assessment Agency of Canada (the Agency) and the Panel on:

- *Surficial geology and terrain hazards*: information on surficial geology and terrain hazards in the project area and the potential of landslides that could impact project activities and infrastructure.
- *Seismicity*: faults, seismicity and induced seismicity as a result of fracking in the project area; and
- *Hydrogeology*: impacts to groundwater quantity as it relates to project activities such as mine pit dewatering, groundwater flow modelling, and the evaluation of the Proponent's groundwater monitoring program.

6. NRCan is a member of the Federal Review Team (FRT) for the environmental assessment, led by the Agency, that coordinates federal departments and agencies participating in the review process. The FRT identifies technical issues, facilitates discussions between federal departments on issues that cut across departmental mandates and promotes a consistent approach amongst departments for federal submissions. In addition, NRCan participates in the whole-of-government approach to consultation with Indigenous Peoples by participating in consultation activities during the environmental assessment process.

7. NRCan's participation in the environmental assessment process is summarized below:

8. **April 2015 (CIAR #20):** In response to the Agency's request for information for the Federal Authority Advice Record (FAAR), NRCan noted that the Department may be required to issue a licence under the *Explosives Act* to allow the Project to proceed. NRCan also noted that the Department is in possession of expertise related to hydrogeology, geohazards, and seismicity that may be relevant to the environmental assessment of the Project pursuant to Section 20 of the *Canadian Environmental Assessment Act, 2012*.

9. **February 2016 (CIAR #37):** In response to the Agency's request to review the Environmental Impact Assessment for the Project (CIAR #29), NRCan provided expertise related to hydrogeology, surficial geology, terrain hazards, and seismicity.

10. **October 2016 (CIAR #49):** In response to the Agency's August 16, 2016 request to review the revised EIA (CIAR #42) and Proponent's responses to the first round of IRs, NRCan provided expertise related to hydrogeology, surficial geology, terrain hazards, and seismicity.

11. **July 2018 (CIAR #73):** In response to the Agency's May 1, 2018 request to review Addendum 6 of the EIA (CIAR #70) and the Proponent's responses to the sixth round of IRs, NRCan provided expertise related to seismicity, terrain hazards, and the storage and manufacture of explosives.

12. **December 2018 (CIAR #103):** In response to the JRP's November 2, 2018 request for federal expertise (CIAR #91), NRCan submitted a description of expertise and knowledge within its mandate that may assist the JRP in reviewing the Project. NRCan identified expertise in the areas of hydrogeology, surficial geology and terrain hazards, and seismicity. NRCan also identified that it may issue a licence pursuant to section 7(1)(a) of the *Explosives Act* to allow the Project to proceed.

13. **January 2019 (CIAR #167):** On November 5, 2018, the JRP announced the beginning of a comment period on the sufficiency and technical merit of the information available on the Canadian Impact Assessment Registry (formerly known as the Canadian Environmental Assessment Registry) for the Project. NRCan provided comments and recommendations to the JRP on hydrogeology.

14. **October 2019 (CIAR #283):** In response to the JRP's September 9, 2018 request to provide comments on the sufficiency and technical merit of Addenda 9 and 10 (CIAR #185 and #251, respectively) of the EIA for the Project, NRCan provided expertise in hydrogeology and explosives.

15. **May 2020 (CIAR #347):** In response to the JRP's March 19, 2020 request to provide comments on the sufficiency and technical merit of Addendum 11 (CIAR #313) of the EIA and the Proponent's responses to the sixth round of IRs, NRCan provided expertise related to hydrogeology.

16. **August 2020 (CIAR #503):** NRCan reviewed the Proponent's final submission in its areas of mandate in the context of its final review.

Chapter 2 – Seismicity

2.1 Introduction

17. Seismic hazard assessment is the study of expected earthquake ground motions on the earth. In Canada, the development and evaluation of regional earthquake hazard models for applications in the National Building Code of Canada (NBCC) is the responsibility of the Geological Survey of Canada within NRCan. The seismic hazard maps prepared by the GSC are derived from the statistical analysis of past earthquakes and from advancing knowledge of Canada's tectonic and geological structure and are updated as new information becomes available, both at the national and international levels.

2.2 Approach to Review and Results

18. NRCan has reviewed the Proponent's EIA and Addenda related to faults, seismicity and potential induced seismicity from fracking in the project area. During the pre-panel review of the Environmental Impact Assessment (CIAR #29), NRCan recommended that the Proponent describe the induced seismicity that may result from hydraulic fracturing in the project's vicinity (CIAR #49). The Proponent responded in its 4th Addendum to the EIA – Attachment 2 ((CIAR #55) .pdf page 31), stating that there is currently no hydraulic fracturing operations occurring in the vicinity of the Project.

19. The Proponent also summarized seismic activity that occurred within approximately 40 km of the Project as published by the Alberta Seismic Events Interactive Map (Alberta Geological Survey, 2017). The Proponent found that all events registered below 2.5 M and concluded that seismic conditions were not

expected to adversely affect the Project and result in impacts to the environment. NRCan is satisfied with the Proponent's characterization of seismicity and potential induced seismicity from fracking in the project area.

20. NRCan requested that the Proponent remove reference to the 1985 National Building Code of Canada (NBCC) in its EIA documentation, and confirm that the 2015 NBCC values would be considered for the dam design. To supplement this recommendation, NRCan noted that the Canadian Dam Association Guidelines 2013 would be an important document for reference to support the Proponent in responding to seismic concerns. As well, NRCan requested confirmation that the shaking values be modified in the EIA, as required, based on actual shear-wave velocities observed at the project site.

21. The Proponent responded in its 4th Addendum to the EIA ((CIAR #55) .pdf page 31) stating that, "*As the detailed design progresses, the current codes and standards will be referenced*". The Proponent also confirmed that their "*...analysis will be modified, as required, based on actual shear-wave velocities at the Project site.*"

22. In the Proponent's 8th Addendum submission and the corresponding IR responses (CIAR #89 .pdf page 148), the Proponent noted that observations were conducted on available exposed areas on Grassy Mountain and no evidence of post-glacial stratigraphic levels were observed. NRCan has no further recommendations related to post-glacial faulting in the area.

2.3 Recommendations

23. NRCan recommends that the Proponent adhere to their commitment to use the most current NBCC and Canadian Dam Association Guidelines during the construction phase of the Project.

Chapter 3 – Surficial Geology and Terrain Hazards

3.1 Introduction

24. Landslides are a common occurrence around the world and there are different types of landslides that can occur. Experts distinguish between those that occur in bedrock versus those that occur in unconsolidated sediments. Landslides have different sizes, some being large (km^3) and others much smaller (m^3). Their rate of mass-flow movement is variable from creep at mm/year to rapid at 100 km/hour. Several factors contribute to landslide activity including both natural (e.g., topography, excessive rain, or erosion at the base of a slope) and anthropogenic/human factors (e.g., loading the top of a slope or excavation at the base of a slope).

3.2 Approach to Review and Results

25. NRCan has reviewed the Proponent's EIA and Addenda and provided advice related to surficial geology and terrain hazards in the project area that could impact project activities and infrastructure. During the conformity review in October 2016, NRCan recommended that a map showing the landslide potential of the project area be provided. In addition, NRCan also requested an explanation of how the landslide potential would be addressed and mitigated.

26. In the April 2018, 6th Addendum to the EIA (CIAR #70) the Proponent provided a response to NRCan's information request on landslide potential of the project area. The Proponent's response included the mapping of the local study area into 10 regions (CIAR #70 Appendix E-1 Terrain Assessment – Figure 1-1) each being attributed a landslide susceptibility rating varying from low to moderately high (CIAR #70 Appendix E-1 Terrain Assessment – Table NRCAN 1-3 and Figure 1-2). The rating was established by considering slope angle, bedrock type and structure, thickness of soil cover, vegetation cover, precipitation, and historical landslide frequency. Five infrastructure elements (CIAR #70 Appendix E-1, Section 5.0 –Figure 1-2 Grassy Mountain Project Landslide Susceptibility Regions Within Consultation Zone Colour Coded) identified at seven locations at the Project site were characterized as areas of potential concern.

27. The Proponent confirmed that the proposed mitigation measures will include a foot survey to identify geomorphic features diagnostic of landslides in areas of potential concern, a field mapping exercise, annual ground condition inspections with increased frequency after major precipitation events, and a ground monitoring program for areas of potential concern (CIAR #70 Appendix E-1, Section 6.0 – Mitigation measures). NRCan is of the view that these measures are appropriate in addressing the landslide potential of the project area.

28. In June 2020, the JRP requested that NRCan provide expertise in its final submission in several areas, including the "stability of Turtle Mountain" (CIAR #380). To confirm, NRCan has contributed to publications (see Annex 1 – References) that describe past research undertaken in the Turtle Mountain area, including the structural features:

- Structural Analysis of Turtle Mountain (Alberta) using digital elevation model: Toward a progressive failure, 2009
- InSAR monitoring of the Frank Slide, 2005; and
- Monitoring deformation at the Frank Slide from InSAR techniques, 2003

29. Additionally, the Canadian Centre for Mapping and Earth Observation of NRCan responded to a request in April 2020 from the Alberta Geological Survey of the Alberta Energy Regulator to provide satellite-based monitoring of Turtle Mountain and related products to support their in-situ radar monitoring system. It is NRCan's understanding that the Alberta Geological Survey has been leading the *Turtle Mountain*

Monitoring Program since 2005 (*Alberta Geological Survey, 2020*). NRCan is not conducting active research or monitoring related to Turtle Mountain at this time.

3.3 Recommendations

30. NRCan recommends that the Panel request that the Proponent implement their commitments to perform: a foot survey to identify geomorphic features diagnostic of landslides in areas of potential concern, a field mapping exercise, annual ground condition inspections with increased frequency after major precipitation events, and a ground monitoring program for areas of potential concern.

Chapter 4 – Hydrogeology

4.1 Introduction

31. Hydrogeology is the study of the laws governing the movement of subterranean water, the mechanical, chemical, and thermal interaction of this water with the porous solid, and the transport of energy and chemical constituents by the flow. It deals with the distribution and movement of groundwater in the soil, sediment and rocks of the Earth's crust and groundwater is the water contained in the porous spaces beneath the surface of the earth.

4.2 Approach to Review and Results

32. NRCan provided advice related to impacts to groundwater quantity as it relates to project activities, in areas such as mine pit dewatering, groundwater flow modelling, and evaluation of the Proponent's groundwater monitoring program. Specifically, NRCan reviewed relevant sections of the EIA and related addendums, and the Proponent's sufficiency letter of January 31, 2019, IR 5.18 and IR 5.19.

33. NRCan recommended that the JRP request additional information related to the Proponent's groundwater numerical model and provide an update on their baseline groundwater monitoring and analysis program (CIAR #167). The Proponent responded to NRCan in their sufficiency letter of January 31, 2019 (CIAR #191) by referencing the role of the Alberta Energy Regulator with jurisdiction over groundwater in Alberta who will require that, "*Benga develop for approval a comprehensive and robust groundwater monitoring plan" as part of its EPEA approval*". The Proponent also committed to sharing information obtained through the Groundwater Monitoring Plan. As such, NRCan was of the view that any uncertainties or issues related to the modeling could be addressed through effective adaptive management and the use of a well-designed Groundwater Monitoring Plan.

34. On February 15, 2019 (CIAR #192) and May 20, 2019 (CIAR #220) the Tsuut'ina Nation raised concerns to the JRP including but not limited to the potential for leaching of minerals such as selenium that could potentially reach groundwater. As detailed in IR 5.18, concern was noted related to the groundwater transport model's consideration of potential fractures or existing mine tunnels that could be potential pathways for contaminated groundwater.

35. With regards to the complete identification and 3D modeling of the groundwater pathways, including the historical mine tunnels, the Proponent confirmed that attempts were made to locate and identify the historical mines without success. The Proponent confirmed that uncertainties within the model would be addressed using their proposed Adaptive Monitoring and Management Plan. Results from monitoring will be compared with the modeling predictions, and in context with the mining operations. The need for additional monitoring or the implementation of adaptive management will be re-assessed regularly.

36. The Proponent has proposed seepage capture wells constructed across groundwater flow paths to mitigate contamination of groundwater. There have been concerns raised by participants (including the Tsuut'ina Nation) that due to the complexity of the groundwater regime, in their view it seems unlikely that an extraction system could be adequately designed to collect all potentially contaminated seepage water.

37. In IR #5.19, the JRP requested that the Proponent conduct an alternative means analysis that investigated mitigation measures (impermeable, engineered liners) as an alternative to the proposed seepage capture wells. The Proponent did not conduct a formal alternative means analysis however provided clarification on the mitigations proposed as part of the external rock dump design and Selenium Management Plan including several methods for seepage capture.

38. In NRCan's view, the proposed measures by the Proponent for seepage collection were found reasonable and technically feasible given the hydrogeological setting.

4.3 Recommendations

39. NRCan recommends that the Panel request that the Proponent provide the Groundwater Management Plan including metrics and parameters used to evaluate the performance of the drainage ditches and seepage wells. The plan should be updated and adaptable in accordance with the monitoring activities and acquisition of relevant observation data. Plans should be provided to relevant authorities and accompanied with annual progress reports submitted for review. Relevant authorities should be kept up to date on the status of the site.

5.0 Conclusion

40. NRCan appreciates the opportunity afforded by the Review Panel to participate in this review. NRCan looks forward to participating in the public hearings and would be pleased to answer any questions from the Panel, its staff, the Proponent or other parties to this review.

Annex 1: Publications Related to Turtle Mountain

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Annex 2: Curricula Vitae of Natural Resources Canada's Experts involved in the Grassy Mountain Coal Environmental Assessment Process

John F. Cassidy, Ph.D. (Seismicity and earthquake hazards)

Alain Plouffe, Ph.D. (Surficial geology and terrain hazards)

Miroslav Nastev, Ph.D. (Hydrogeology and natural hazards risk assessment)

John F. Cassidy, Ph.D.
NRCan Expert in Earthquake Hazards

Senior Research Scientist,
Geological Survey of Canada
9860 West Saanich Road,
Victoria, BC
V8L 4B2

Citizenship:
Canadian.

Current Occupation:
Senior Research Scientist, Geological Survey of Canada (Natural Resources Canada) since 1991.
Head, Earthquake Seismology Section (since 2011)
Project Leader, Assessing Earthquake Geohazards Project (since 2012)
Adjunct Professor, University of Victoria (since 1999)

Education:
Ph.D., Dept. of Geophysics and Astronomy, University of B.C. (1991)
M.Sc., Dept. of Geophysics and Astronomy, University of B.C. (1987)
B.Sc. (Honours Physics), Dept. Of Physics and Astronomy, University of Victoria (1982)

Relevant Experience
Dr. John Cassidy is a Senior Research Scientist with Natural Resources Canada and an Adjunct Professor at the University of Victoria. Dr. Cassidy specialises in earthquake hazard studies and earth structure studies, and during the past 30 years has published more than 200 scientific papers and public information articles and has authored/co-authored more than 330 presentations at scientific conferences and workshops. Dr. Cassidy has served on 31 Graduate student committees, and has supervised 12 Ph.D and M.Sc. students. He is an internationally recognized expert in earthquake hazard studies and he works closely with the engineering community and emergency management organisations that utilise the results of earthquake research.

Dr. Cassidy serves as Co-Chair of the British Columbia Seismic Safety Council, and served as an invited member of the Canadian Association of Earthquake Engineers Chile Earthquake Reconnaissance Team in 2010. Dr. Cassidy regularly conducts Environmental Assessments for major project proposals in Canada. He has served as an Expert Witness in earthquake hazards at National Energy Board Hearings in 2012 and 2013, at the Roberts Bank Port Expansion Hearing in 2019 and has conducted more than 30 Environmental Assessments over the past 15 years. He serves as a reviewer of large-scale international research proposals and scientific publications for national and international organisations.

Employment History:

1993- present: Geological Survey of Canada, Research Scientist II, III, IV, V, Head – Earthquake Seismology Section, Project Leader – Assessing Earthquake Geohazards.
1999-present: Adjunct Professor, School of Earth and Ocean Sciences, University of Victoria
1991-1993: Visiting Fellowship, Geological Survey of Canada, Ottawa, ON
1984-1990: Teaching Assistant, Dept. of Geophysics and Astronomy, University of B.C.
1982-1984: Engineering Research Assistant, TRIUMF Laboratory, Univ. British Columbia

Memberships and Committee Service:

- Co-Chair, British Columbia Seismic Safety Council (2011-present)
- United States Geological Survey, Advanced National Seismic Systems Advisory Committee Member (PNW) (2014-present).
- Canadian Federation of Earth Scientists, International Committee, Member (2011-2015)
- Canadian Association of Earthquake Engineers - Chile Earthquake Reconnaissance Team (2010)
- Editorial Board Member, Journal of Seismology (2020-present)
- Editorial Board Member, International Journal of Geophysics (2008-2017)
- POLARIS - National Steering Committee Member (2002-2015)
- Interagency Volcanic Event Notification Plan (IVENP) National Committee, Member (2009-present)
- Canadian Disaster Management Information System - Steering Committee Member (2002-2005)
- Seismological Society of America Annual Meeting 2002 - Meeting Co-Chair
- Seismological Society of America - Member (1991-present)
- Canadian Association of Earthquake Engineering - Member (2003-present)

Government Awards or Honours

- 2011 – NRCan, Earth Sciences Sector Recognition Award for “Response to Japan March 2011 Disasters" and provision of scientific information after the M9 Japan earthquake
- 2012 – Queen Elizabeth II Diamond Jubilee Medal (Science Excellence).
- 2013 – NRCan Departmental Achievement Award – for service as an Expert Witness at the Northern Gateway NEB Hearings
- 2015 - NRCan, Earth Sciences Sector Merit Award for serving as a Guest Editor for the M7.8 Haida Gwaii Earthquake Special Issue of Bulletin of the Seismological Society of America

Scientific Publications (since 2009):

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Ph.D., Dept. of Geology and geological engineering, Laval University (1998)
M.Sc., Institute of earthquake engineering, University of Ss. Cyril and Methodius, Skopje, North Macedonia (1986)
B.Sc., Dept. of Civil Engineering, University of Ss. Cyril and Methodius, Skopje, North Macedonia (1980)

Research Interests and Experience:
Dr. Miroslav Nastev is a Senior Research Scientist with Natural Resources Canada and an Adjunct Professor at five other universities. His scientific, engineering and teaching experience extends over a unique spectrum of competencies related to geology, hydrogeology, geotechnics, earthquake engineering and software development. Since joining the Geological Survey of Canada, Dr. Nastev has led a team of scientists and students in the development of a wide range of groundwater flow models. These range from regional hydrogeological characterization of fractured and granular aquifers in the Châteauguay and Chaudière watersheds to specific issues of water quantity and sustainability related to development and use of groundwater resources. His present interests focus on the development of standardized methods and tools for quantitative analysis of physical vulnerability and social and economic impacts from earthquakes, floods and wildfires. During his federal public service career, Dr. Nastev has conducted more than 30 Environmental Assessment for major projects in Canada. He has co-authored 56 scientific papers and book chapters, and about 200 conference proceedings and 130 departmental and engineering reports. Dr. Nastev has supervised 26 graduate students and served on 30 graduate student committees.

