CMD 25-H9 CNSC Staff Submission

Reference Package for CMD 25-H9 CNSC Staff Submission on Denison Mines Licence Application to Prepare Site and Construct the Wheeler River Project

Classification	Unclassified
Type of CMD	References
CMD Number	25-H9 (Volume 1)
Original CMD	25-H9
Public hearing date	8 October 2025
PDF e-DOC #	7562400
Summary	This supplemental CMD includes all publicly available documents referenced in CNSC staff CMD 25-H9.
Actions required	There are no actions requested of the Commission. This CMD is in support of the actions and recommendations set out in CNSC staff CMD 25-H9

CMD 25-H9 – Soumission par le personnel de la CCSN

Références liées au CMD 25-H9 Soumission par le personnel de la CCSN la demande de Denison Mines visant à prépare le site du projet de Wheeler River et à entamer les activités de construction

Classification	NON CLASSIFIÉ
Type de CMD	Références
Numéro de CMD	25-H9 (Volume 1)
CMD Original	25-H9
Date de l'audience	8 octobre 2025
Numéro e-Doc du PDF	7562400
Résumé	Ce CMD supplémentaire comprend tous les documents accessibles au public mentionnés dans le CMD 25-H9 du personnel de la CCSN.
Mesures requises	Aucune mesure n'est requise de la Commission. Le présent CMD appuie les mesures et les recommandations énoncées dans le CMD 25-H9 du personnel de la CCSN.

CMD 25-H9

Reference Package for CMD 25-H9 CNSC Staff Submission on Denison Mines Licence Application to Prepare Site and Construct the Wheeler River Project

Signed by:

Sigouin, Luc
C=CA, O=GC, OU=CNSC-CCSN, CN="Sigouin, Luc"
2025.08.22
07:35:44
-04'00'

X

Luc Sigouin
Director General, DNCFR

Table of contents

1 Denison letter, R. Nagel[(Denison) to D. Saumure (CNSC), Subject: Denison Mines Corp. Application for the Wheeler River Operation, June 29, 2023

Denison Mines Corp.
345 4th Ave. South
Saskatoon, SK S7K 1N3

T: 306-652-8200
F: 306-652-8202

www.denisonmines.com

June 29th, 2023

Denis Saumure
Commission Registrar
Commission Registry
Canadian Nuclear Safety Commission

Denison Mines Corp. Application for the Wheeler River Operation

Dear Denis Saumure,

Pursuant to the *Nuclear Safety and Control Act* and the *Uranium Mines and Mills Regulations*, Denison Mines Corp. (Denison) is seeking a licence to prepare a site and construct a uranium mine and mill. Please find the enclosed the primary top-level documents intended to initiate the application process for Denison's Wheeler River Operation:

- Facility Licensing Manual - Wheeler River Operation
- Facility Description Manual - Wheeler River Operation

Required licensee and related project information can be found within the enclosed manuals.

Subsequent licensing documents will be provided by Denison to the Canadian Nuclear Safety Commission (CNSC) over the remainder of 2023 as discussed with our representative Project Officer, Konrad Gorzkowski.

As the project advances and aspects of design are finalized revisions will be made to the documents enclosed. Updated copies will be provided to the CNSC accordingly.

For further inquiries regarding this submission please contact the undersigned.

Regards,

Kevin Himbeault
Vice President Operations and Regulatory Affairs
Denison Mines Corp.

cc: Patrick Burton, Konrad Gorzkowski; CNSC (email)
Janna Switzer, Ryan Nagel; Denison (email)

2 CNSC Letter, C. Salmon (CNSC) to J. Switzer (Denison), Subject: Wheeler River Project – Final Submission of Documents to Support a Licence Application to Prepare Site and Construct a Uranium Mine and Mill, November 22, 2024

File no.:
e-Doc 47342109

November 22, 2024

Ms. Janna Switzer
Vice President, Environment, Sustainability and Regulatory
Denison Mines
Saskatoon Office
345 4th Avenue South
Saskatoon, SK S7K 1N3