Employment History:

1999/present	Research Scientist, Geological Survey of Canada, Québec City
1997/99	Project Manager, Dessau Engineering-Construction, Québec City
1995/97	Project Manager, Soprin-ADS Engineering-Construction, Québec City
1991/92	Project Manager, Data Engineering, Skopje (North Macedonia)
1989/91	Project Manager, ENKA Engineering-Construction, Istanbul (Turkey)
1981/86	Assistant professor, Institute of Earthquake Engineering, University Ss. Cyril and Methodius, Skopje (North Macedonia)

Academic Appointments:

2012/18	Adjunct Professor: Dept. of Civil and Environmental Engineering, University of Western Ontario, London
2009/present:	Adjunct Professor: Institute of Earthquake Engineering and Engineering Seismology, University Ss Cyril and Methodius, Skopje, North Macedonia
1999/present	Adjunct Professor: Institut National de Recherche Scientifique - Eau Terre Environnement INRS-ETE, Québec City
1999/present	Adjunct Professor: Dept. Géologie et génie géologique, Université Laval, Québec City
2005/present	Adjunct Professor: Dept. of Applied Sciences, Université du Québec à Chicoutimi UQAC, Saguenay
1987	Visiting Fellow: Dept. Civil Engineering, Columbia University, New York
1986/88	Visiting Fellow: Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

Memberships and Committee Service:

2020	Technical Evaluation Jury: Intersectoral Flood Network of Québec RIISQ, Fonds de recherche du Québec – Nature et technologies FRQNT grant applications (https://riisq.ca/).
2020	Technical Evaluation Jury 'Interface - Institute of Multi-Hazard Systemic Risk Study (https://interface.mcmaster.ca/), McMaster University, Hamilton
2019/present	Advisory committee on Federal Flood Risk Assessment Procedures'. Coordinated by NRCan's Canada Centre for Mapping and Earth Observation CCMEO
2019/present	International Society for Soil Mechanics and Geotechnical Engineering (https://www.issmge.org/)
2019/present	Serbian Association for Earthquake Engineering (https://suzi-saee.rs/index).
2019/present	Intersectoral Flood Network of Québec RIISQ, Fonds de recherche du Québec – Nature et technologies FRQNT (https://riisq.ca/)
2018/19	Technical Evaluation Jury: NSERC Industrial Research Chair grant applications – Hydrogeology; NSERC Collaborative Research and Development grant applications - Hydrogeology.
2018/present	Technical Working Group on Flood Mapping. Coordinated by Canada Centre for Mapping and Earth Observation CCMEO-NRCan.
2017	Technical Evaluation Jury: Establishing the European Geological Surveys Research Area GeoERA grant applications (https://geoera.eu/)
2016/present	Technical adviser to the 'Directorate for public safety and fire safety'. Coordinated by the Disaster Management Centre, Government of North Macedonia (lead Dr. S.Stefanovski, Head of Department), Skopje.
2014/present	Technical adviser to the 'Table de concertation sur les risques sismiques'. Coordinated by the Ministere de la Securite publique du Quebec (lead Dr. P.Marceau, Direction generale de la securite civile et de la securite incendie), Quebec (QC).
2014/present	Macedonian Association for Geotechnics (https://mag.net.mk/).
2011/12	US FEMA scientific committee for regional seismic risk assessment of

	New England (USA).
2011	Signatory of the Technical Annex to the Agreement between the Government of the United States and the Government of Canada for Cooperation in Science and Technology for Critical Infrastructure Protection and Border Security, Portland (OR).
2010/present	HAZUS Technical User's Group. U.S. Federal Emergency Management Agency (FEMA)
2010/2014	Advisory committee for seismic risk assessment U.S. Federal Emergency Management Agency (FEMA)
2010/present	Canadian Association for Earthquake Engineering (https://www.caee.ca/).
2009/present	International Association for Engineering Geology IAEG
2008/present	Association des Hydrogeophysiciens du Quebec
2008/12	Canadian Geotechnical Society
2008/09	Expert Committee for elaboration of the Quebec's 'Programme d'Acquisition de Connaissances sur l'Eau Souterraine', Ministère du Développement durable, de l'Environnement et des Parcs du Québec
2007/09	Scientific Committee of the Ministère du Développement durable, de l'Environnement et des Parcs du Québec for Restoration of hydrocarbon contaminations
2007/08	Technical Committee for the elaboration of Water Master Plans for integrated water management. Ministère du Développement durable, de l'Environnement et des Parcs du Québec
1996/08	Canadian Ground Water Association
1993/05	Professional Engineer : Ordre des Ingénieurs du Québec
1981/88	Professional Engineer : Association of Engineers, Macedonia
2010	Guest Editor: Canadian Water Research Journal – CWRJ (https://www.tandfonline.com/toc/tcwr20/35/4)
2004/08	Expert committee Bureau d'audiences publiques sur l'environnement, Québec
2004/08	Steering Committee Adirondack Aquifers, Québec
2004/06	Steering Committee Hydro Météorologie Appliquée – HYMAP, Québec
2003/07	Associate Editor: Hydrogeology Journal

Awards or Honours

2019	Notable Alumnus, University of Ss. Cyril and Methodius, Skopje, North Macedonia, in recognition of scientific achievements in Civil Engineering.
2019	Special Honour to International Scientist in the field of 'Mechanics of Structures' for outstanding contribution to the international promotion and affirmation of the University of Zagreb, Croatia (https://www.facebook.com/100008859694718/videos/2187649281540374/?id=100008859694718).
2018	NRCan's Best Team Lead 2018 for managing the development of the Rapid Risk Evaluator ER2 web-platform (https://www.nrcan.gc.ca/21643).
2018	NRCan Departmental Achievement Award for his work on development of methods and tools for regional natural hazard risk assessment

2008	NRCan Departmental Achievement Award for serving as hydrogeology expert on public hearings for 'Shallow gas infill drilling development project', Suffield national wildlife area, Alberta
2006	Head of the Public Service Canada Award for serving as hydrogeology expert on 'Hydrogéologie régionale du système aquifère fracturé du sud-ouest du Québec' project

Scientific Publications:

Savor-Novak, M., Atalic, J., Uros, M., Prevolnik, S., Nastev, M. (2019). Seismic Risk Reduction in Croatia: Mitigating the challenges and grasping the opportunities. Book chapter in "Future trends in Civil Engineering", Ivankovic-Mandic, A. and Lakusic, S. editors, University of Zagreb, Croatia, pp. 71-109 (https://doi.org/10.5592/CO/FTCE.2019.04).

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Nastev, M. and Todorov, N. (2013). Hazus: A standardized methodology for flood risk assessment in Canada. Canadian Water Resources Journal - Taylor and Francis, 38(3): 223-231 (https://www.tandfonline.com/doi/full/10.1080/07011784.2013.801599).

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- 2004: project leadership
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- 2015: contribution to the development of the GEM-2 program
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Scientific Publications:

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TAB 5

SUBMISSION TO THE JOINT REVIEW PANEL GRASSY MOUNTAIN COAL PROJECT, AB

GOVERNMENT OF CANADA PRELIMINARY ASSESSMENT OF POTENTIAL IMPACTS ON ASSERTED OR ESTABLISHED ABORIGINAL OR TREATY RIGHTS

IMPACT ASSESSMENT AGENCY OF CANADA – IAAC -

<Original signed by>

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September 21, 2020

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List of Abbreviations

AER: Alberta Energy Regulator

AMP: Access Management Plan

CEAA: Canadian Environmental Assessment Act

CEAR: Canadian Environmental Assessment Registry

C&R Plan: Closure and Reclamation Plan

DFO: Department of Fisheries and Oceans

ECCC: Environment and Climate Change Canada

EIS: Environmental Impact Statement

FRT: Federal Review Team

HC: Health Canada

IAA: Impact Assessment Act

IAAC: Impact Assessment Agency of Canada

JRP: Joint Review Panel

KNC: Ktunaxa National Council (?Akisq'nuk First Nation, ?aq'am (St. Mary's Indian Band), Lower Kootenay Indian Band, Tobacco Plains Indian Band)

LSA: Local Study Area

NRCan: Natural Resources Canada

RSA: Regional Study Area

SARA: Species at Risk Act

SNN: Stoney Nakoda Nation (Bearspaw Nation, Chiniki Nation and Wesley Nation)

TK: Traditional Knowledge

TK/TU: Traditional Knowledge/Traditional use

TLU: Traditional Land Use

TFN: Tsuut'ina First Nation

TOR: Terms of Reference

VC: Valued Component

WSCT: Westslope Cutthroat Trout

1.0 Introduction

The Impact Assessment Agency of Canada (the Agency) is submitting this document on behalf of the Government of Canada to the Joint Review Panel (JRP) for the Grassy Mountain Coal Project (the proposed Project) to inform the JRP in carrying out its mandate as described in the Terms of Reference (TOR) in the Joint Review Panel Agreement. This submission contains a preliminary assessment of the potential impacts of the proposed Project on the asserted or established Aboriginal or Treaty rights for the Treaty 7 First Nations and the Ktunaxa Nation Council (KNC) First Nations.

The preliminary assessment of current use of lands and resources for traditional purposes, and of potential impacts of the proposed Project on Aboriginal or Treaty rights, applied the Agency's *Interim Guidance: Assessment of Potential Impacts on the Rights of Indigenous Peoples* to the five Treaty 7 First Nations and the KNC. The five Treaty 7 First Nations are Kainai, Piikani, Siksika, Stoney Nakoda, and Tsuut'ina First Nations. The KNC is comprised of four Ktunaxa First Nation communities of ?Akisq'nuk First Nation, ?aq'am (St. Mary's Indian Band), Lower Kootenay Indian Band, Tobacco Plains Indian Band.

Information used to support this preliminary analysis is based on submissions provided to the Crown to date from the Treaty 7 First Nations and Ktunaxa Nation Council (KNC) for the purpose of the environmental assessment.

This submission to the JRP is intended to:

(1) describe the Agency's methodology for assessing potential impacts on the rights of Indigenous peoples;
(2) provide the Government of Canada's preliminary assessment that applies this methodology with respect to potential impacts of the proposed Project on Aboriginal or Treaty rights; and
(3) provide recommendations for mitigation measures suggested by the Indigenous groups consulted and mitigation measures that arise from the application of the methodology.

Recognizing that the JRP has a mandate to make recommendations related to the manner in which the proposed Project may adversely impact Aboriginal or Treaty rights, the Government of Canada intends to utilize the report conducted by the JRP to further inform ongoing consultations with Indigenous groups. The JRP Report will also inform the assessment of potential impacts on the exercise of Aboriginal or Treaty rights, and any appropriate accommodation measures that may be considered by the Minister of the Environment and Climate Change (the Minister) in making a decision regarding the proposed Project.

The Government of Canada is of the view that consultation in the context of environmental assessment is not a rights determination process. As such, this submission does not contain, and is not intended to be used for, a determination of rights for any of the identified Indigenous groups or peoples. That said, the Government of Canada has been consulting with Treaty 7 First Nations, Ktunaxa Nation Council, Métis rights holders, the 4 Maskwacis First Nations, Shuswap Indian Band and non-Treaty Indigenous groups whose asserted or established Aboriginal or Treaty rights might be impacted by the proposed Project.

As well, this submission is intended to help provide information to the JRP, and should not replace the JRP's independent consideration of all relevant submissions in the assessment that the JRP is required to undertake in accordance with its mandate in the TOR. In the course of consultations, the Government of Canada has encouraged Indigenous groups to provide submissions directly to the JRP, and it is likely that Indigenous groups will provide information to the JRP that speaks to their own perspectives on the proposed Project.

2.0 Mandate and Role of the Impact Assessment Agency of Canada

The Government of Canada takes a "whole of government" approach to consultation with Indigenous peoples in respect of the potential adverse impacts of a designated project on the exercise of Aboriginal or Treaty rights in the context of environmental assessments (EA). This ensures that Indigenous groups are sufficiently consulted when the Government of Canada contemplates action(s) that may adversely impact the exercise of potential or established Aboriginal or Treaty rights that are recognized and affirmed under Section 35(1) of the *Constitution Act, 1982*.

In August 2019, the *Impact Assessment Act* came into force and the Canadian Environmental Assessment Agency became the Impact Assessment Agency of Canada (IAAC). However, given that the EA of the proposed Project began under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), the assessment will continue following the requirements of CEAA 2012 as per subsection 183(1) of the *Impact Assessment Act*.

1) Crown Consultation – Whole of Government

The Agency is a federal body accountable to the Minister of Environment and Climate Change. The duties, objects and responsibilities of the Agency are set out in the *Impact Assessment Act* (formerly CEAA 2012). In the context of EAs by review panels, such as the JRP, the Agency's legislative responsibilities include, in particular: a) providing support to the JRP; and b) advising and assisting the Minister in exercising the powers and performing the duties and functions conferred on him by the CEAA 2012. In this latter role, the Agency contributes to informed decision making, and functions as the Crown Consultation Coordinator for major projects undergoing a federal EA.

In its capacity as the Crown Consultation Coordinator, the Agency supports and facilitates the integration of consultation activities into the EA process to the greatest extent possible. For EAs by review panel, this role requires that the Agency lead the Government of Canada in the integration of consultation into the review panel process to the extent possible, to ensure best use of the information provided to the JRP and an understanding of potential impacts of a designated project on Aboriginal or Treaty rights. The Crown Consultation Coordinator functions to provide a whole of government approach to Indigenous consultation by coordinating the review of materials provided by Indigenous groups related to potential project effects and impacts, and assisting federal authorities in the consideration of potential impacts on rights in the context of their technical review related to environmental effects.

On June 29, 2020, the JRP indicated that the Agency has expertise on matters relevant to the proposed Project and requested its participation in the public hearing in accordance with section 6.1 of the Joint Review Panel Agreement and section 20 of the CEAA 2012.

Since January 27, 2016, the Government of Canada has followed the interim principles to guide and inform decisions on major projects undergoing a federal EA[1]. This submission is consistent with these principles, specifically the following principles:

- decisions will be based on science, Indigenous knowledge, and other relevant evidence;
- the views of the public and affected communities will be sought and considered; and
- Indigenous Peoples will be meaningfully consulted and, where appropriate, impacts on their rights and interests will be accommodated.

The Government of Canada recognizes that many Indigenous issues and concerns extend beyond the mandate of any one single department. Therefore, all relevant federal departments and agencies participate as subject matter experts in the consultations making up the federal review team (FRT), with the Agency leading the government's consultation on the proposed Project. As such, this Whole of Government submission has been developed in collaboration with federal departments that have expertise or a regulatory authority with respect to the proposed Project including: Department of Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC), Natural Resources Canada (NRCan), and Health Canada (HC). The FRT's preliminary responses to Indigenous groups' concerns are included in this document. Given the collaborative nature of this submission, questions concerning the responses should be directed to the appropriate federal department. Each of the federal departments will provide a separate technical submission to the Review Panel as it pertains to their mandate and expertise.

2) Methodology

This submission also describes the results of the application of a methodology collaboratively developed in 2018 by the Agency and the Mikisew Cree First Nation during the Environmental Assessment Review of the Teck Frontier Oil Sands Project. This methodology is referred to in section 5.0.

Section 6.0 provides a preliminary assessment of the potential impacts of the proposed Project as determined by the application of the methodology, and recommendations for mitigation measures for the JRP to consider.

3.0 Mandate of the Joint Review Panel and Link to the Government of Canada Submission

The Terms of Reference (TOR) described the mandate of the JRP, and specified that the JRP consider evidence regarding the potential impacts of the proposed Project on asserted or established Aboriginal

[1] https://www.canada.ca/en/natural-resources-canada/news/2016/01/government-of-canada-moves-to-restore-trust-in-environmental-assessment.html

or Treaty rights, and that the JRP take into account community knowledge and Aboriginal traditional knowledge. The JRP shall also consider evidence presented concerning the measures proposed to manage, mitigate and compensate for any identified effects on asserted or established Aboriginal or Treaty rights. The TOR set out that the JRP can make recommendations regarding measures to potentially mitigate any adverse environmental effects caused by the proposed Project that could adversely affect those asserted or established Aboriginal or Treaty rights. In addition, the JRP is required to prepare a report that provides its rationale, conclusions and recommendations, including any mitigation measures and follow up programs under CEAA 2012.

The Minister will take into account the rationale, conclusions and recommendations set out in the JRP report when making a decision with respect to the proposed Project. This decision will also consider any mitigation measures considered appropriate, in determining if the proposed Project is likely to cause significant adverse environmental effects under section 52 of CEAA 2012. The implementation of any mitigation measures taken into account by the Minister in making his significance decision under section 52 must be included as conditions in the decision statement, should the proposed Project be allowed to proceed. This includes mitigation measures related to Indigenous peoples as contemplated by paragraph 5(1)(c) of the CEAA 2012.

4.0 Project as it Relates to the Government of Canada's Understanding of Indigenous Groups.

4.1 Indigenous Groups involved in the Environmental Assessment

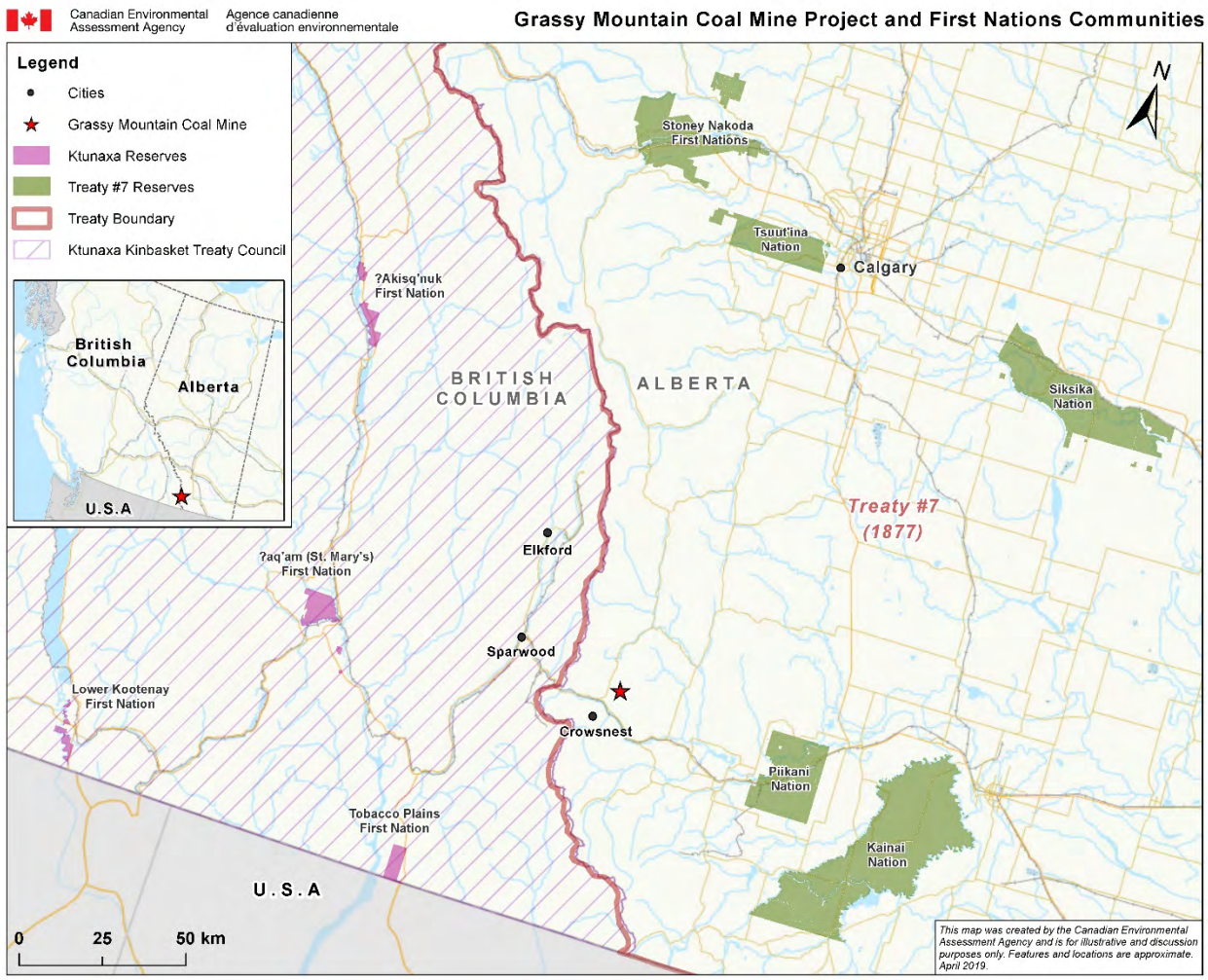
For the purposes of this EA, the Government of Canada identified 14 Indigenous groups in southern Alberta and eastern British Columbia that may be directly impacted by the Project as follows:

Treaty # 7:	**Treaty # 6:**
• Kainai	• Ermineskin
• Piikani	• Louis Bull
• Siksika	• Montana
• Stoney Nakoda	• Samson
• Tsuut'ina	
	Métis:
Ktunaxa Nation Council (B.C.):	• Métis Nation of Alberta Region # 3
• ?Akisq'nuk	• Métis Nation of B.C. Region # 1
• ?aqam	**Individual First Nations:**
• Lower Kootenay	• Shuswap Indian Band (B.C.) **Other Indigenous Groups:**
• Tobacco Plains	• Foothills Ojibway First Nation (non-status)

Note: In addition to supplying the Agency with the most information, the Treaty 7 and KNC First Nations communities were determined to have the most potential adverse impacts of all Indigenous groups. The remaining Indigenous groups have not provided the Agency with sufficient information to undertake an Impact on Rights Assessment. However, if the Agency receives additional and sufficient information, post-hearing, the Agency remains open to undertaking an Impacts on Rights Assessment for additional groups before the Minister makes his decision on the proposed Project.

Figure 1 shows the location of the Treaty 7 First Nations and the Ktunaxa Nation Council and the proposed Project location. Appendix A contains a brief profile of these Indigenous groups.

Figure 1 – First Nations and Project Location



4.2 Environmental Effects and Potential Impacts on Aboriginal or Treaty Rights

The proposed Project is likely to have adverse biophysical environmental effects that may have implications for the current use of lands and resources for traditional purposes as defined under paragraph 5(1)(c)(iii) of the CEAA 2012, in addition to potential impacts on the exercise of Aboriginal or Treaty rights.

The proposed Project footprint has a history of previous development that has already interfered with the exercise of rights by Indigenous peoples. From 1970 to 1975, proponents have conducted mining and exploration activities in the area. These activities were halted because the underground coalmines in the area could not compete with the surface mines that opened on the BC side of the Crowsnest Pass.[2] However, Indigenous groups in the area have been aware of the mining activities in the region since the early 1900's.

Potential Impacts: Indigenous Rights and Environment

The Constitution Act (1982) "recognized and affirmed" Aboriginal rights in Section 35 (s.35) based on rights "arising out of the native historic occupation and use of ancestral lands" (R. v. Van der Peet, [1996]) These rights are not defined in s. 35 but continue to be defined through case law and assertions of Indigenous Peoples. Treaty rights, as in Treaty 7 (1877), are derived from agreements that were made at the time between the signatory Indigenous nations or groups and the Crown. These rights are more prescriptive than Aboriginal rights. Here is an excerpt from Treaty 7:

> *It is also agreed between Her Majesty and Her said Indians that Reserves shall be assigned them of sufficient area to allow one square mile for each family of five persons, or in that proportion for larger and smaller families, and that said Reserves shall be located as follows, that is to say:*[3]

The Treaty continues to define the individual boundaries (i.e. reserves) for the Kainai, Piikani, Siksika, Stoney Nakoda and Tsuut'ina First Nations.

This distinction between Aboriginal and Treaty Rights is important because there are some Indigenous groups that do not have a Treaty with the Crown, but still have s. 35, constitutionally protected rights that are considered in the consultation process and preliminary assessment of impacts on rights. For instance, there are some Indigenous groups involved in the project that do not have a Treaty such as the Ktunaxa Nation Council, Métis Nation of Alberta (Region #3), Métis Nation of B.C. (Region #1) and the Foothills Ojibway First Nation. However, these Indigenous groups represent established or potential rights holders that are involved in consultations on the Project.

The overlap between potential impacts on the exercise of Aboriginal or Treaty rights and the predicted environmental effects is referred to under subparagraph 5(1)(c) of the CEAA 2012 as it relates to current use of lands and resources for traditional purposes. As a result of this overlap, the preliminary assessment contained in this submission uses information provided by the First Nations that is relevant to both areas of consideration by the JRP. It is recognized, however, that impacts on rights may be broader than the environmental effects as identified through an EA.

Figure 2 represents how the Crown views the overlap and broader nature of Aboriginal and Treaty Rights with CEAA (2012) Section 5(1)(c) effects. In particular, Section 5(1)(c) effects focus on impacts to

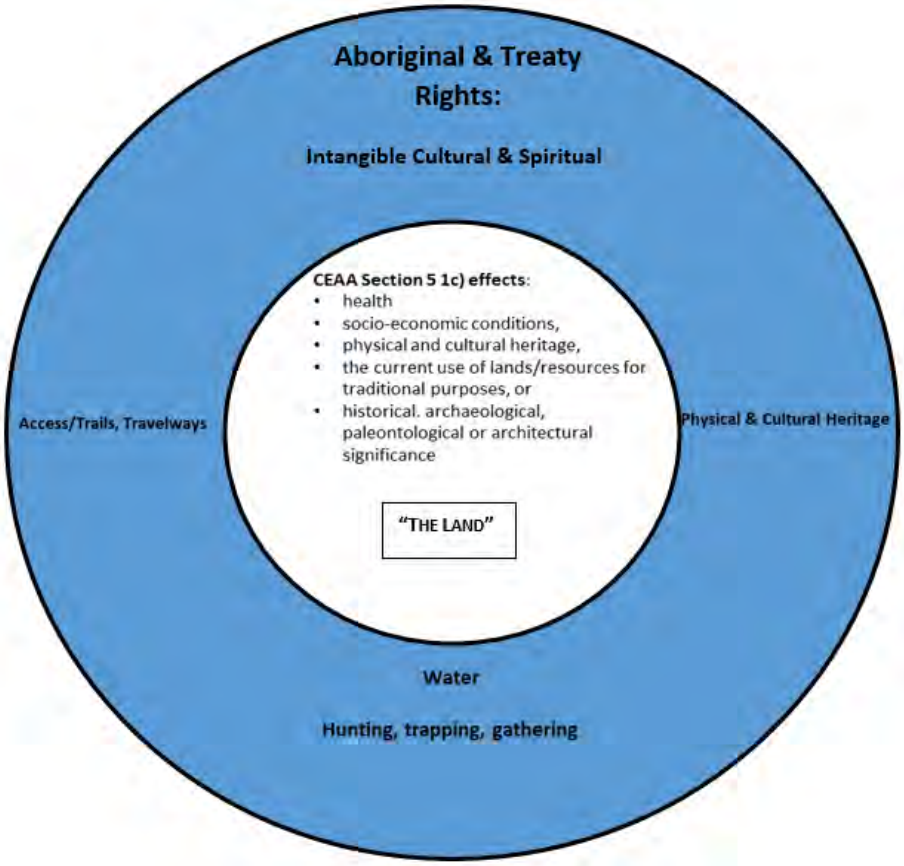
[2] *Grassy Mountain Coal Project Description;* Riversdale Resources, March 2015

[3] COPY OF TREATY AND SUPPLEMENTARY TREATY No. 7, MADE 22ND SEPT., AND 4TH DEC, 1877, BETWEEN HER MAJESTY THE QUEEN AND THE BLACKFEET AND OTHER INDIAN TRIBES, AT THE BLACKFOOT CROSSING OF BOW RIVER AND FORT MACLEOD.

Indigenous peoples that are typically beyond biophysical effects. The rights of Indigenous peoples extends to non-physical considerations such as the experience, perception and spiritual aspects.

The Crown understands that the land, including water, is a central component to many Indigenous cultures. The land is viewed as paramount to the survival of Indigenous peoples because it supports so many vital aspects of Indigenous life. Many environmental effects originate from land-based activities regardless if they are measured as air or water impacts. Therefore, environmental effects could be seen as the core of any potential effect on Aboriginal or Treaty rights. From an Indigenous perspective, environmental effects are those that impact the land. However, impacts to Indigenous rights can extend beyond biophysical impacts on the land to include potential impacts on cultural connections with the land, knowledge transfer, language, experience, and culture.

Figure 1 - Overlap of Potential Impacts on Aboriginal and Treaty Rights



5.0 Methodology for Assessing Impacts on the Exercise of Aboriginal or Treaty rights for Treaty 7 First Nations and the Ktunaxa Nation Council[4]

[4] The Agency has not yet received sufficient information regarding rights of other groups, but will continue dialogue with these groups, including Métis, throughout the process.

The methodology has three main objectives:

(1) To collaborate with Indigenous groups to better articulate their views on the potential impacts to their rights from the Project;
(2) To provide the JRP with an approach that it may consider in conducting its assessment of potential adverse impacts of the proposed Project on the exercise of Aboriginal or Treaty rights; and
(3) to assist the federal government in upholding its legal obligation to consult and ensure that potential impacts on the exercise of s.35 Aboriginal or Treaty rights arising from the proposed Project are adequately considered and accommodated, where appropriate.

The Government of Canada applied this methodology to conduct a preliminary assessment of potential impacts of the proposed Project on the exercise of rights for the Treaty 7 First Nations and the Ktunaxa Nation Council (KNC). The information to support this preliminary analysis takes into consideration submissions provided by these Indigenous groups that are on the public record for review. The preliminary results of the analysis are provided in section 6.0.

The main steps of the methodology are summarized below:

Step 1 – Determine the context in which potential impacts on rights will occur through:

a) identifying the conditions that support the community's exercise of their rights;
b) understanding how historic, existing and approved activities have affected the conditions that support the exercise of rights; and
c) identifying the importance of the Project's location in relation to the exercise of rights.

Step 2 – Evaluate the potential impacts through:

a) identifying the pathways for potential impacts of the Project (positive and negative) on the exercise of rights;
b) determine the potential severity of impacts on the exercise of rights, using information from Step 1, including the guiding principles.

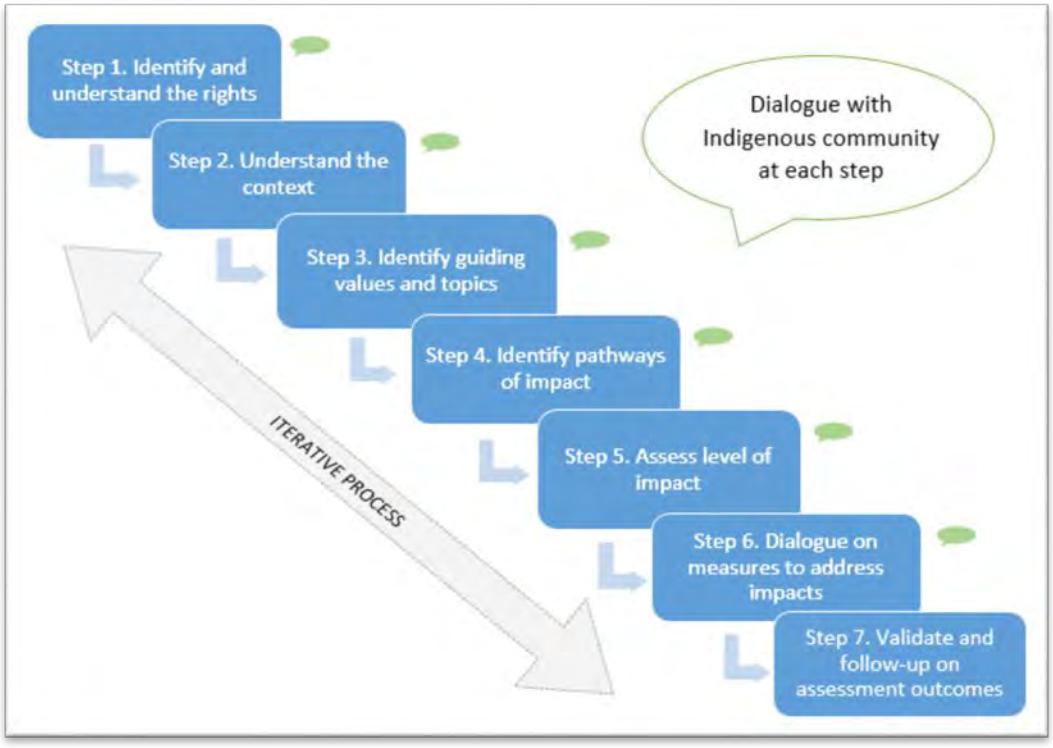
Step 3 – Follow-up and validation of the implementation of the methodology:

a) providing the opportunity for Indigenous communities to comment on the assessor's understanding of Indigenous knowledge, values and thresholds, and the application of steps 1 and 2;

The Agency has invited the Treaty 7 First Nations and the KNC communities to discuss the appropriateness of applying this methodology to assess the potential impacts of the proposed Project on Aboriginal or Treaty rights. To date, discussions have not occurred; however, the Agency will continue to be open to discussing the use of this methodology in the context of the Project prior to the decisions required under CEAA 2012.

Figure 3 shows an overview of the steps in the methodology. All seven steps shown in the figure are summarized in the three steps outlined above.

Figure 2 - Overview of the Steps in the Methodology



Source: https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/practitioners-guide-impact-assessment-act/interim-guidance-assessment-potential-impacts-rights-indigenous-peoples.html

6.0 Preliminary Assessment of Potential Impacts to the Exercise of Asserted or Established Aboriginal or Treaty Rights

Using the methodology described above, this section provides a preliminary assessment of the potential impacts to the exercise of asserted or established Aboriginal or Treaty rights for Treaty 7 First Nations (Kainai, Piikani, Siksika, Stoney Nakoda and Tsuut'ina First Nations) and for the Ktunaxa Nation Council (KNC). Mitigation measures proposed by these Indigenous groups have been also included for the JRP to consider.

The Government of Canada understands that the Indigenous groups may provide their own submissions to the JRP that will be considered independent of this submission. The Government of Canada's preliminary views are not intended to replace the JRP's consideration of all relevant submissions in the assessment that it is required to undertake in accordance with its mandate in the TOR.

The preliminary assessment is based on information provided by Indigenous groups to date which informs the conditions required for the exercise of Aboriginal or Treaty rights. The Agency will remain open to dialogue with Indigenous groups to further support the assessment of the impact on Aboriginal or Treay rights. The methodology identifies the pathways of potential effects that may interfere with the exercise of rights; and applies established criteria for assessing the severity of potential impacts on rights. The JRP may also wish to consider this information in the context of the environmental effects assessment of the current use of lands and resources for traditional purposes under paragraph 5(1)(c)(iii) of CEAA 2012.