Subject: Wheeler River Project – Final Submission of Documents to Support a Licence Application to Prepare Site and Construct a Uranium Mine and Mill

Ms. Switzer,

With reference to the Wheeler River Project licence application, received July 4, 2023, I write to confirm that CNSC staff have performed a sufficiency check of the licensing documents submitted by Denison pursuant section 8.1 of the *Uranium Mines and Mills Regulations* (the Regulations). CNSC staff have determined that the documents Denison provided are sufficiently detailed and that section 8.3(1) of the Regulations is triggered. This section stipulates:

> **8.3(1)** The **Commission** shall render its decision in respect of an application within a time period of 24 months from the day on which the notice is posted in accordance with paragraph 8.2(b).

Note that section 8.3(2) of the Regulations contains various exclusions from the licensing timeframe in section 8.3(1). This includes paragraph 8.3(2)(d), which stipulates:

> **(d)** any period that is required to conduct, and render a decision on, an environmental assessment of the proposed preparation of the site for, and construction of, the uranium mine or mill, or its operation, decommissioning or abandonment, by any jurisdiction that is obligated by law to conduct that assessment and render a decision.

As the federal environmental assessment for the Wheeler River Project is still progressing, the exclusion above applies. This excludes the Wheeler River Project from the requirement for the Commission to render a decision within 24 months from the date on which the notice is posted.

CNSC staff continue to work on both the environmental assessment and the technical assessment of licensing aspects in Denison's file as a matter of priority, in preparation for a Commission Hearing at some point in the future.

Sincerely,

Candace Salmon
Commission Registrar
Commission Registry
Canadian Nuclear Safety Commission

cc: K. Himbeault, R. Nagel, B. England, Regulatory (Denison)
L. Sigouin, P. Burton, K. Gorzkowski, D. Pandolfi, T. Takala, D. Beaton, N. Kwamena,
J. Way, B. Duhaime (CNSC)

3 Wheeler River Project: Final Environmental Impact Statement:

Environmental Impact Statement

4 Denison Mines Corp. Wheeler River Operation, Facility Licensing Manual, Version 2, June 2023

Facility Licensing Manual

5 Denison Mines Corp. Wheeler River Operation, Facility Description Manual, Version 1, June 2023

The information in this reference document is subject to a request for confidentiality under rule 12 of the *Canadian Nuclear Safety Commission Rules of Procedure*. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca) for more information concerning confidentiality.

6 CSA Group Standard, N286 – Management System Requirements for Nuclear Facilities, 2012 edition, reaffirmed in 2022

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

7 Denison Mines Corp. Wheeler River Operation, Management Systems Program, Version 2, March 2025

Denison Mines Corp.
Wheeler River Operation

Management System Program

Document # 6

Version 2

March 2025

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
Version 1	September, 2023	For CNSC Review			
Version 2	March, 2025	Submission to CNSC	T.Gaudry	R.Nagel, K. Himbeault	J.Switzer

Revision History

Version	Date	Description of Revision
Version 1	September, 2023	For CNSC Review
Version 2	March, 2025	2 Organization – *added section containing information on organizational charts, roles and responsibilities, business planning, and safety culture.* 1.4.1 Definitions – *added definitions.* 4.7 Non-Conformance Reporting and Management – *updated section.*

Table of Contents

Figures

1 Introduction

The *Management System Program* (Program) is the cornerstone document for all other Program documents of the Wheeler River Operation (the Operation). It introduces the key processes and procedures that govern how the Operation is managed and is foundational to the eleven Programs following it in the document framework (as shown in Figure 1).

The processes and procedures included in this Program and supporting documents apply to all phases of the Operation and support development in a manner that is efficient, reliable, safe for workers, the environment, and community.