The assessment is divided into the following categories:

- 6.2 Potential Impacts to Aboriginal and Treaty Rights for Hunting and Trapping
- 6.3 Potential Impacts to Aboriginal and Treaty Rights for Plant Gathering
- 6.4 Potential Impacts to Aboriginal and Treaty Rights for Fish, Fish Habitat and Fishing
- 6.5 Potential Impacts to Aboriginal and Treaty Rights for Cultural and Spiritual Values
- 6.6 Potential Impacts to Aboriginal and Treaty Rights for Water Resources.

The preliminary analysis supporting the assessment of the potential adverse impacts on the exercise of rights for Treaty 7 First Nations and KNC is available should the JRP wish to review.

6.1 Context for the Exercise of Asserted and Established Aboriginal orTreaty Rights in the Project Area

The Crowsnest Pass and Grassy Mountain have a history of supporting the rights of Indigenous peoples from both sides of the continental divide, which also forms the boundary between the provinces of British Columbia and Alberta. The information that the Agency has received to date that the Treaty 7 First Nations and the KNC communities have a historical relationship with each other.

In addition, communities such as the Shuswap Indian Band and some of the Maskwacis Cree communities have stated they have used the area for generations, as have Métis communities on either side of the provincial boundary - Métis Nation of Alberta (Region 3) and the Métis Nation of British

Columbia (Region 1). Therefore, the Crowsnest Pass and the Grassy Mountain area have clearly supported Indigenous rights, both present and past.

For instance, Piikani First Nation traditionally refers to Grassy Mountain as "Ksiistsiiko'om oomoiyyi"[5] in the Blackfoot language, which illustrates how long the area has been used and how important it is to Piikani. Similarly, the Ktunaxa Nation have submitted evidence based on historical relationships with Piikani, Siksika and Stoney peoples. These relationships were used for trade and for the sharing of rights in the Project area.[6]

Indigenous groups that have been practicing their rights in the area of the proposed Project advise that over the last 100 years, they have experienced changes to the landscape from industrial development that include:

- Impacts to ecological values, including fisheries and wildlife in the Crowsnest River;
- Impacts to traditional use in the Crowsnest Pass area; and
- Impacts to lands and waters within the Elk Valley drainage.

These cumulative impacts derived from diverse industry operations such as mining, transportation and logging have gradually decreased the communities' trust of the land and water-based resources.

6.2 Potential Impacts on Aboriginal or Treaty Rights for Hunting and Trapping

Several wildlife species such as mule deer, elk, moose, and bear are culturally, spiritually, and nutritionally important to the Treaty 7 First Nations and KNC. Treaty 7 First Nations and KNC members were historically nomadic peoples and hunted in areas overlapping the Crowsnest Pass and Crowsnest River. However, since the development of Grassy Mountain over a century ago, their hunting practices are relatively less intensive.

Impacts to Buffalo/Bison

Buffalo is a keystone species that used to be hunted throughout the region and became extirpated when the majority of the regional landscape surrounding the project area was converted to anthropogenic cover types, primarily farmland.

KNC members consider the Project area as a place where bison (buffalo) were once abundant and were harvested as a staple food by Ktunaxa ancestors up until the animal's extirpation. Plains bison (buffalo) are critically important, both culturally and ecologically, to past and future practice of KNC rights in the Project area and eastern slopes of the Rockies. While bison are currently extirpated and habitat in the area of the Project is currently vacant, "the return of plains bison and Ktunaxa harvest of bison in the Project area is "planned and reasonably foreseeable".

[5] Updated Review of Riversdale Resources Riversdale Limited Grassy Mountain (Ksiistsiiko'om oomoiyyi) Coal Project Environmental Impact Study, for Piikani Nation (Schaldemose & Associates), July 2016

[6] TECHNICAL MEMORANDUM - *Ktunaxa Nation Rights and Interests in relation to Benga Mining Limited's proposed Grassy Mountain Coal Project,* for Ktunaxa Nation Council (Dr. Craig Candler and Mathew Murray, the Firelight Group), January 28, 2019

All of the Treaty 7 First Nations and KNC signed "The Buffalo: A Treaty of Cooperation, Renewal and Restoration" (aka The Buffalo Treaty) initiated in 2014. The Buffalo Treaty not only speaks to the re-establishment of bison as a wild species, but also to the maintenance of the cultural connection between buffalo and Indigenous groups by perpetuating all aspects of their cultures related to buffalo including customs, practices, harvesting, beliefs, songs, and ceremonies.

Wildlife habitat fragmentation

Habitat availability will be further altered by the Project, either directly through habitat loss within the Project footprint, or indirectly through wildlife avoidance as a result of sensory disturbance. It is estimated that 80% of the regional study area is already inaccessible for traditional land use due to presence of private land, and protected/fenced areas. The practice of hunting declined with the loss of almost half of the regional landscape, an issue compounded by private land ownership, non-traditional land use activities, and community member avoidance due to concerns about contamination, safety, and overall negative experience on the land.

Further, the population declines in elk, mule, deer, moose, grizzly bear, American marten, Canada lynx and golden eagle have resulted in reduced opportunities to hunt. Treaty 7 First Nations also indicated that Grassy Mountain is prime golden eagle nesting habitat, located along a major eagle migratory flyway.

Siksika noted they have reduced their level of hunting in the area and shifted to less disturbed areas. Following the current trend of industrial development, Siksika will have no practical traditional use sites remaining in their Territory — "meaning possible extinguishment of Blackfoot culture".

For Piikani Nation, there is a major concern about impacts to hunting and access "now and for future generations". Stoney Nakoda First Nation members continue to hunt primarily deer and elk within their territories today, including within the Project area, for subsistence, ceremonial (e.g., sacred bundle and Sun Dance ceremonies), spiritual, medicinal and cloth-making purposes.

Pathways

Land clearing during Project construction creates a direct loss of habitat, leading to reduced wildlife population size, increased hunting /trapping/fishing pressure and restricted access to land for traditional purposes. Wildlife species with small home ranges and highly specific habitat requirements may be affected at the local level. Sensory disturbance associated with Project development (e.g., noise, artificial lighting, blasting, and human activity) will also result in indirect habitat loss. The sensory disturbances may result in wildlife avoiding otherwise suitable habitat, reduced reproductive success, reduced foraging ability or increased mortality.

In order to ensure that traditional hunting practices can continue, the Treaty 7 groups and KNC have identified the following requirements with respect to the hunted/trapped wildlife:

- a healthy population;
- continued existence of pristine habitats;
- accessibility to members in an area where there is trust in the quality of the water and food consumed by the herd; and

- no increases in predation rates, including an ability for both the wildlife and the landscape to maintain a natural characteristic.

Table 1- Pathways for Potential Impacts on the Exercise of Rights Related to Hunting and Trapping

Potential Environmental Effects of the Proposed Project	Description of potential changes to the environment	Potential Pathways	Preliminary description of potential changes to the exercise of rights related to Hunting and Trapping
Destruction and/or disturbance of terrestrial habitat for large wildlife species (i.e. elk, mule deer, wolf, moose) including fragmentation of habitat and interruption of travel routes	• Alteration of landscape and destruction of habitat within the proposed Project footprint, including associated infrastructure, pits, sedimentation ponds • Potential changes in habitat due to reduction of water flows around Blairmore and Gold creeks and the Crowsnest River. • Destruction or alteration of wildlife movement corridors, wintering areas, and habitat use by elk, moose, and other species. • Increased ease of access to area by predators	• Effects on wildlife abundance due to changes in mortality, habitat availability, or movement • Reduced reproductive success and survival rate, risk of deteriorating wildlife health change in wildlife distribution and change in animal behavior. • Reduced access to wildlife and reduced food quality due to effects of water contamination and associated loss of confidence in country foods • continuing decline, population size (elk and mule deer) largely due to on-going habitat conversion and fragmentation • Reduced hunting/trapping opportunities, reduced hunting/trapping success, reduced access to wildlife and concern for the food quality. • Direct impact to preferred elk and moose harvesting areas across the Crowsnest area.	• Potential reduced harvesting success as a result of a decline in the quantity of wildlife available and increased predatory-prey interactions. • The effects on the current use of lands and resources valued by the Treaty 7 First Nations and KNC, limited access to hunting areas within the Project area could affect the cultural and spiritual relationship between the Nations and surrounding lands and resources and the overall interests and traditions of the Nations. • Potential impairment or diminishment of land use experience including perceived or observed contamination, disturbance to sense of place and reduced confidence in harvested resources, reduced access to wildlife and concern for the food quality. • Potential reduced harvesting success or potential reduced ability to return to harvesting preferred wildlife species in preferred locations as a result of a decrease in the size of the wildlife populations, and pressure from non-Indigenous hunting. • Potential for a loss of the ability to hunt if reduced abundance of wildlife in customary harvesting areas, extirpation or near-extirpation of the wildlife, resulting in continuation of self-imposed hunting bans or restrictions due to limited access in privately- owned lands. • Potential for change to the season round which assists with conserving traditional resources. • Potential interruptions of harvesting result in reduced ability to transmit way of life to future generations (culture, language, spirituality) as a result of time lag (25 years) of project effects, assuming reclamation of wildlife habitat is successful and for even more generations if not successful. • Potential reduced ability to govern and steward wildlife habitat in a manner consistent with Treaty 7 rights. • Potential reduced opportunities for preferred harvesting methods and timing if the wildlife is no longer in preferred areas during the appropriate season. • Potential reduced opportunity for teaching land-based skills including fishing, hunting, and trapping and TK transfer.
Sensory disturbances • noise • odour • fugitive dust • light contamination • visual / aesthetics	• Project activities related fugitive dusts, air emissions	• Impacts on the wildlife species, and on also Indigenous hunters and land users who may experience the land differently.	
Restricted access	• Limited access, road closures and fenced lands	• Hindered wildlife movement patterns	
Increase in non-Indigenous population in the area (Project workers and contractors)	• Increased ease of access to area by predators • Increased hunting pressure	• Indigenous hunters may avoid their preferred hunting/trapping areas and methods • Self-imposed hunting bans or restrictions.	

6.2.1 Preliminary Assessment of Potential Impacts on Aboriginal or Treaty Rights related to Hunting and Trapping

Spatial Extent

The Project effects will span the footprint area and adjacent areas, including Crowsnest Mountain, Crowsnest Pass, Crowsnest Lake, and core traditional territory of Treaty 7 First Nations and KNC. Project residual effects may possibly extend beyond the mine footprint.

Likelihood / Duration / Frequency / Reversibility

The Project activities during construction and operation will have a high likelihood of disrupting wildlife habitat for large species. Treaty 7 First Nations and KNC members noted that they have reduced their level of hunting in the area and shifted to less disturbed areas following the current trend of industrial development. In particular, Siksika Nation indicated that they will have "no practical traditional use rights or property remaining in their Territory — "meaning possible extinguishment of Blackfoot culture". The project-related habitat fragmentation and resulting migration of large species used for hunting is likely to reduce hunting opportunities and access to preferred hunting areas and methods for a long term duration(longer than one generation), and result in long term or irreversible changes to hunting practices.

Way of Life / Livelihood

Treaty 7 First Nations and KNC have indicated the culturally important species associated to their way of life/livelihood. Traditionally, the Treaty 7 First Nations and KNC relied primarily on buffalo, which followed an annual migration where buffalo would locate on the prairies in summer and move to the foothills in winter. Members travelled to various hunting grounds using jumps and runs to trap and harvest buffalo. The Project is expected to remove areas that are currently used for hunting and interfere with the traditional seasonal practices. Treaty 7 First Nations and KNC have long engaged in and continue to practice a seasonal round, whereby people travel to hunt, gather resources, go to campsites, and go to sacred sites for spiritual and cultural ceremonies when conditions allowed. The Grassy Mountain area was used as a trading route to reach Shuswap Lake to the west, and to the north to trade buffalo robes, dried meat and horses to the Hudson's Bay Company in the fall and in the spring. Throughout the seasons, large game and plant resources were exploited. They continue to share a relationship of reciprocity in their intimate connections to the land through their collective experiences, particularly their ways of life before European settlement.

The ability of Treaty 7 First Nations and KNC to hunt the wildlife species in their natural state and habitat is linked to confidence in the quality and quantity of the resource, and a sense of wellbeing on the land. A lack of continuity in access to hunting preferred species, or a decrease in the availability, variety and sustainability of such species, could impact their ability to maintain their way of life in the same places and ways as their ancestors.

Historic / Regional / Cumulative Context

Treaty 7 First Nations and KNC have indicated that the area in which the wildlife species are hunted has already been impacted by past mine developments, and other anthropogenic uses including private land

ownership. It is estimated that 80% of the regional study area (broader than the Project footprint) is inaccessible for traditional land use due to presence of private land.

The infrastructure associated with the Project may further prevent or restrict the use of areas for harvesting wildlife species that are identified as high priorities for Treaty 7 First Nations and KNC. Increased sensory disturbance may impact not only the species, but also Indigenous hunters and land users who may experience the land differently.

Stewardship and Governance

Treaty 7 First Nation and KNC members cling to their hereditary and transgenerational responsibility to preserve their traditional lands in the Project area and the ability to use lands for traditional activities for generations to come. The physical presence of the Project, and its potential effects, will remove areas that support the governance of the land, in accordance with the traditional laws and historic and modern trading regimes and knowledge transfer that exists between these communities.

Impact Inequity

KNC and Treaty 7 First Nations' Elders expressed "a mix of sadness for ancestors and past damages witnessed on Grassy Mountain", and hope for an improved working relationship with the Proponent on the proposed Project. Treaty 7 First Nations have indicated that the ability to transfer knowledge related to hunting may disproportionately affect specific members, particularly the inability to pass on information to younger generations which may result in an erosion of knowledge held by active land users.

6.2.2 Key Measures to Address Potential Impacts on Aboriginal or Treaty Rights related to Hunting and Trapping

Indigenous groups' views of required mitigation measures

1. Establishment of a network of provincial and national parks and sanctuaries where hunting is prohibited. These areas provide refugia for wildlife and act as source areas for repopulating adjacent areas where mortality rates may be higher.

2. Road sanctuary buffers on selected roads. These buffers are generally applied to roads where hunting is prohibited within 365 metres of the road right of way.

3. Prohibition of some forms of transportation (such as Off-highway vehicles) along selected linear features (roads, seismic lines) during defined times of the day or week.

4. Integrated landscape management strategies that seek to reduce the quantity of linear footprint that is needed to extract natural resources.

5. Allowing animals that live on the property time to find a new home, which means ensuring they have continued access to water and that the project is developed slowly.

6. There is an abundance of golden eagles that live and nest seasonally on the property since the property is on a major eagle migratory flyway. Eagles are sacred in Blackfoot culture. The project should include establishment of appropriate, alternative nesting locations off the property but nearby for those eagles that will be impacted by the project.

7. Negotiate and sign agreements with Indigenous communities so they can still go hunt and practice their traditional ways on the property.

Treaty 7 First Nations have indicated in letters to the JRP that they are satisfied with the proposed mitigation measures and commitments made by the Proponent thus far. For instance, Stoney Nakoda First Nation stated that the Proponent has addressed project-specific concerns and are of the view that the Proponent's consultation should be deemed adequate**.**

The Proponent has outlined project specific mitigation and commitments to reduce the Project's potential adverse effects on wildlife, health and habitat; the practice of hunting and access to preferred hunting areas. The Proponent is confident that monitoring and adaptive management where appropriate will be part of ensuring the measures are successful.

The Proponent has committed to the implementation of an Indigenous Environmental Stewardship Committee and an Indigenous monitoring program that will both function to address issues related to traditional use, wildlife and hunting throughout the life of the Project. The Proponent has also committed to working with Indigenous groups to ensure that Indigenous goals are effectively incorporated in the reclamation planning process. Further, the Proponent has indicated it would consider the inclusion of measures specific to supporting re-establishment of bison to the area, and that an Indigenous-led assessment of the potential carrying capacity of the land to support quality buffalo habitat essential for the successful reintroduction of the species will be implemented.

Preliminary Assessment of Impacts on Aboriginal or Treaty Rights Related to Hunting and Trapping

Taking into consideration the information provided by Indigenous groups and the Proponent's mitigation measures and commitments, the Government of Canada's preliminary assessment is that the proposed Project may have a potentially low to moderate impact on the exercise of Aboriginal or Treaty rights for Treaty 7 First Nations and KNC.

6.3 Potential Impacts on Aboriginal or Treaty Rights for Plant Gathering

The property has an abundance of plant life in small microclimates along the principal waterways roughly running the length of the proposed Project property, Gold Creek (east side) and Blairmore Creek (west side), as well as forested areas just near entrance into the property. Medicinal and ceremonial plants are found in several locations on the proposed Project property, particularly in fertile micro-systems and other sunny slopes with unique climate and adapted abundant plant biodiversity. Plants are gathered during all seasons for subsistence, ceremonial and medicinal purposes. Many of the plant species found in the alpine at Grassy Mountain are central to Treaty 7 First Nations and KNC ceremony, healing practices, and spirituality, and plant harvesting has always been an important undertaking among their members. Treaty 7 First Nations and KNC value gathering plants and foods for medicinal, cultural identity ceremonial, spiritual, artisanal, traditional teaching purposes. For example, serviceberries and chokeberries were widely used for making pemmican, and the tree-covered foothills of the Rocky Mountains were a primary source of lodge pole pine for constructing tipis. Other targeted species were Aspen, poplar and birch, nutritional, medicinal and ceremonial plants. The tree-covered foothills of the Rocky Mountain were primary source of lodgepole pine for constructing tipis.

Stoney Nakoda has identified some plant species of importance for the construction of sweat lodges in preparation of vision quests in the mountains, including cedar branch needles and sweet grass. A select group of members were appointed by the Elders to erect the sacred lodge, and its construction was vigilantly observed by everyone in the community. The lodge's frame is made from willow and branches shaped into a dome roof and covered in animal skins and hides. Also used are spruce bark and branches and poplar leaves. Within the sacred lodge, the Stoney Nakoda Nation built a fire using sweet grass, cedar branch needles and other plants. In addition, the Stoney Nakoda Nation shelters were constructed using spruce bark.

Stoney Nakoda has raised the concern that "there should have been an abundance of medicinal plants, but there was nothing. Lots of plows disturbance, making the land all grasses and sedges and no medicinal plants" (Stoney Nakoda Nation, 2015).