Consistent with all other Program documents, the *Management Systems Program* is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

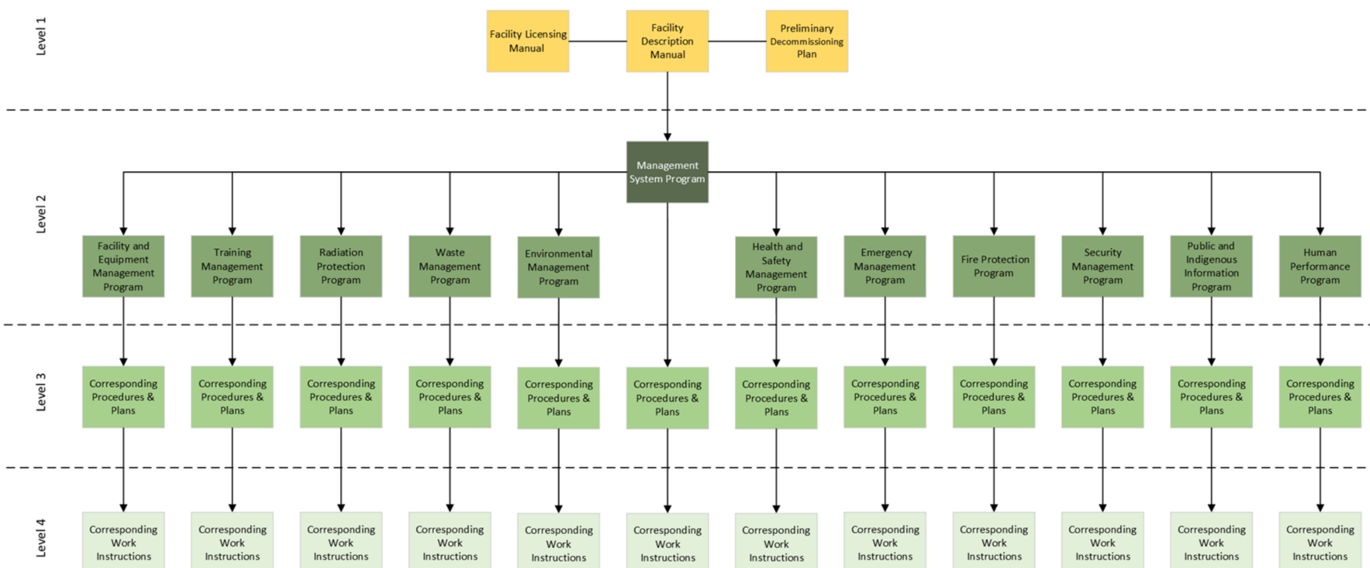


Figure 1: Document Framework for the Wheeler River Operation

1.1 Purpose

This Program provides the structure for the management of licensed activities at the Operation. This Program and the associated supporting programs, plans, procedures, and work instructions describe the systematic management of activities. Activities are managed to achieve consistent product, process, and support services that protect the workers and the environment and comply with legal and other requirements. This Program also describes the organization of the Wheeler River Operation and position responsibility.

1.2 Scope

The *Management System Program* integrates the management practices into a documented, managed, and auditable process, and encompasses:

- Supporting the Operation's commitment to safety, health, and the environment;
- Meeting stakeholder (e.g., local communities, indigenous groups, customers, regulators, shareholders, governments, the public) expectations;
- Supporting activities, processes, and services that consistently meet the needs and expectations of stakeholders in a manner that is integrated with business processes;
- Providing a framework for all programs and underlying processes;
- Following the Plan-Do-Check-Act (PDCA) framework and continually improving processes; and
- Following a risk-based approach which is graded to align the level of risk and control.

1.3 Program Principles and Denison's Environment, Health, Safety & Sustainability Policy

Denison's leadership and employees are committed to managing the Operation in accordance with it's corporate *Environment, Health, Safety & Sustainability (EHSS) Policy*. The *Management System Program* is based on the principles outlined in the EHSS policy, and can be found at Denison's website Environment, Health, Safety & Sustainability Policy.