Káínai sources over 27 important plant species used for food, ceremonial (e.g. Sun Dances) and medicinal purposes specifically in the Project area. Tsuut'ina Nation commented that many plants linked to their ceremonial, healing, cultural and spiritual practices are not found at lower elevations, and that at least 12 medicinal plants are located near the Project area. Ktunaxa Nation identified the Project area as containing an array of ecological values and ties to cultural use and landscape stewardship.

Siksika indicated that there is an abundance of plants that make up important parts of traditional use of the lands and waters in the proposed Project area (particularly in fertile micro-system and over sunny slopes). They have stated that traditional use plants that will otherwise be destroyed by the mine should be dug up and moved just off the property, or to the edge of the mine out of harm's way, and that year round access to those plants should be made available.

Piikani continues to use the Crowsnest Pass area for the acquisition of plants for ceremonial, medicinal and spiritual purposes. Plant species found in the alpine Grassy Mountain are crucial to Piikani ceremony, healing practices, and spiritually and are particularly important because they cannot be found at low elevations where most Piikani presently reside. (Piikani Nation, 2015: Piikani Traditional

Knowledge and Land Use in the Matoyihko Yiistak Area). Piikani's engagement in plant gathering is sensitive to disruption, and past and present activities have placed traditional land use at high risk.

Tsuut'ina has indicated that many plants found in the Grassy Mountain area are important for the community to practice ceremonies, healing, cultural identity and spiritual purposes. These plants are not found near Tsuut'ina's location (southwest of Calgary), given the lower elevation and different overall environmental conditions. Harvesting plants for different uses is also a key component of intergenerational knowledge transfer for their Nation. Overall changes in sensory environment implies that Tsuut'ina members will have to practice their rights in a different way or stop altogether. Tsuut'ina raised the following concerns around access to and the health of plants: "right now the roads are locked off and only Riversdale has access …Is there a possibility for us to still go up and harvest our plants? In the future? We can't always assume that all the plants are going to be accessible all the time, in the future".[7]

Impacts on medicinal, ceremonial and sacred plants

As outlined above, Treaty 7 First Nations and KNC are concerned about reduced access to the area and the changes in the availability of plant species of importance for the Nations, and how this will impact the ability of communities to exercise their rights. Some plant species are only available in this area and are used for smudging on a daily basis. The Crown has been told that other plant species have been used successfully to treat cancer and diabetes of Indigenous community members.

In order to ensure that traditional and ceremonial plant gathering practices can continue, the Treaty 7 groups and KNC have identified the following proposed requirements with respect to the plant gathering:

- Available, diverse and sustainable plant communities;
- Continued existence of pristine habitats;
- Quiet enjoyment of the landscape and access to seasonal camp properties for traditional plant gathering activities;
- Accessibility to members in an area where there is trust in the quality of the water and country foods, medicine and sacred plants; and
- No increases in harvesting competition rates, including an ability for the landscape to maintain a natural characteristic.

Pathways

Potential effects of the Project on key vegetation resources are predominantly related to clearing of vegetation, destruction of terrestrial ecosystems and physical alteration of the landscape for the Project's mine pit and associated waste rock dump and infrastructure. The Project is expected to remove traditional use plants within the Project's Local Study Area. Construction and operation of the Project will result in the removal of vegetation from the Project footprint and a temporary reduction of native species diversity in the LSA that will result in a reduction in species diversity, community diversity,

[7] Tsuut'ina Nation, 2015, Public Report on Tsuut'ina Traditional Knowledge and Use of the Grassy Mountain Area, EIA Volume 3, Appendix 7c,

landscape diversity and fragmentation. Construction, operation and reclamation of the Project would reduce the types and area of wetlands and would result in the removal of some rare plants observed within the Project footprint (e.g. Whitebark Pine, Native Fescue). Fugitive dusts, air emissions released into the atmosphere during Project construction and operations, may result in direct and indirect effects on vegetation.

Access disturbance

With road closures and access restrictions and limitations, increased traffic, and air emissions, the Project may affect access and use of trails and travelways and associated features, as well as plant harvesting areas, especially within the LSA. This would constitute a major impact on plant gathering for Nations' members due to reduction in harvesting opportunities, loss of preferred harvesting methods and places, engagement in plant gathering, and harvesting success during construction.

Sensory disturbance

Project-associated changes in the overall sensory environment (e.g. noise, light, traffic, fugitive dust emissions, odours, etc.) associated with the pollution of areas used by Nations' members for harvesting will consequently affect the quality and health of the plant species and country foods. Fewer plant species available for subsistence harvesting combined with an unsuitable sensory environment for spiritual practices may result in an artificial environment not conducive to intergenerational knowledge transmission.

Table 2- Pathways for Potential Impacts on the Exercise of Rights Related to Plant Gathering

Potential Environmental Effects of the Proposed Project	Description of potential changes to the environment	Potential Pathways	Preliminary description of potential changes to the exercise of rights related to Plant Gathering
Direct vegetation removal and alteration of the landscape Indirect vegetation change Change in use or access to vegetation Change in preferred plant gathering locations	• Loss of ecosystems and plant habitats within the footprint, including dewatering of wetlands, disturbance of Blairmore and Gold creeks, and reduced water levels downstream of the proposed Project. • Vegetation change and habitat loss as a result of groundwater drawdown during construction.	• Loss of plant health and diversity, availability • Changes in preferred plant gathering methods • Less plant species available for BT/K to practice ceremonies and traditions • Less plant species for subsistence • Plant species affected by pollution , air contaminants and risk to Nations members' health • Loss of confidence in the quality of traditional foods due to contamination concerns • Sensory environment not suitable for spiritual practices • Changes in environment not suitable for intergenerational knowledge transmission	• Potential loss of preferred areas for harvesting food and medicinal plants and wildlife species will result in changes in cultural and spiritual relationship between the Treaty 7 and KNC Nation members and plants and will impact on Treaty 7 Nations and KNC's rights • Treaty 7 and KNC communities engagement in plant gathering is sensitive to disruption and past and present activities have resulted in traditional land use at high risk. • Overall changes in sensory environment implies that KNC and Treaty 7 Nation's members will practice their rights in a different way or they will stop practicing their rights. • Potential impacts on gathering plants for cultural or medicinal purposes, and concerns regarding the quality and quantity of plants and other resources gathered as result of project effects such as removal of lands and air quality (i.e. fugitive dust deposition) • The numerous effects consisting of change in identified plant species and habitat change in use or access to identified plant gathering locations and change in preferred gathering method. • The removal of plants could lead to loss of access to country foods and result in food insecurity and to impacts to social, mental well-being. The Project would result in negative effects on the long-term abundance, diversity, distribution and sustainability of species used for plant gathering by the Nations' members. • Changes to plant habitat (particularly wetlands and old growth forests) may influence the plant gathering activities and therefore affect the interests, culture and traditions of the Treaty 7 Nations and KNC. Harvesting plants for different uses is also a key component of intergenerational knowledge transfer. • Alteration of the landscape and ecosystems will hander the spatial context for intergenerational knowledge transmission particularly for medicinal and ceremonial plants, storytelling and symbology.
Sensory disturbances • Noise • Odour • Fugitive dust • Light pollution • Visual / aesthetics	• Concerns regarding the health of plant and quality of country foods and species of importance • Reduced availability and diversity of old growth forests and wetlands	• Limited access to preferred harvesting locations • Changes to preferred harvest methods and protocols • Loos of confidence in the quality of traditional foods due to contamination concerns • Increased sensory disturbance in key harvesting areas associated with activities and increased traffic at the Project property	
• Restrained access to the area	• Limited access, road closures and fenced lands	• Changes to access of preferred harvesting locations and methods	

6.3.1 Preliminary Assessment of Potential Impacts on Aboriginal or Treaty Rights related to Plant Gathering

Spatial Extent

The Project effects will span the footprint area and adjacent areas, including Crowsnest Mountain, Crowsnest Pass, Crowsnest Lake, and core traditional territory of Treaty 7 First Nations and KNC. Project residual effects may possibly extend beyond the mine footprint.

Likelihood / Duration / Frequency / Reversibility

The Project activities during construction and operation will have a high likelihood of disturbing plant habitats. Treaty 7 First Nations and KNC members adhere to their hereditary and transgenerational responsibility to preserve their traditional lands in the Project area for use by generations to come. The physical presence of the Project, and its potential effects, will remove areas that support the governance of the land in accordance with traditional laws, modern trading regimes and knowledge transfer that exists between these communities.

This disturbance will potentially be long-term in duration, because it will only stop when Project operations discontinue and reclamation plans begin to be implemented. The frequency of the disturbance will be low, as the disruption of ecosystems and plant habitat will happen mainly during project construction.

The reversibility of effects on plant harvesting is low. Once terrestrial habitats, old growth forests, wetlands are destroyed, the success of reclamation measures is not guaranteed, particularly when rare and fragile plant communities are uprooted or disturbed. According to the Proponent, reclamation is planned and expected to re-establish natural processes and ecosystems that support sustainable plant communities, wetlands and old growth forest. Hypothetically, the reclaimed land will support a range of communities with equivalent capabilities to those of the surrounding lands that existed prior to development. The Proponent acknowledged that the Project will result in some loss of traditional use vegetation within the LSA and it will take decades for wetlands and mature forests to re-establish.

In light of these changes to the landscape, and the environmental effects identified, the modification of harvesting behaviours on the land is likely and long term (more than one generation) in duration. The potentially irreversible nature of the effects will interfere with the ability of Indigenous groups to practice harvesting culturally important and or medicinal plants.

Way of Life / Livelihood

Treaty 7 First Nations and KNC have acknowledged the culturally important, sacred and medicinal plant species associated to their way of life/livelihood that are found in the Crowsnest Pass area.

Based on information provided by Tsuut'ina, Siksika, and Piikani there are multiple alpine plants found at Grassy Mountain that are crucial to ceremonies, healing practices, cultural identity and spirituality and are not found at lower elevation. Piikani members stated "…The plants in the Grassy Mountain area are used for a variety of subsistence and cultural purposes. Plants also have an intrinsic right to belong on our territory". Elders acknowledged that Crowsnest Pass was an important east-west travel corridor both for harvesting plants and buffalo in times of peace and to defend their territory in times of war Treaty 7 First Nations. Indigenous groups indicated that the main plant species (Aspen, poplar, birch, etc.) that covered foothills of the Rocky Mountain were primary source of lodge pole pine for constructing tipis. Blackfoot members in particular have expressed interest in harvesting lodgepole pine for tipi poles in the Project area. Ktunaxa members noted that canoes were construct with white pine. Treaty 7 and KNC members indicated that parents teach their children how to harvest plants at an early age. The harvesting of plants for multiple uses is practiced at the same time as hunting.

A lack of continuity in access to sacred plant gathering areas, or a decrease in the quality and quantity of traditional plants and medicine, could impact the ability of Treaty 7 First Nations and KNC to maintain their way of life, and to pursue their livelihood in the same places and in the same ways as their ancestors. Among the critical cultural and spiritual knowledge that is passed along is information on the seasonal conditions and ecology, especially medicinal plants. Harvesting skills are inextricably bound with ceremonial teaching. Treaty 7 First Nations and KNC assert that they rely on the maintenance of physical, social, spiritual and knowledge-based relationships specific to plant harvesting, symbology and story-telling, to ensure their ability to pass on their way of life to future generations. For the Treaty 7 First Nations and KNC, the ability to harvest traditional pants and country foods in their natural state and habitat is linked to confidence in the quality and quantity of the resource, and a sense of wellbeing on the land.

The inability to harvest these plants will reduce the opportunity of Indigenous groups to practice a culturally important activity intrinsic to their way of life and livelihood.

Historic / Regional / Cumulative Context

Current land use for plant gathering around Grassy Mountain has been impeded since coal mining began in the 1900s. The construction of the railway system in southern Alberta resulted in changes in plant species and changes in the availability of plant gathering areas. Any further decline in opportunities for traditional land use may be of concern given that risk to traditional land use is already high. It is estimated that 80% of the regional study area is inaccessible for traditional land use due to presence of private land. Treaty 7 First Nations and KNC have indicated that the area in which plants are gathered has already been impacted by past mine developments, and other anthropogenic uses including private lands. There are stories of community members (Tsuut'ina) failing to transplant plants from one place to another because the elevation and soil is unique to the Mountains. Treaty 7 First Nations and KNC have historically valued gathering plants and foods for medicinal, cultural identity, ceremonial, spiritual, artisanal, healing, traditional teachings, subsistence purposes or for crafting tools, camps and canoes, and continue to gather plants for these purposes today. Plant gathering is part of Treaty 7 First Nations' cultural identity.

Stewardship and Governance

Treaty 7 First Nations and KNC have long engaged in and continue to practice a seasonal round, whereby people travel from one place to hunt, gather resources, go to campsites, and access sacred sites for spiritual and cultural ceremonies when conditions allowed. The Grassy Mountain area was used as a trading route to reach Shuswap Lake to the west and towards the north to trade buffalo robes, dried meat and horses to the Hudson's Bay Company in the fall and in the spring. During all seasons, large game animals and plant resources were exploited. They continue to share a relationship of respectful reciprocity in their intimate connections to the land as a result of their collective experiences, particularly through their pre-European lifeways. Among the numerous effects of the mining Project consist of potential changes in identified plant species and habitat, changes in use or access to identified plant gathering locations and change in preferred gathering methods. These effects could affect the cultural and spiritual relationship between the Nations and plants.

Impact Inequity

Transfer of knowledge on plant gathering and use to future generations could be interrupted during the Project activities. KNC and Treaty 7 First Nations' Elders expressed "a mix of sadness for ancestors and past damages witnessed on Grassy Mountain", and hope working with the Proponent on the proposed Project will be better than what was done in the past. Treaty 7 First Nations and KNC have indicated that the ability to transfer knowledge related to plant gathering (especially for medicine and sacred plants) may disproportionately affect specific members particularly the inability to pass on information to younger generations, potentially resulting in an erosion of knowledge held by active land users.

6.3.2 Key Measures to Address Potential Impacts on Aboriginal or Treaty Rights related to Plant Gathering.

Treaty 7 First Nations and KNC had specific concerns regarding the proposed Project's residual effect on sacred plants. The Indigenous groups did not agree with disturbing the area before the plants with special significance were located and protected through a formal consultation process, particularly plants growing in the microclimate of Gold Creek and elsewhere at Grassy Mountain that were omitted from the Proponent's Environmental Impact Assessment (EIA), because those plants only bloom at specific times of the year.

Implementation of mitigation measures for plant gathering will be done through the commitments contained within agreements with the Indigenous groups, as well as expected conditions of regulatory approvals. Mitigation effectiveness will be monitored through development and implementation of Indigenous-led monitoring program with advice from the Indigenous Environmental Stewardship Committee. Such Committee will include vegetation identification and monitoring of reclamation success. However, the proponent acknowledged that the project will result in some loss of traditional use vegetation within the LSA.

Treaty 7 First Nations and KNC suggested some refinements to the Proponent's proposed mitigation measures. As an example, the Nations suggested that the mitigation plan should protect the medicinal and ceremonial plants found in the Project property, including present harvesting, near term green housing and eventual replanting of important species during remediation.

Preliminary Assessment of Impacts on Aboriginal or Treaty Rights Related to Plant Harvesting

Taking into consideration the information provided by Indigenous groups and the proponent's mitigation measures and commitments, the Government of Canada's preliminary assessment is that the proposed Project may have a potentially low to moderate impact to the exercise of Aboriginal or Treaty rights to Treaty 7 First Nations and KNC.

6.4 Potential Impacts on Aboriginal or Treaty Rights related to Fish, Fish Habitat and Fishing

Treaty 7 First Nations and KNC indicated that they have fishing interests in the proposed Project area and identified fish species including Westslope Cutthroat Trout (WSCT), Rainbow Trout, Whitefish and Bull Trout. The Nations highlighted the importance of the habitat in the Crowsnest River, Blairmore Creek, Gold Creek and two upstream tributaries, which provides a unique setting for these fish species to thrive.

The Indigenous groups also identified concerns related to current access to the portions of the watercourses adjacent to Grassy Mountain, which is located on the Proponent's private land. The use of this road is discouraged by the Proponent now and will be closed to the general public. Fishers will use alternate routes to access fish in portions of Blairmore Creek and Gold Creek via other trails from south of the north end of the Project.

The Project is predicted to affect aquatic and riparian habitat and hydrology in Blairmore and Gold Creeks and could result in a change in fish habitat, change in use or access and a change in preferred fishing methods. The Project will affect the cultural and spiritual relationship between Nations' members and fish. Siksika Nation identified an interest in fishing Rainbow Trout, Whitefish, Pike and Bull Trout (Siksika Nation, 2015) and they are particularly concerned with fish habitat loss, potential contamination and erosion. It was noted that the community members generally viewed fish as an unclean source of food at present.

Piikani, Siksika, and Tsuut'ina Nations do not heavily engage in fishing activities and fish are generally not eaten anymore, except when necessary for subsistence (e.g. a survival food when there is a decline in large game availability). The Stoney Nakoda Nation identified species of

interest including Whitefish and Trout (Stoney Nakoda Nation, 2015). Stoney Nakoda Nation and Ktunaxa Nation have always valued fish for subsistence as it has been a staple of their diets. Ktunaxa Nation indicated that its members use fish for ecological, cultural, traditional and commercial purposes and fish for WSCT and Rainbow Trout primarily in British Columbia.

Káínai has indicated that they fish for subsistence purposes in the watersheds north of the Project (e.g., Livingston Range). The Nation raised concern that disturbances to fish habitat in the watershed, especially Blairmore Creek and Gold Creek, could interfere with the availability of subsistence fish species such as Mountain Whitefish or WSCT and impact the Káínai Nation rights to fish for food (O'Connor, 2018). Káínai Nation members have expressed a desire that appropriate water quality and fisheries mitigation measures be put in place to ensure disturbance to fish habitat in Blairmore and Gold Creek is addressed as it could affect the availability of subsistence fish species and affect Káínai Nation rights to fish for subsistence purposes.