Policy principles for development, implementation, maintenance, and application of the management system processes include:

- Promoting safety and protection of the environment as the paramount consideration;
- Fostering a strong safety culture;
- Identifying, assessing, documenting, and managing work processes;
- Identifying, assessing, and managing risk;
- Applying controls that are proportionate to the level of risk;
- Checking, assessing, and auditing processes to confirm adherence to requirements;
- Benchmarking and using experience from internal and external sources to improve processes;
- Reporting, recording, and evaluating incidents, near-misses, relevant information, and experience to implement preventive actions, corrective actions, and continually improve the management system;
- Managing information including records and documents;
- Managing contracted work;
- Managing effective and timely internal, external, and regulatory communication;
- Managing physical, process and organizational change; and
- Managing human and physical resources and assets.

1.4 Compliance with Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act* and associated regulations, including the *General Nuclear Safety and Control Regulations,* the *Uranium Mines and Mills Regulations.* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.2.1 *Management Systems.*

Additionally, the Program meets CSA 286-12 *Management system requirements for nuclear facilities.*

1.5 Terminology

1.5.1 Definitions

Term	Definition
Employees	Worker employed directly by Denison Mines
Contractors	Workers employed by a company outside of Denison Mines
Workers	Defines all workers at the Operation, including both Denison employees and contractors
Third Party	Independent evaluations conducted by external organizations

1.5.2 Acronyms and Abbreviations

The following acronyms and abbreviations are commonly used in the Program.

Acronym or Abbreviation	Term
ADDIE	Analysis, Design, Development, Implementation, and Evaluation
ALARA	As Low as Reasonably Achievable
CM	Construction Management
FMEA	Failure Mode and Effects Analysis
FEMP	Facilities and Equipment Management Program
FLRA	Field Level Risk Assessment
HAZOP	Hazard and Operation Study
IAEA	International Atomic Energy Agency
ISR	In-situ Recovery
JHA	Job Hazard Analysis
KPI	Key Performance Indicators
MS	Management System
SAT	Systematic Approach to Training
SMARTER	Specific, Measurable, Achievable, Relevant, Time-Bound, Evaluated, and Reviewed

2 Organization

2.1 Business Planning

Denison's senior management team along with board members meet regularly for the purposes of strategic and business planning, resource planning, dealing with issues and discussing any recent events. Senior management is responsible for:

- Creating vision, values and policies
- Identifying requirements and expectations
- Establishing objectives
- Identifying and controlling risks to the objectives
- Establishes plans, measures and targets
- Measuring and monitoring to achieve planned results

The Corporate Legal Secretary retains minutes of the meetings.

Senior management along with board members will ensure that the Wheeler River Operation has the resources necessary to carry out the business plan.

2.2 Wheeler River Operation Management Team

The Vice President, Operations is the most senior person related to the Wheeler River Operation, having authority over all operational activities at the Wheeler River Operation. All site personnel will report to the Vice President, Operations, who reports to the President & CEO for Denison Mines Corp. The Vice President, ESR is responsible for managing work affecting the Management System Program at the Wheeler River Operation.

Each of the Vice Presidents are responsible within their own department for:

- The work being carried out safely by personnel within their own department
- Ensuring that personnel are competent, adequately qualified, experienced and trained to perform the duties of their position
- That expectations for performance shall be established and employees tested against them
- Workers will be provided feedback on their performance
- Ensuring that employees understand the Management System, and this Program which includes procedures and work instructions necessary for their position
- Ensuring that employees and contractors understand and work to the Environment, Health, Safety & Sustainability policy

The senior management team has the authority for implementing the requirements set out in the Management System Program and the other Programs mentioned in Section 3.5 Work Planning.

2.3 Leadership

Safety of workers, the public and the environment is of paramount consideration guiding decisions and actions. A primary responsibility of leadership is promoting a strong safety culture and providing the resources and processes to support work practices that demonstrate the commitment to safety. Safety Culture processes are outlined in the *Health and Safety Management Program*.

Leadership provides the purpose and direction for the Operation and work performed. Leadership is committed to implementing and maintaining this Program and its associated processes to define, plan, and control of the Operation activities. Leadership actively promotes Program requirements to employees and contractors to support excellence in work performance through its Leadership suite of documents.

Leadership provides direction to workers through the use of daily toolbox meetings, weekly and monthly safety meetings where a variety of Health & Safety topics are discussed.

Safety culture throughout Denison is periodically assessed through the use of anonymous safety culture surveys. Safety culture is assessed by key performance indicators and leading indicators such as near miss reporting and hazard reporting.

2.4 Wheeler River Operation

The Wheeler River Operation consists of four main departments:

Operations Department:

- Design and construction of the Wheeler River Operation and support facilities;
- Site wide training programs, along with Health & Safety and Radiation Protection programs; and
- The Integrated Project Team.

Environment, Sustainability & Regulatory Department:

- Gain regulatory approvals necessary for construction and eventual operation;
- Responsible for Environment, Sustainability and Governance (ESG) reporting as well as public and Indigenous engagement processes; and
- Monitor and report the effects of the operation on the environment.

Technical Services & Project Evaluation Department:

- Design of the In-Situ Recovery Wellfield and Freeze Wall.

Supply Chain Management Department:

- End to end cycle of sourcing goods or services through payment, logistics, warehousing and procurement of materials.

2.4.1 Staff responsibilities

Personnel, regardless of their position (contractor or employee) are responsible for the following:

- The function of their position
- Environmental management

- Radiation protection
- Occupational health and safety

2.5 Overview of Organization

2.5.1 Operations

The Operations Department concentrates on the construction of the Wheeler River Operation. This includes civil works of the site, engineering design and construction of the plant and its auxiliary facilities, operational readiness in preparation for Operation and oversight on conventional health and safety and radiation protection measures.