Ktunaxa Nation members indicated that they practice fishing for WSCT and other fish in streams and lakes, fishing salmon at Columbia Lakes and along the Columbia River drainage, and fishing for mariah or ling in winter in the area of Tobacco Plains. Fishing has always been important for food, subsistence and sustenance. The activity of fishing has important cultural and spiritual considerations, as intergenerational knowledge of ceremonies, legends as well as fish use as medicine is shared while fishing In addition to this educational context, the activity of fishing is typically linked to other intangible values with spiritual, artistic and aesthetic elements. For example, fishing typically provides for quiet enjoyment of the landscape or access to water for other uses. Past Ktunaxa studies have shown that contamination and health concerns associated with upstream mining often result in a direct impact on Ktunaxa citizen's confidence in wild foods, and on Ktunaxa members' ability to rely on preferred places and species with confidence. Any further decline in opportunities for traditional land use may be of concern given that risk to traditional land use is already assessed as high.

Impacts to Westslope Cutthroat Trout (WSCT)

WSCT is a species with a Provincial and Federal Status of special concern and is of traditional use, the only native fish species within the LSA to be potentially affected through potential direct habitat loss and/or alteration (i.e., changes in stream flows). WSCT is distributed throughout the Crowsnest River watershed. The Alberta population of WSCT is listed in Schedule 1, part 3 of the *Species at Risk Act* (SARA) as a "Threatened". Because the Project has the potential to cause effects on fish habitat in Blairmore Creek and Gold Creek including several local tributary streams in each watershed, fish and fish habitat in these watercourses are expected to be vulnerable to the proposed Project effects. The high levels of selenium have resulted in serious concerns for the health of WSCT and other fish species.

Pathways

The physical footprint of surface water management infrastructure and open pits will cause permanent change to fish habitat (alteration, fragmentation, contamination), and the loss of riparian and aquatic habitat will reduce or modify fish habitat. Road closure during construction and operation will result in disruption of trails and will hinder access to preferred fishing locations and fishing methods, thereby decreasing existing fishing opportunities. Adverse effects on air quality (dust and emissions), odour and lighting, noise, and water contamination will result in loss of confidence in fish quality. Improved access could increase fishing pressure and fish harvesting in local fish-bearing watercourses by non-Indigenous people. It is expected that noise, dust and visual impacts of the proposed Project may alter the quality of the sensory and visual experience of fishers and affect the exercise of Indigenous groups' rights. The project could potentially impact the habitat and availability of WSCT, which is already listed as a threatened species. This effect would directly impact the right to fish of Indigenous groups.

Such impacts often result in Indigenous groups' decreased confidence in wild foods and on the ability to rely on preferred places and species.

Table 3- Pathways for Potential Impacts on the Exercise of Rights Related to Fish, Fish Habitat and Fishing

Potential Environmental Effects of the Proposed Project	Description of potential changes to the environment	Potential Pathways	Preliminary description of potential changes to the exercise of rights related to fish, fish habitat and fishing
Impact on fish habitat in watercourses adjacent to Grassy Mountain. The project activities will result in alteration of the hydrology, water quality, and in water flow regimes The physical footprint of surface water management infrastructure and open pits will cause permanent change to WSCT critical habitat in Blairmore and Gold creeks. Road to portions of the watercourses adjacent to Grassy Mountain will be closed to the general public for safety reasons.	• Increase of sediment content in water bodies due to surface water runoff from the Project • Loss of fish habitat availability and quality • Decrease of fish health due to potential exposure to contaminants from sediment discharge and habitat fragmentation • Reduction in stocks of WCT and other fish species of importance for the Nations • Lack of access to preferred fishing propertys • Changes in overall environment surrounding	• Changes in access to fishing sites • Changes in availability and health of fish species • Loss of confidence in water quality and fish due to perceived/actual contamination • High contaminant levels in fish, impact to the WSCT critical habitat • Sensory disturbance, concerns regarding contamination, safety and the overall negative experience on the land. • Changes in access to preferred fishing locations • Alteration of fishing experience and enjoyment • Changes in fish species availability and sustainability	• The direct effects (change in fish habitat, change in use or access to fishing locations, or change in preferred fishing method) could affect the cultural and spiritual relationship between the Nations and fish • It is expected that noise, dust and visual impacts of the Project may alter the quality of the sensory and visual experience of fishers and affect the exercise of Indigenous groups' rights • The project could potentially impact the habitat and availability of WSCT, which is already listed as a threatened species. This fact and the overall changes from the project, would directly impact Nations' rights to fish. • Continuing decline in fish populations largely due to on-going habitat conversion and fragmentation. This Project would continue reducing access to fishing locations thereby decreasing existing fishing opportunities • The project could potentially impact the habitat and availability of WSCT, which is already listed as a threatened species. This fact

The destruction of riparian and aquatic habitat will reduce/modify the fish habitat.	fishing areas: increased noise, increased lighting during the night, air quality changes due to dust and other emissions, water and soil quality changes due to release of potential contaminants of concern.		and the overall changes from the project, would directly impact rights to fish. • The presence of contaminants would decrease the confidence of Nations' members to use the area for fishing, hunting and other cultural and spiritual related uses and impact on intergenerational transfer of knowledge
Sensory disturbance due to Air emissions, odour, lighting from construction, operations Water pollution Changes in water quantity Increase in non-Indigenous population (Project workers and contractors)	• Predicted increase in flow to Blairmore Creek (discharge of treated water) • Predicted decrease in flow to Gold Creek	• Increased impact on the already endangered WSCT	
	• Changes in fish habitat	• Loss of fish habitat for preferred fish species	
	• Changes in the experience for the enjoyment of preferred fishing locations and water bodies	• Impacts on sense of place • Impacts on the ability to use areas close to water bodies	
	• Increases pressure in fishing activities	• Avoidance of the preferred fishing places due to perceived personal safety concerns • Less availability of resources for the enjoyment of Indigenous groups	

6.4.1 Preliminary Assessment of Potential Impacts on Aboriginal or Treaty Rights related to Fish, Fish habitat and Fishing

Spatial Extent

The project's effects will span across the entire Crowsnest area watershed with Blairmore Creek and Golden Creek being the most affected, and two upstream tributaries.

Likelihood / Duration / Frequency / Reversibility

The project activities during construction and operation will have a high likelihood of disturbing and disrupting fish habitats and ecosystems. This disturbance will have a long-term duration, because it will only stop when project operations discontinue and reclamation plans begin to be implemented. The frequency of the disturbance will be continuous, as the disruption of ecosystems and fish habitat will happen throughout project construction and operations. Reversibility is low. Once fish habitats are destroyed, the success of reclamation measures is not guaranteed, particularly when one of the fish species, the WSCT, is already endangered. The inability to fish preferred fish species in preferred fishing spots within the Grassy Mountain area will reduce the opportunity of Indigenous groups to practice a culturally important activity intrinsic to their way of life and livelihood.

Way of Life / Livelihood

Treaty 7 First Nations and KNC members have indicated that they fish for subsistence, and do so regularly in the summertime. They have expressed concern that disturbances to fish habitat in the watershed, especially Blairmore Creek and Gold Creek, could interfere with the availability of subsistence fish species such as Mountain Whitefish or WSCT and impact their rights to fish for food (O'Connor, 2018). For example, Siksika members indicated that they have fished and continue to fish "in the rivers and creeks downstream from the Project Area" and intend to "fish in the future as fish has been in our diet all our lives" (Siksika 2016). Fish, wildlife and vegetation are part of the ecosystem that forms the basis of Siksika's way of life (Siksika Nation-Statement of Concern, January 2016). Restrictions to access preferred fishing areas coupled with reduction in abundance, distribution and sustainability of fish species potentially harvested by First Nations' members could impact traditional way of life of all the Indigenous groups exercising their rights in the area.

Historic / Regional / Cumulative Context

Current use for fishing around Grassy Mountain has been disrupted since coal mining began in the 1900s. Treaty 7 First Nations have reduced their level of fishing in the area and shifted to less disturbed areas. Following the current trend of industrial development Treaty 7 First Nations and KNC have stated they will have no practical traditional use rights or sites remaining in their Territory — "meaning possible extinguishment of Blackfoot culture"[8] . Since the development of Grassy Mountain over a century ago, fishing is not as intensive as it used to be.

[8] Siksika 2018, Siksika Traditional Use Study Report #4, EIA Addendum 9, Appendix D

A cumulative effect is anticipated in relation to the continuing decline in fish habitat and fish populations largely due to on-going habitat conversion and fragmentation that would affect Treaty 7 First Nations and KNC fishing rights. The Project would also contribute to reduced access to fishing locations, thereby decreasing existing fishing opportunities. A regional study revealed that the fish community was found to be at risk due to fragmentation and access to fishing and could be at a high risk over the next 50 years due to global warming.

Unless rigorous mitigation measures are put in place, adverse impacts from other planned or foreseen projects in the immediate proximity will act cumulatively to increase the magnitude and duration of significant effects. In January 2020, a regulatory application has been submitted to DFO for a proposed coal mine project (Elan South Coal Mine) to be located just to the North of Grassy Mountain Coal Project. Further, in August 2020, another regulatory application was submitted to DFO for the Cabin Ridge Coal Project, also located in the vicinity of the Grassy Mountain Coal Project. Treaty 7 First Nations have noted a negative trend in the quality of the water and fish habitat. Regarding the survival of the WSCT species, the Project is planned within an ecological and social sensitive context.

Stewardship and Governance

Treaty 7 First Nations and KNC members fish for subsistence and cultural purposes in the Crowsnest River watershed and the Old Man River watershed north of the Project Regional Study Area. The Káínai Nation Elders report that current methods of fishing are adaptations to western practices undertaken on reservoirs near communities. This includes fishing in the fall as well as ice fishing in the winter (Káínai Nation, 2015). On their side, Siksika members testified that they have fished in the rivers and creeks downstream from the Project area. However their raised concerns about contamination and fish health issues resulting in decreased confidence in wild foods and the ability to rely on preferred fishing places and fish species. This will impact the KNC and Treaty 7 First Nations' stewardship of the area.

Impact Inequity

Effects from reduced quantity and quality of fish will disproportionately impact certain members of the Indigenous communities, especially the young, the elderly and the unhealthy that rely on this food source. Lack of access to preferred fishing sites could affect members with lower capacity to reach alternative fishing sites in higher proportion.

6.4.2 Key mitigation Measures to Address Potential Impacts on Aboriginal or Treaty Rights related to Fish, Fish habitat and Fishing

The Proponent has drafted a suite of mitigation measures to address the potential impacts to fish and fish habitat, such as measures to prevent increases in sediment concentration in surface water, to prevent changes in water temperature, to prevent increases in calcite precipitation, to prevent selenium and other metals from reaching water bodies, etc. The Aquatic Monitoring Plan will monitor water flows in Gold Creek. The Fisheries Offsetting Plan will be implemented to counterbalance predicted loss of fish habitat caused by the reduction in flow to Gold Creek.

Some of the mitigation measures specific to protect WSCT habitat and food supply are:

- Minimize the removal of riparian vegetation;
- Maintain appropriate riparian reserves and management zones from watercourses, where feasible;

- Construct online settling ponds for clean or non-contact water and for mine-influenced or contact water in lowest reach of affected tributary streams;
- Monitor discharges and ambient variables in receiving environments to ensure that water quality is within tolerances for WSCT;
- Under Species At Risk Act, a recovery strategy - Action Plan for WSCT (Alberta populations) has been prepared by DFO.

Preliminary Assessment of Impacts on Aboriginal or Treaty Rights Related to Fish, Fish Habitat and Fishing

Taking into consideration the information provided by Indigenous groups and proponent's mitigation measures and commitments, the Government of Canada's preliminary assessment is that the proposed Project may have a potentially moderate to high impact to the exercise of Aboriginal or Treaty rights to Treaty 7 First Nations and KNC.

6.5 Potential Impacts on Aboriginal or Treaty Rights for Cultural and Spiritual Values

Grassy Mountain is considered a spiritual complex place, believed to be the oldest Blackfoot spiritual property in Alberta.

Consultations with Treaty 7 First Nations and KNC have indicated that Grassy Mountain Area and adjacent areas, including Crowsnest Mountain, Crowsnest Pass, Crowsnest Lake, and the area of Frank, are of paramount importance for the practice and continuity of cultural and spiritual values. Crowsnest Mountain is considered the home of the creation and therefore many ceremonial practices are performed in this area.

Kainai/Blood Tribe advised that the Crowsnest Pass area is a "very sensitive area" and is central to Blackfoot culture and spirituality. Blackfoot Nations maintain a strong and historically rooted cultural and spiritual connection to the land and animals in the area of the proposed Project. The area is still used for ceremonial and religious purposes.

The Project area is considered by Ktunaxa knowledge holders to be *ʔamakʔis Ktunaxa* (Ktunaxa territory or homeland) and associated with the traditional land district of *qukin ʔamakʔis* (Raven's Land) which includes *Ku⧣wiaʔki* (the Crowsnest Pass), as well as the Michel Creek and Elk Valleys. KNC citizens count on the Project area for the preferred practice of a range of rights and interests that rely on particular preferred or critical places, species and practices.

Piikani Elders noted that many of their traditional stories are connected with Grassy Mountain. The Piikani Nation's creation story is linked to the mountains. The First Nation's camps sites and sacred spaces are located in the flat places in the mountains and Grassy Mountain represents an important area for Piikani, as ancient warriors protected these places and therefore the land is considered a storybook. Piikani draw their culture from the area, the land, the landscape and the animals.

Siksika Nation's interest and spiritual ties to the lands of Grassy Mountain remain undiminished to this day: ceremonies — especially the sacred Thunder pipe ceremony held at Grassy Mountain for millennia — tie Siksika Nation to the mountain. It is at Grassy Mountain that the Siksika received the Thunder Pipe

from Thunder before he was forced by Crow to live at Chief Mountain. Siksika members view their spirituality as expressed in sites that are part of a group of symbols, from Gold Creek and Blairmore Creek, and connecting between Grassy Mountain and Grassy Mountain South. There are many well-known and documented sacred places and gathering areas throughout the Siksika First Nation territory. These sacred sites are unifying symbols, provide evidence for cultural continuity that establish and reinforce national and personal connections to the landscape. The valley area of Blairmore Creek and Gold Creek is a burial site for Siksika. The area was desecrated by previous mine owners, before 2013.

The Stoney Nakoda Nation Elders and knowledge holders have conveyed the importance of spirituality to the Stoney Nakoda way of life. “Honouring spirit is crucial to linking different worlds (i.e., animal, people, Creator). Stoney Nakoda spirituality and peoples’ connection to the land is profound; the land is where spirit is renewed. Respecting, observing and trying to understand Stoney Nakoda spirituality is at the core of an appreciation for Stoney Nakoda traditional knowledge and land use” (Stoney Nakoda Nation, 2015). Stoney Nakoda members recognized areas on the mountain intended as meditation sites.

The geography and landscape of the Crowsnest Pass and the surrounding area play important roles in the spirituality of the Tsuut’ina Nation. Members have indicated the existence of sacred sites, ceremonial sites and natural material to make ceremonial paint and items. Various alpine plants of the Grassy Mountain area are crucial for ceremonial purposes, for healing practices and cultural identity. Tsuu’tina Nation advised that “connection to their homeland through stories, myths and the continued use of and reverence for, sacred elements in the landscape such as Crowsnest Mountain is paramount to their cultural identity and survival” (Tsuut’ina Nation, 2015).

Indigenous groups have indicated that whether the real or perceived, contamination to traditional lands, water, plants and animals from development can directly affect how and where traditional practices are carried out, thereby affecting cultural values associated with these traditional practices.

Sensory Disturbance and Experience

Indigenous groups highlighted the potential of sensory disturbance to the experience while practicing cultural and spiritual traditions in the Project area. Project activities will introduce a series of elements into the environment surrounding the Project footprint that can potentially alter the peaceful enjoyment of the environment by Indigenous groups. Wildlife inhabiting the area can also be sensitive to the disturbance, forcing them to escape to other less disturbed habitats.

Some examples of potential sensory disturbances are:

- Potential adverse air quality effects: air emissions (dust, odours) generated during Project construction and operations;
- Potential adverse noise and vibration effects during Project construction and operations;
- Potential adverse light effects: light contamination from Project activities;
- Potential adverse visual / aesthetic effects: visual obstruction of infrastructure associated with the Project that could interfere with the natural landscape of the area; and
- Increased use of rail route and Crowsnest highway: could impact sense of place and access.

Generation and Transmission of Indigenous Knowledge

Cultural, spiritual and ceremonial teachings are inextricably bound together. Intergenerational knowledge about ceremonies, traditions and customs as well as use of harvested animals and plants for medicine, food, tools, clothing, shelter and more is shared while hunting, fishing or harvesting plants. In additional to this educational context, hunting, fishing and plant harvesting practices are typically linked to other intangible values with spiritual, artistic and aesthetic elements.

The potential Project interactions with various cultural components have the potential to affect transmission of Indigenous Knowledge, particularly with regard to intergenerational transmission. The operation phase of the Project is projected for 25 years; this means that at least two generations will be affected by the interruption of the transmission of knowledge, affecting the integrity of Indigenous culture.

Piikani members voiced their concern regarding the potential impact of the proposed Project on the loss of culture, now and future generations*: "If the program proceeds, it will impact our younger generation. It will be part of our culture, our history, our storytelling. From what I heard when I grew up, I used to hear stories form my Elders, from my grandfather (naahsa), Wolf Tail (aapi'sosoysis), Small Legs, they used to sit around and talk about the old days, about the mountains, about history. We were just young kids, we had to sit around and listen. You [Benga] will impact our future, our storytelling will change. The sites that we have seen so far that is just a fraction of what's up there and what's going to be disturbed. It is against our culture*" Piikani Elder (Benga Mining Limited, 2019).

"*So my kids down the road, they (and their kids) are the ones that are going to be robbed of all those sites that will be impacted. I have not even heard 1% of the stories, the different things that are out there that are powerful that helped our people for thousands of years. I have not even heard 1%. So what's going to happen to my kid's kids when all those sites are destroyed? Who is going to know the stories, proper protocol? What a vision question is to really about? If you take away those sites, who is going to have the opportunity to do that*? …." Piikani Member (Benga Mining Limited, 2019).