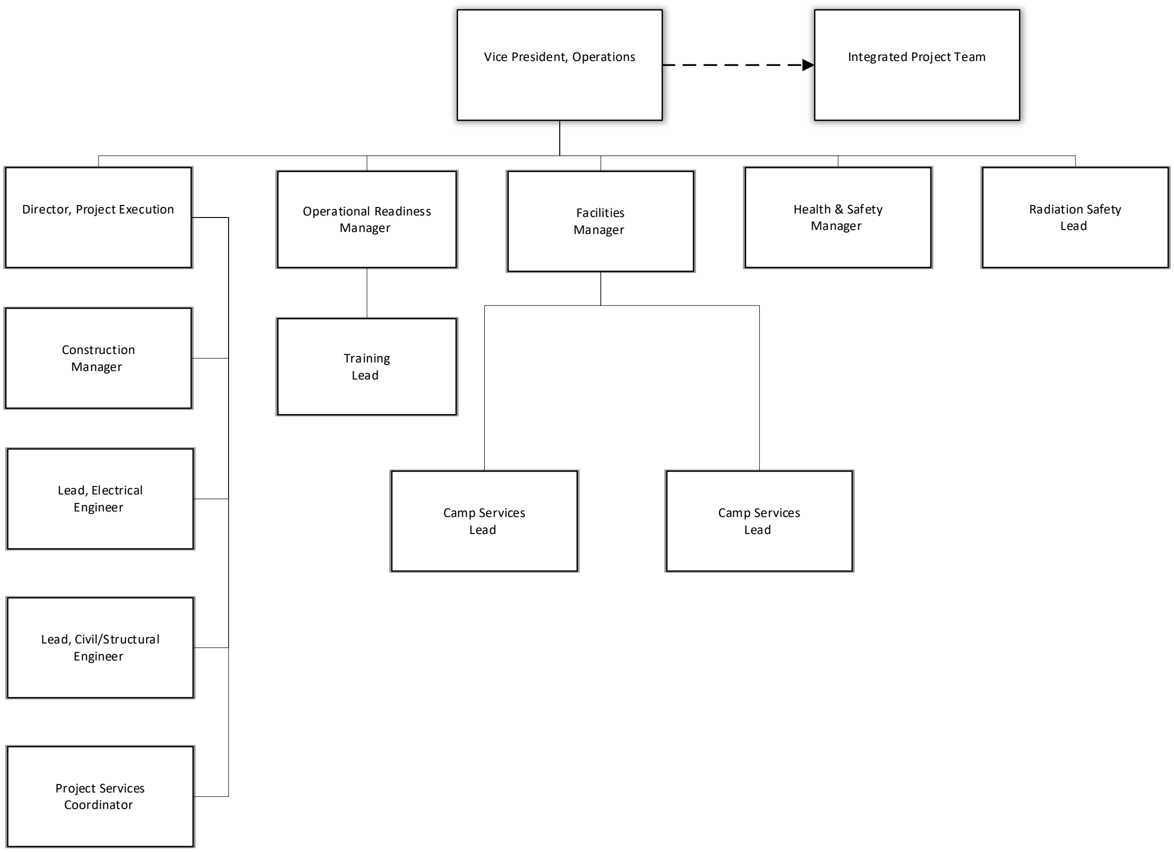


Figure 2 Operations Group

Vice President, Operations

Responsible for the overall construction and operation of the Wheeler River Project, including the wellfield, process plant and other auxiliary facilities.

Director, Project Execution

Responsible for overall engineering and project execution deliverables.

Construction Manager

Responsible for ensuring construction activities are consistent with Project Execution Plan.

The intermediary between Denison and the Construction Management Contractor.

Lead, Electrical Engineer

Responsible for the design of electrical components of the Project

Lead, Civil/Structural Engineer

Responsible for planning and design of civil grading, buildings and infrastructure.

Operational Readiness Manager

Responsible for operational planning.

Training Lead

Responsible for the Training Program for the operation.

Facilities Manager

Responsible for overseeing Wheeler River camp and its facilities.

Camp Services Lead

Oversee the day-to-day operations of camp, hospitality staff and guests at Wheeler River.

Health & Safety Manager

Responsible for the Health & Safety Program, as well as training related to Health & Safety.

Radiation Safety Lead

Responsible for the Radiation Protection Program.

2.5.2 Integrated Project Team (IPT)

This Project is a large-scale project and involves a contracted Construction Management team integrated with Denison's project team to ensure the safe and efficient execution of the project deliverables.

The Project Sponsor has overall responsibility for the efficacy of the Project. The Project Sponsor authorizes the execution of the Project, including the scope, budget, schedule and contractual arrangements. The Project Sponsor for the construction of the Project is the Vice President, Operations.

Note: the organization chart showing in green are Denison employees that will be a part of the IPT. Their roles and responsibilities can be found in: Section 2.5.3, ESR & Section 2.5.1, Operations.