Physical and Cultural Heritage

The Project area contains numerous pieces of cultural significance for the Blackfoot Nations as well as for KNC, Stoney Nakoda and Tsuut'ina. Archaeological features have been identified such as pre-contact camps, tipi rings, erratic rocks, artifacts, tools, medicine wheels, bison jumps, burial sites, as well as art, including rock drawings. The area also contains specific natural materials that are used to make ceremonial paint and items.

Information from Indigenous Traditional Knowledge (ITK) studies indicate that structures and landscapes with cultural and spiritual importance represent more than just an historical artifact for the Indigenous groups. According to these studies, being in the presence of these structures and places brings the First Nation's members in contact with their ancestors, with the wholeness of the universe, and reminds them of the interconnectedness of humanity with nature (O'Connor, 2018).

The Historical Resources Impact Assessment prepared by the Proponent (Section E.13, EIA, CEAR 42) addresses potential effects to sites as defined as any work of nature or humans that is of value for its palaeontological, archaeological, prehistoric, historic, cultural, natural, scientific, or aesthetic interest.

There are 32 recorded archaeological or historic resources located in the Project area including sites that are valued as cultural heritage sites to Indigenous group (O'Connor, 2018). Of the 32 sites, 10 overlap the Project footprint.

The Káínai Nation Traditional Knowledge and Use Assessment report indicates, "The Project area remains a highly significant, culturally important and environmentally sensitive area". Further, the Project will "disturb and destroy evidence of human occupation and material culture and heritage artifacts that have remained on the land for thousands of years," (O'Connor, 2018).

Some of the areas of cultural importance identified by Kainai First Nation are:

- Ancient camps and associated archaeological features along Blairmore Creek;
- Tipi rings and stone cairns, ancient camps and battle grounds in the proposed South Dump;
- Buffalo jump site and archaeological and heritage resources also in the South Dump area;
- Tipi rings and iniskim along the ridge of the rail load-out area;
- Crowsnest River Valley pre-contact travel and trade route;
- Wetlands (Tall Grass Lakes) as nesting grounds and migratory bird habitat;
- Natural sulphur spring in the RSA; and
- Several burial sites that will be substantially impacted or destroyed by the project.

Piikani, Siksika and Tsuut'ina also presented evidence of sacred sites of importance for the continuity of their culture and highlighted the reinforcement of the members' personal connections to the landscape.

As an example of the significance of sacred places for the Tsuut'ina First Nation, they recorded the following information for Waypoint 03: "Sheltered area surrounded by trees with rocks stacked on top of one another. Possible fasting area for vision quest. Fasting typically lasts for 4 days. This is an important area. Tsuut'ina suggested that any disturbance be avoided and suggested a 100 m buffer around this and all vision quest areas.

The Project will intersect or be in proximity to sacred, gathering and habitation sites identified by the KNC. One site-specific cultural site called *maǽuk* (Dirty Water/ Bellevue) was reported in the category of cultural activity within the Project area (Firelight Group, 2019). Additionally, *ʔakit≠aʔis* (Raven's House or Crowsnest Mountain) is of significance as it not only serves as the headwaters for the Crowsnest watershed, but is also considered the home of the creation being, Raven.

Pathways

During Project construction there will be disturbance to sacred and culturally or spiritually important propertys. Access to these sites could also be disturbed or permanently lost.

During Project operations, the sensory experience for the enjoyment of sacred and spiritually important sites could be disrupted from noise, odours, artificial lighting and dust generated by Project activities.

The cultural value and importance associated with the engagement with the sites or features of cultural or spiritual value could therefore be changed due to the potential impacts mentioned above.

In order to ensure that cultural and spiritual practices can continue, the Treaty 7 First Nations and KNC have identified the following requirements with respect to cultural and spiritual values:

- Access to cultural / spiritual significant sites
- Continued existence of pristine habitats surrounding those significant sites
- Quiet enjoyment of the landscape and access to seasonal campsites for the practice of cultural and spiritual traditions;
- Ability to trust the quality of the water and country foods, medicine and sacred plants close to the significant sites; and
- Limit the increase of non-Indigenous people visiting sites of cultural importance.

Table 4 - Pathways for Potential Impacts on the Exercise of Rights Related to Cultural and Spiritual Values

Potential Environmental Effects of the Proposed Project	**Description of potential changes to the environment**	**Potential Pathways**	**Preliminary description of potential changes to the exercise of rights related to Cultural and Spiritual Values**
Damages to cultural/ spiritual significant sites - removal of soil, vegetation - landscape changes – water contamination	• Disturbance to sites with cultural / spiritual significance • Changes to the cultural value and importance associated with the spiritual engagement with sites of cultural / spiritual significance	• Changes in the perception of the land • Avoidance of the area due to perceived environmental, aesthetic or safety concerns, such as the potential for large scale slope failure	• The area will be less accessible for members of Indigenous groups • Overall changes to the experience of engaging with sites and landscape features that represent cultural or spiritual value • Changes to inter-generational teaching of traditions and culture • Changes in resource availability and quality will also impact rights • Potential impacts on governance, stewardship and relationships with neighboring indigenous communities in the Crowsnest Pass area
Sensory disturbances - noise - odour - dust - light contamination - visual / aesthetics	• Changes to experience of engaging with sites and landscapes with cultural / spiritual value • Changes to the environment that interfere with the enjoyment of the site and overall spiritual experiences	• Sensory environment not suitable for cultural and spiritual practices	
Restricted access Rail routes	• Changes to preferred trails and travelways used to access sites with cultural / spiritual significance. • Physical exclusion from the lands and water bodies through fencing	• Restricted access deters members from visiting the area	
Increase in non-Indigenous population in the area (Project workers and contractors)	• Interferences with the practice of cultural and spiritual experiences • Less resources available for Indigenous groups • Less space available for the practice of cultural and spiritual traditions	• Avoidance of the area due to perceived personal safety concerns	

6.5.1 Preliminary Assessment of Potential Impact on Aboriginal or Treaty Rights related to Cultural and Spiritual Values

Spatial Extent

The project area and adjacent areas, including Crowsnest Mountain, Crowsnest Pass, Crowsnest Lake, and the area of Frank, represent a deeply important cultural landscape for Blackfoot groups and for KNC, Stoney Nakoda Nations and Tsuut'ina Nation. These groups have indicated that the mine footprint will destroy both documented and previously undocumented sites of archaeological, historical, cultural, or spiritual significance in both the Project area and outside the Project footprint.

Likelihood / Duration / Frequency / Reversibility

The Project activities during construction and operation will have a high likelihood of disturbing and disrupting the practice of cultural and spiritual traditions, specifically when physical structures or landscapes linked to spiritual significance are removed or disturbed during Project construction. The disturbance to the practice of spiritual or cultural activities will be long term, during all phases of the Project. The frequency of the disturbance will be continuous, as the disruption of cultural and spiritual practices will happen throughout project construction and operations.

The effect is non-reversible, because the loss of heritage structures will be permanent. As the Project duration is estimated to be 25 years, intergenerational knowledge transmission of cultural and spiritual traditions will be interrupted for at least two generations.

Way of Life / Livelihood

Communities have flagged the close proximity of the proposed mine to Crowsnest Mountain as an area of concern. The potential for negative changes to the viewscape and sensory environment (noise, smell, air quality) associated with direct mine activities (construction, operation) and incidental activities (rail traffic) are a concern for communities' current and future use, and stewardship associated with the Crowsnest Mountain and nearby areas with place-based cultural and spiritual practices.

Historic / Regional / Cumulative Context

Despite the impacts from past coal mining, road development, and extirpation of buffalo, Indigenous groups still use the Project area to practice their rights. The operation of an additional mine project will likely add impacts that could be received in a disproportionate share by the Indigenous groups that rely on the area for spiritual and cultural practices.

The limited availability of Crown land within the Project area has already reduced Indigenous groups' ability to maintain some aspects of their traditional occupancy and use of such areas where structures of cultural importance are located.

Stewardship and Governance

This aspect will be affected by the removal of cultural sites of importance for Indigenous groups, given that their connection to culture represented through those sites might be severed, and thus their cultural sustainability could be affected. Use and sense of connection to this portion of their traditional

territory has the potential to change permanently, and interfere with the ability of the groups to govern their culture in accordance with stewardship values.

Tsuut'ina voiced the following concerns regarding their stewardship to protect the health of the land: "*The way that I was taught about our place is that we are not here to own the earth, we are here as stewards. We are here to take care of it and protect it*." (Benga Mining Limited, 2019). The community also stated the importance of protecting traditional lands, regardless of whether they are considered Crown or private lands: "*Traditional land is traditional land. Private land is the depth of the plow. First Nations don't distinguish between the Crown and private lands. We didn't exploit our lands. The Creator gave us everything that we needed to live – plants, animals, water. A lot of companies don't have an understanding of this. Companies have a responsibility to protect the land as well. Our people talk about the seven generations, protecting the land for those ahead of us to keep everything intact to sustain life. Proponents should do everything possible to protect wildlife, waters, vegetation, etc. Western medicine cannot heal everything"* (Benga Mining Limited, 2019).

Impact Inequity

Given that intergenerational knowledge transfer will be impacted during all phases of the Project, the younger generations will be affected by the lack of opportunities for learning their culture and spiritual traditions.

6.5.2 Measures to Address Potential Impacts on Aboriginal or Treaty Rights related to Cultural and Spiritual Values

Indigenous groups have proposed the following mitigation measures:

The Piikani First Nation indicated during consultations with the Proponent that the Nation would like to maintain an on-going Environmental & Cultural Monitoring Program and regime funded by the Proponent in accordance with the guidelines as set forth by the Piikani Consultation Policy. The objective is to ensure the integrity of the project area remains intact, prior to, during and throughout the project area life. Waypoints 10, 11, and 26 are ceremonial plant locations requiring harvest of the plants before this area is developed.

A Piikani Elder noted the value of developing a plan that includes Piikani spiritual practices as a way of moving forward together with the Proponent: "*This project is in the infant stages… A the end of the day, it is critical that we map it all out and have a path. We have to walk out there and talk about it... We have to unravel this in a way that the message goes out peacefully and the understanding is there*". ~ Piikani Elder (Benga Mining Limited, 2019)

Siksika members advised: "The operations of the mine should include awareness training for non-Native employees of the sacred nature of the Southern Gate and Crowsnest Mountain through workshops with Siksika Elders and Society members. The Proponent should sponsor ceremonial and other important Siksika events in the region including the opening of the pipe on its property before, during and after the project is operated as a mine to maintain the sanctity of the relationship between the Creator, the animals and Man at that location" (Benga Mining Limited, 2019).

Siksika indicated that the most recent Traditional Use Study identified yellow ochre at their sites near the golf course, and that further impacts to this sacred paint source should be permitted.

Tsuut'ina and Kainai members suggested imposing a no-go buffer zone of 100 metres around all sacred sites, focusing research efforts on areas that have not been disturbed, continuing traditional knowledge work as part of healthy business relations, and respecting the Nation's members' input.

KNC advised that the proposed Project is in an area of ʔamakʔis Ktunaxa with a deep history of Ktunaxa use and occupancy, and ongoing cultural-spiritual importance. The Project is considered likely to result in significant adverse effects, including impacts on Ktunaxa traditional use and access to lands and resources, sensory experience and cultural connection to sacred areas nearby, impacts to ecological values including fisheries in the Crowsnest River and wildlife, and Ktunaxa stewardship commitments related to bison *(i.e.,* Buffalo Treaty) and ʔa·kxaṁ is q̓api qapsin (all living things). Nevertheless, KNC explained that discussions with the Proponent are ongoing regarding reliable and effective means to reduce, mitigate, or offset impacts and Ktunaxa cultural values, lands and resources, as well as social, economic, and educational and employment related values.

The Government of Canada recognizes that the Proponent has been in conversations with Treaty 7 First Nations and KNC on the development of several measures that will be led by Indigenous groups, such as Indigenous Environmental Stewardship Committees, Indigenous-led monitoring programs, and Cultural Property Discovery Contingency plans. The Proponent has committed to engaging with the Indigenous groups during all phases of the Project, including the review and input into management and monitoring plans, to discuss options to facilitate assess for traditional activities, construction timing and reclamation. In addition, the Proponent has committed to implementing a cultural competency program for its employees and contractors.

After implementing the mitigation measures related to physical and cultural heritage, the Proponent is of the view that the Project would still affect Indigenous groups' cultural and spiritual values and interests. Should the Project proceed, it is likely that there will be an impact on the cultural and spiritual integrity of the landscape despite reclamation efforts.

However, all the Treaty 7 First Nations have indicated that they are in full support of the Project and are satisfied with the consultations carried out by the Proponent.

Preliminary Assessment of Impacts on Aboriginal or Treaty Rights Related to Cultural and Spiritual Values

Taking into consideration the information provided by Indigenous groups, the Government of Canada's preliminary assessment is that the proposed Project may have a potentially moderate impact to the exercise of Aboriginal or Treaty rights to Treaty 7 First Nations and KNC.

6.6 Potential Impacts on Aboriginal or Treaty Rights for Water Resources

Water is an element of spiritual importance for all the Indigenous groups, given the implications it has for human life and supporting the ecosystem. Water is considered the basis for the existence and health of fish, wildlife and bird habitat, in addition to being the source of drinking water for all living creatures.

Treaty 7 First Nations and KNC consider the Crowsnest watershed area and its related water bodies are critical for the health and survival of the ecosystem. Springs, creeks, rivers and lakes are particularly important to all Indigenous groups consulted on this Project. Many water places in the Crowsnest area carry spiritual significance, usually as the resting place for spirits and creator beings.

The Nations consider the Crowsnest Pass area as an important ceremonial area associated with water and cultural features. For example, the Ktunaxa translation for *Ku⧣wiaʔki* (Crowsnest Lake) is “Heart of the Water”. The Nation embraces this area as an extremely important and at-risk sacred and ceremonial place.

Piikani Nation indicated that the Grassy Mountain area is part of the watershed that contains the headwaters of one of the major rivers in their traditional territory. Piikani Nation members have long observed the relationships between water and plants, as well as water and animals. For example, Piikani link streams and waterways with good hunting areas for moose, elk or deer. In addition, berries and poplars are known to use large quantities of water; therefore, they are used by Piikani members as indicators of either wet or dry environments or during warm or cool years.

Treaty 7 knowledge holders advised that there has been a negative trend in the quality of the water in preferred harvesting camps, attributed to mining activities in the area. There is an existing impact along the Gold and Blairmore Creeks, including avoidance of fish and aquatic resources, as well as other subsistence resources.

Siksika Nation also voiced their concern about water contamination from Project activities. They indicated the possibility for calcite precipitation from waste rock within downstream receiving environments that could affect fish habitat.

Further, Siksika Nation advised: “The Grassy Mountain project, as proposed, using one of the three proposed materials dumps sites in addition to the mine site, will severely impact the movement and well-being of those animals by displacing them from their homes for many years and blocking their migratory routes. Perhaps more importantly the springs and streams running off Grassy Mountain and hillsides nearby that will be impacted by the project seem likely to become polluted by the mine run-off causing unnecessary deaths of animals we’re sworn to protect.” (Siksika, 2015).

KNC members have been following the incidence of high levels of selenium in the Elk River in British Columbia from adjacent coal mining. The high levels of selenium have resulted in serious concerns for the health of WSCT and other fish species. Such impacts often result in member’s decreased confidence in wild foods and on the ability to rely on preferred places and species.

KNC advised: “Anticipated Project impacts include mobilization of mining contaminants into adjacent waterways by airborne deposition, runoff from the mine site, and releases of treated wastewater into the environment. Based on the location of the Project, Blairmore Creek and Gold Creek drainages appear likely to receive impacts from upslope development of the Project. Both waterways flow into Crowsnest River” (Firelight Group, 2019).

Most of the Indigenous groups voiced their concerns regarding the link between the impacts on environmental and cultural-spiritual values associated with the integrity of water resources at the headwaters of the Crowsnest River and downstream.

Table 5 - Pathways for Potential Impacts on the Exercise of Rights Related to Water Resources

Potential Environmental Effects of the Proposed Project	**Description of potential changes to the environment**	**Potential Pathways**	**Preliminary description of potential changes to the exercise of rights related to water resources**
Impact on surface water quality - surface water runoff - process water released from Project activities - Saturated Backfill Zone mitigation - Leaching of blasting residues: nitrates - Domestic wastewater from camp operations - Air emissions from construction, operations - Accidental leaks and spills of hydrocarbon, chemicals and waste products	• High concentration of nitrate, selenium, calcite and other contaminants in surface water • Potential bioaccumulation of contaminants in wildlife • Increase of sediment content in water bodies due to surface water runoff from the Project • Loss of fish habitat availability and quality • Decrease of fish health due to potential exposure to contaminants from sediment discharge	• Loss of confidence in water quality due to perceived/actual contamination • High contaminant levels in fish and wildlife • Increased impact on the already endangered WSCT.	• Potential loss of trust in water quality, resulting in a loss of the ability to exercise the rights • Potential reduction in the use of areas close to water bodies due to the low confidence in water quality, therefore impacting the rights to hunt, harvest plants and fish • Potential reduction in the ability to transmit knowledge to future generations related to trapping and fishing in preferred areas, compounded by younger generations viewing the water as contaminated. • Potential reduction in the ability to steward the land • Potential loss of peaceful enjoyment of the land • Potential decrease in the exercise of the right to fish • Potential impacts on environmental and cultural-spiritual values associated with the integrity of water.
Changes in water quantity	• Predicted increase in flow to Blairmore Creek (discharge of treated water) • Predicted decrease in flow to Gold Creek	• Impacts to fish and fish habitat • Impacts to other aquatic organisms	
Changes in surface water temperature from releases of process water	• Changes in fish habitat	• Loss of fish habitat for preferred fish species	
Sensory disturbances around the proposed Project and close to water bodies - Noise - Odours - Dust - Light pollution	• Changes in the experience for the enjoyment of water bodies	• Impacts on sense of place • Impacts on the ability to use areas close to water bodies • Changes on the use of preferred areas	

Increase in non-Indigenous population (Project workers and contractors)	• Interferences with the enjoyment of water bodies • Increase in fishing activities by non-Indigenous population	• Avoidance of the area due to perceived personal safety concerns • Less availability of resources for the enjoyment of Indigenous groups • Changes to preferred trails and travelways used to access water bodies	

6.7.1 Preliminary Assessment of Potential Impacts on Aboriginal or Treaty Rights to Water Resources

Spatial Extent

Project operations will potentially affect the Crowsnest area watershed, Blairmore Creek and Gold Creek being the most impacted. All the Indigenous groups consulted have voiced their concerns about the spiritual and cultural importance of the Crowsnest area and specifically the connotation that water has for the Nation's worldviews.

Likelihood / Duration / Frequency / Reversibility

Project activities during construction and operations will have a high likelihood of disturbing and disrupting water bodies. This effect could have important consequences on how the Nations' members practice their rights, given the overarching importance that water represents for Indigenous communities. Practice of fishing, hunting, plant gathering, cultural and spiritual ceremonies are all linked somehow to the sanctity of water in the Crowsnest watershed.

The effect on how the Nations perceive water will be continuous through the Project duration, and depending on the mitigation measures and reclamation plan, the effects on the quality and quantity of water could be reversed.

Way of Life / Livelihood

Water is considered a sacred component of all forms of life. If water quality cannot be relied on, then all the traditional way of life of all the Indigenous groups exercising their rights in the area could be affected.

Indigenous groups have indicated that their confidence in the enjoyment of the resources found in the Crowsnest area is based on a healthy water quality, including healthy surface and groundwater that support wetlands, forests, medicinal plants, fish, and wildlife.

Siksika members testified that they "have fished and keep fishing in the rivers and creeks downstream from the Project area...We fish regularly in the summertime. In the winter time we ice fish... We intend to fish in the future. It has been a part of our diet all our lives" (Siksika Statement of Concern , January 4, 2016).

Once the quality of water is compromised from potential Project effects, Indigenous groups could become hesitant on the use and enjoyment of the area, given the lack of confidence..

Historic / Regional / Cumulative Context

Based on past work in the Elk Valley, KNC has determined that cumulative effects on KNC's rights and interests stemming from impacts to water bodies in the Elk Valley have already exceeded a threshold whereby water can no longer support ecosystem functions for values of importance to Indigenous groups. Without substantial mitigation measures, adverse impacts from other projects in the region will act cumulatively to increase the magnitude and duration of significant effects.

Treaty 7 First Nations also voiced their concern regarding the impacts already present in the area. They have observed a negative trend in the quality of the water.

Stewardship and Governance

The Crowsnest area is of paramount importance for the Treaty 7 First Nations and KNC. If the Project negatively affects the quality and quantity of water, this will impact the groups' stewardship of the area.

The First Nations voiced their concern about the current trends of industrial development and their impacts in the Grassy Mountain area. The consequences of the impacts on water bodies in the area of the proposed Project will further add to the trend towards the extinguishment of all the Indigenous cultures that base their spirituality and culture in the waters that originate in the Crowsnest watershed.

Impact Inequity

The inability to trust the quality of water resources may result in avoidance behaviours in the exercise of hunting, fishing and gathering rights. The reduced opportunities for practicing rights may disproportionately affect younger generations who learn these practices on the land, and Elders, expecting women and community members with compromised health, who rely on the harvested resources.

6.7.2 Measures to Address Potential Impacts on Aboriginal or Treaty Rights related to Water Resources

Several Elders from Kainai recommended implementing an emergency preparedness plan in the event of leaks, spills, or other disasters. This plan would address concerns the Elders have about effects on water quality and species dependent on clean water sources.

Siksika members suggested: "Our concern is for all animals living on the mountain. There is abundant evidence of a variety of animals living there, drinking from the springs that run down the side of the mountain, eating and resting in protected areas nearby. The lagoons holding runoff from the mountain and effluent from the mine pit should be fenced so that animals big and small do not drink from them. Alternative clean water drinking spots for those animals should be created for them nearby. The springs appearing at elevation throughout the mine property seem likely to be destroyed by the project. If this is the case, it must be done in such a way that no industrial sediment or other downstream effects are allowed to impact Blairmore or Gold Creeks or the Crowsnest River because those impacts could cause

serious hard to the animals that rely on the that spring water to live" (Siksika, 2015).Further, Tsuut'ina members advised: "Springs running down the west side of the mountain. Tsuut'ina would like to see these protected. That is, prevent waste and tailings from getting in them" (Tsuut'ina, 2015).

The KNC indicated that their members have extensive experience with mitigation and offsetting measures undertaken for similar mines in adjacent areas of BC. Discussions are ongoing, but KNC anticipates that additional mitigation and other measures to reduce, mitigate, or offset impacts, and increase benefits, will be needed. For example, the Proponent focusses on impacts on water downstream of the Grassy Mountain Project but does not consider Project residual impacts on regional airborne deposition of contaminants that could impact the Elk River watershed.

The Government of Canada acknowledges the Proponent has developed a water management strategy, which will help manage surface water and ground water efficiently to minimize hydrological effects on water bodies. The water management plan will ensure that water process containing selenium and other metals are treated before release to natural watercourses. Further, the implementation of the Fisheries Offsetting plan is intended to compensate the changes to aquatic habitat in Blairmore Creek and Gold Creek. However, the Fisheries Offsetting Plan is pending approval from DFO, and the Aquatic Monitoring Plan is not yet finalized.

The Proponent has also committed to continue to consult with and engage all potentially affected Indigenous groups to reduce and mitigate potential Project and cumulative effects on hydrology and surface water quality.

Preliminary Assessment of Impacts on Aboriginal or Treaty Rights Related to Water Resources

Taking into consideration the information provided by Indigenous groups, and considering that the mitigation measures are not well defined, the Government of Canada's preliminary assessment is that the proposed Project may have a potentially moderate to high impact to the exercise of Aboriginal or Treaty rights to Treaty First Nations and KNC.

7.0 Conclusions and Path Forward

The Treaty 7 First Nations and the Ktunaxa Nation Council have provided the Agency with information that illustrates the potential impacts from the Project to the biophysical elements and, more broadly, the impacts to potential or established Aboriginal and/or Treaty Rights.

WATER

Water Quality

All of the Indigenous groups have indicated that there is the potential that water sources will be affected by the Project activities. The Project represents a potential source of contaminants such as selenium, nitrates, carbonates, suspended solids and incidental contaminants.

Water Quantity

There is a predicted increase in flow to Blairmore Creek and a decrease in Gold Creek. This may affect the habitat for fish and insects and animals.

Overall, the potential effects from predicted changes in flows to both Blairmore and Gold Creeks can adversely affect the rights of the Indigenous groups. The perceived impacts to the water can adversely affect the confidence the Indigenous groups have in the water from the Project area.

Based on the information shared to date by the Treaty 7 First Nations and the KNC communities, the potential impacts to water are at a moderate to high level.

FISH, FISH HABITAT AND FISHING

Westslope Cutthroat Trout

Potential impacts to water quality and quantity will affect the habitat of the WSCT. The WSCT is a listed species under SARA.

Fishing

The potential effects on WSCT and other species will in turn adversely affect the rights of Treaty 7 First Nations and KNC in relation to fishing. Based on information shared to date, other species the Indigenous groups harvest for fish are bull trout, rainbow trout, and whitefish. The potential adverse impacts to WSCT and other species will further degrade the confidence in the local fishery and the practice of fishing in the area in and adjacent to the Project area. This effect will have a potential impact on the rights of Indigenous groups and the ability to transfer knowledge of fishing.

Based on the information shared by the Treaty 7 First Nations and the KNC communities, the potential impacts of the Project to Fish, Fish Habitat and Fishing are at a moderate to high level.

CULTURAL AND SPIRITUAL VALUES

Grassy Mountain

The Indigenous groups in the area, predominantly the Treaty 7 First Nation and KNC communities, have a long, established history in the area. They have shared information that demonstrates the relationship they have with the Project area. For instance, Piikani has shared that Grassy Mountain remains an important area for their community and Siksika has shared that Grassy Mountain is the location of the Thunder Pipe Ceremony.

The potential effects from the Project has the potential to adversely affect the transmission of knowledge from one generation to another during the lifetime of the Project and potentially beyond.

Overall, the Project has the potential to interrupt many aspects of culture for the Treaty 7 First Nations and KNC with respect to Traditional Knowledge, spirituality, and way of life.

Based on the information shared to date, the potential impacts to rights remain at a moderate level.

PLANT GATHERING

The Treaty 7 First Nations and KNC communities shared information on the traditional practice of plant gathering. Based on the information shared to date, the Project has the potential to impact plants found in the Project area.

The Project will require the removal of certain plants. As well, the Project activities could potentially affect the areas adjacent to the Project property and beyond the Project footprint during construction and operation. There is some uncertainty about reclamation efforts and how successful they will be once the mine closes. Therefore, some areas may be impacted for many decades.

Potential impacts to rights for plant gathering could include impacts to species such as lodgepole pine, aspen and birch as well as species of plants used for medicinal, ceremonial and cultural purpose.

Overall, the potential impacts from the removal of vegetation for construction and during the operation of the mine may impact the plant species used by the Indigenous groups as a residual effect.

Based on the information shared to date by the Treaty 7 First Nations and the KNC communities, the potential impacts to plant gathering is at a low to moderate level.

HUNTING AND TRAPPING

The Project has the potential to impact species such as bear (black, grizzly), elk, moose, mule deer. The Project area used to support buffalo/bison which remains a keystone species for the Indigenous groups in the area. The Treaty 7 First Nations and KNC are signatory to the Buffalo Treaty, which is an agreement to initiate measures to re-establish the buffalo/bison to the area.

It is predicted the Project has the potential to further contribute to habitat fragmentation for the above listed species in addition to American marten, lynx and golden eagles.

For instance, information shared by Piikani and Stoney Nakoda Nations indicate that the decline in conditions that support hunting and trapping has an impact not only on subsistence but also on ceremonial, spiritual and way of life aspects.

Based on the information shared to date by the Treaty 7 First Nations and the KNC communities the potential impacts to rights is at a low to moderate level.

PATH FORWARD

As the Project proceeds beyond the Public Hearing stage, the Agency will continue to provide consultation opportunities for the Indigenous groups that are involved in the Project EA up to the decision by the Minister of Environment and Climate Change. Given challenges related to the COVID19 pandemic, we will work with the First Nations and other potentially affected Indigenous groups to provide appropriate and safe venues that enable further discussions about the Project.

The Agency encourages Indigenous groups to bring forward information that will allow a better understanding of how the potential, adverse impacts associated with the Project may adversely impact their Aboriginal and Treaty rights. The Agency remains committed to working with the information shared by Indigenous groups that will support existing or new assessments of impacts on Aboriginal and Treaty rights.

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APPENDIX A- CRITERIA TO DETERMINE SEVERITY OF IMPACTS ON ABORIGINAL OR TREATY RIGHTS

The following table shows the criteria applied to assess the severity of impacts from the Project on the exercise of Aboriginal or Treaty rights.

Spatial Extent	Likelihood	Duration/Frequency/ Reversibility	Way of Life (values, practices, traditions)	Regional/Historic/ Cumulative context	Stewardship/Nation hood & Community Thresholds	Impact Inequity (including future generations)
Definition: Spatial area over which the impact on the exercise of rights and culture/way of life is predicted to occur. Can include quantitative and qualitative scales for characterizing geographic extent of impact.	**Definition:** Prospect of an impact on rights occurring that is based on information from technical and community based experts, including those most likely to be impacted. The full life-cycle of a project's impacts, including its various stages and lifespan (meaning, at a minimum, through to the projected end of the reclamation process), should be considered in determining the likelihood of occurrence of an effect. Likelihood refers to more than	**Definition:** How often disruptions to the practice of rights may occur. Length of time that an impact to a right is experienced, from the community perspective. For example, reclamation does not mitigate impacts to rights during operation and impacts that occur at only certain times of year may be experienced as ongoing impacts if they take place on a weekly, monthly or annual basis. *Note: Reversibility does not include the potential to move practice of rights to	**Definition:** Impacts to ecosystem and cultural values that support a community's way of life and cultural health, including its practices, customs and traditions. Prospect of disruption to preferred ways of continuing customs, traditions and practices. Way of life may be linked to culturally important landscapes, species and determinants of community health identified by the impacted community.	**Definition:** Impacts of past, existing and future projects or activities. Cumulative impacts may have a regional or historic context and may extend to aspects of rights related to socio-economics, health, culture/way of life, heritage, and other matter tied to an Indigenous community's history and connection to the landscape.	**Definition:** Planning and management or stewardship of traditional lands and resources. Indigenous governance and decision-making authority may be expressed through a specific laws, norms, power, and language.	**Definition:** Impacts could be disproportionately experienced by parts of a population, such as women, elders, youth, key harvesters or a particular family group and benefits may only go to a few individuals or segment of a community. Particular consideration to be given to future generations

Spatial Extent	Likelihood	Duration/Frequency/ Reversibility	Way of Life (values, practices, traditions)	Regional/Historic/ Cumulative context	Stewardship/Nation hood & Community Thresholds	Impact Inequity (including future generations)
	just the probability of environmental effects, and also includes the prospect of diminishment of sense of place, confidence in the quality and quantity of resources, and experience of rights.	another jurisdiction or area.				
Low. The impact on the exercise of rights could occur over a small spatial area.	**Low**. A potential impact on the exercise of rights is unlikely but could occur.	**Low**. The impact lasts < 5 years. The impact would be confined to one discrete period during the life of the Project. The impact may be reversed in the short term.	**Low**. No or little indication that there would be any impact to practice of rights, traditional resources or ecosystem and cultural services of the impacted group. Little to no reduction in value of culturally important locations or ability of group to obtain quality and quantity of resources.	**Low**. There is little development in the community's territory that has created restraints on the exercise of rights and the Project or activity would be in an area with few existing impacts. In addition, the Project is not likely to contribute to further cumulative effects.	**Low**. There is a high level of cooperation between the proponent and impacted group. The community has formally indicated to the Crown that risks from the Project are acceptable or have been accommodated or the Project falls into an area already considered for industrial development in the plans of the community.	**Low**. Vulnerable sub-groups (such as elders, children, youth, women, specific families and/or households) are unlikely to experience impacts from the Project and are likely to maintain the exercise of rights. The impacts allow intergenerational transfer of knowledge and exercise of right to continue into the future. Potential benefits resulting from the Project would flow between all segments of the community in a way

Spatial Extent	Likelihood	Duration/Frequency/ Reversibility	Way of Life (values, practices, traditions)	Regional/Historic/ Cumulative context	Stewardship/Nationhood & Community Thresholds	Impact Inequity (including future generations)
						that supports future generations from benefiting from the exercise of rights and connecting to culture/way of life. Strong benefits will be experienced by each sub-group of the population.
Moderate. The impact on the exercise of rights could occur over a moderate spatial extent.	**Moderate**. A potential impact to rights is likely but may not occur.	**Moderate**. The impact will be greater than five years but not last beyond one generation. Within that period, the impact is unlikely to be ongoing or occur on a repeated basis throughout the operation and decommissioning of the Project.	**Moderate**. There may be an impact to practice of rights but impacts are unlikely extend to preferred areas, preferred or scarce resources or to ecosystems, areas, or cultural services of high value to the impacted community. The impact may impede or alter access to practice cultural activities but without limiting connection to an area or sense of place. There may be some loss of habitat or availability of culturally important species. The disturbance may be of a physical or	**Moderate**. There are other land uses, including proposed or existing projects, in the community's territory which impact the practice of rights.	**Moderate**. The impacted community has expressed concern about impacts of the Project. The community has stated that some impacts remain after mitigation and/or accommodation. The community has indicated that the Project may not be compatible with certain aspects of their land use plans or application of traditional laws.	**Moderate**. Transfer of knowledge between generations may be interrupted for a moderate period of time by the Project. Vulnerable sub-groups of the population are likely to experience a higher impact on the ability to exercise rights. Rights may be resumed broadly within one generation. Some benefits may accrue to sub-groups and future exercise of rights is supported. There will be moderate experience of benefits, as defined by the community, by

Spatial Extent	Likelihood	Duration/Frequency/ Reversibility	Way of Life (values, practices, traditions)	Regional/Historic/ Cumulative context	Stewardship/Nationhood & Community Thresholds	Impact Inequity (including future generations)
			sensory nature (noise, visual quality, etc.)			each sub-group of the population.
High. The impact on the exercise of rights could occur over a large spatial extent	**High**. An impact on the exercise of rights is highly likely or certain to occur.	**High**. The impact on the exercise of rights is unlikely to be reversed, either in whole or in part, because the impact is likely to persist beyond one generation. The impact would occur constantly during, and potentially beyond, the economic life of the Project. "Constantly" can mean either that a project activity interacts with rights on an uninterrupted basis or on a sporadic but repeated basis that may coincide with rights activities that take place at certain intervals or seasons.	**High**. Impacts are likely to cause an interference with the meaningful exercise rights in the preferred manner, including limited use of, or access to, preferred quality and quantity of resources and or limitations on scarce or high community value areas. Multiple impacts could occur to one area of high importance. The Project may cause effects on a species that is culturally important, that has limited availability or high sensitivity to change or that is also a federally or provincially listed species at risk. Access to practice cultural activities would likely be disrupted or limited. The disturbance may be	**High**. There are multiple other land uses, including proposed or existing projects, which impact the community's practice of rights. The Project may interact with the exercise of rights in an area highly valued given cumulative context. The rights which may be impacted by the Project are not currently practiced in the preferred manner because of conservation issues, lack of access or government policy/programs.	**High**. The Project would likely prevent or restrict use of areas identified as high stewardship and nationhood priorities. Project may cause interference in traditional land management regime and values. The community has indicated that the Project is not compatible with its land use plans or application of traditional laws.	**High**. One or more vulnerable sub-groups will be disproportionately impacted by the Project, and the mitigations and benefits unlikely to preserve the ability of sub-groups to benefit from their rights. Intergenerational transfer of knowledge would be interrupted for an extended time period and may not be reversed either in whole or part.

Spatial Extent	Likelihood	Duration/Frequency/ Reversibility	Way of Life (values, practices, traditions)	Regional/Historic/ Cumulative context	Stewardship/Nation hood & Community Thresholds	Impact Inequity (including future generations)
			of a spiritual, cultural, social, physical or sensory nature (noise, visual quality, etc.)			