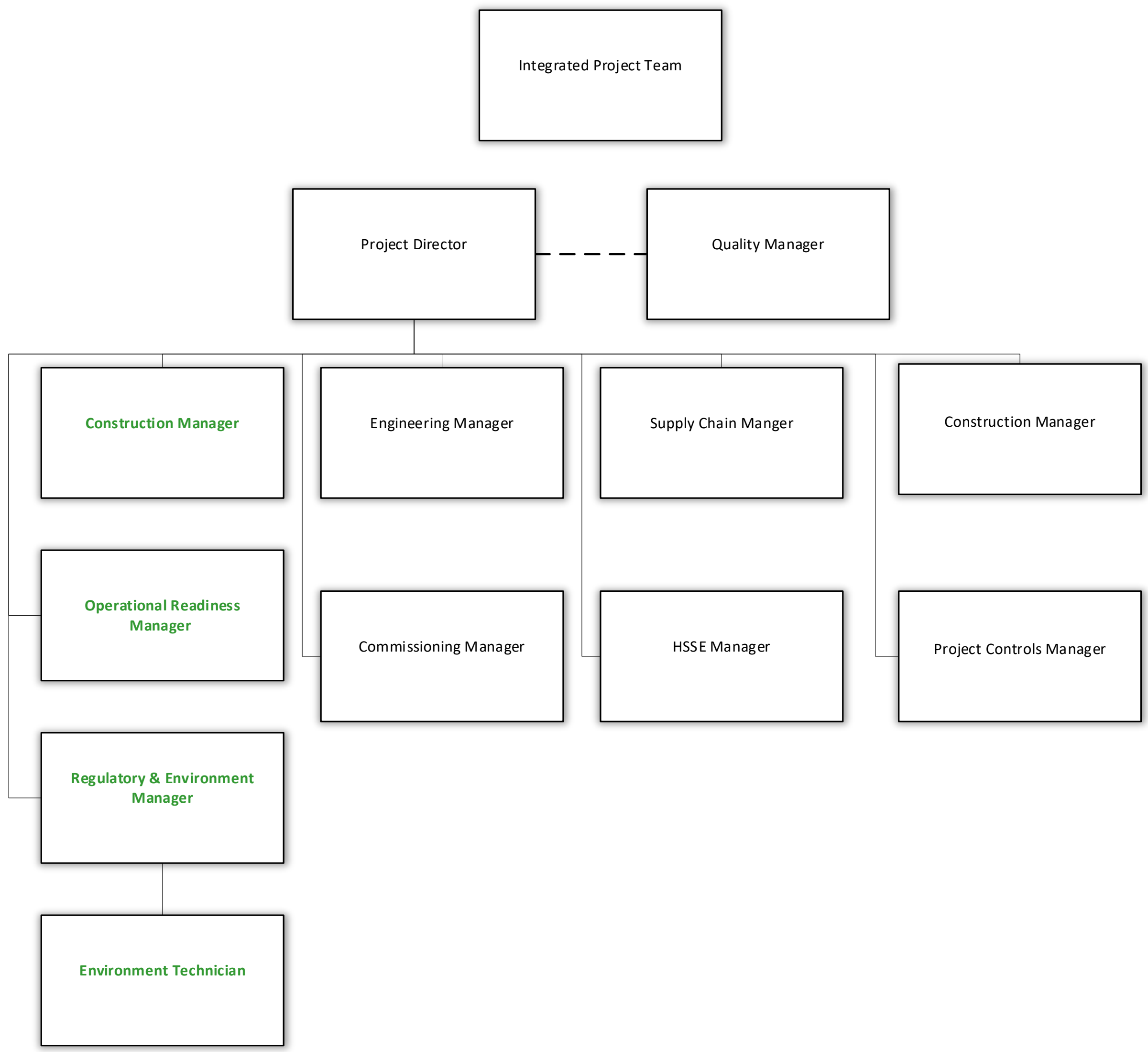


Figure 3 Integrated Project Team

Project Director

Provide leadership to the project team on all matters and ensure employees carry out their duties and responsibilities. Includes providing adequate resources to achieve desired outcomes.

Quality Manager

Responsible for leadership and execution on all matters pertaining to quality management with respect to pertinent requirements.

Engineering Manager

Reports directly to Project Director, is responsible for managing the disciplines Lead Engineers.

Responsible for safe design and implementation of the facility.

Commissioning Manager

Responsible for testing and operating of equipment and systems for the first time after electrical and mechanical completion.

Ensures the design criteria is followed.

Supply Chain Manager

Deals with project requirements for contracts and supplies. Develop RFP packages, and ensures efficient warehousing of goods ordered for the project.

Construction Manager

Responsible for management of all onsite activities required to successfully complete construction.

HSSE Manager

Responsible for the Health, Safety, Security and Environment of the construction site.

Assist and advice the Project Director and Construction Manager in meeting HSSE objectives and targets.

Project Controls Manager

Ensures the cost control of the project. Creates and maintains project controls file, monitors progress of the project according to schedule.

Ensures the coordination and management of all work interfaces with engineering, supply chain management, construction, commissioning, information management, finance, quality and the Denison project team.

2.5.3 Environment, Sustainability & Regulatory (ESR)

The ESR Department is working towards gaining the licenses required to begin construction and the eventual operation of the Wheeler River Operation. The department also monitors and reports on the environment, as well as environment, sustainability and governance reporting. The department is also involved in community engagement, and corporate social responsibility. The ESR Department champions the management system, continual improvement activities and ensures that construction and eventual operation will be in compliance with regulatory requirements.

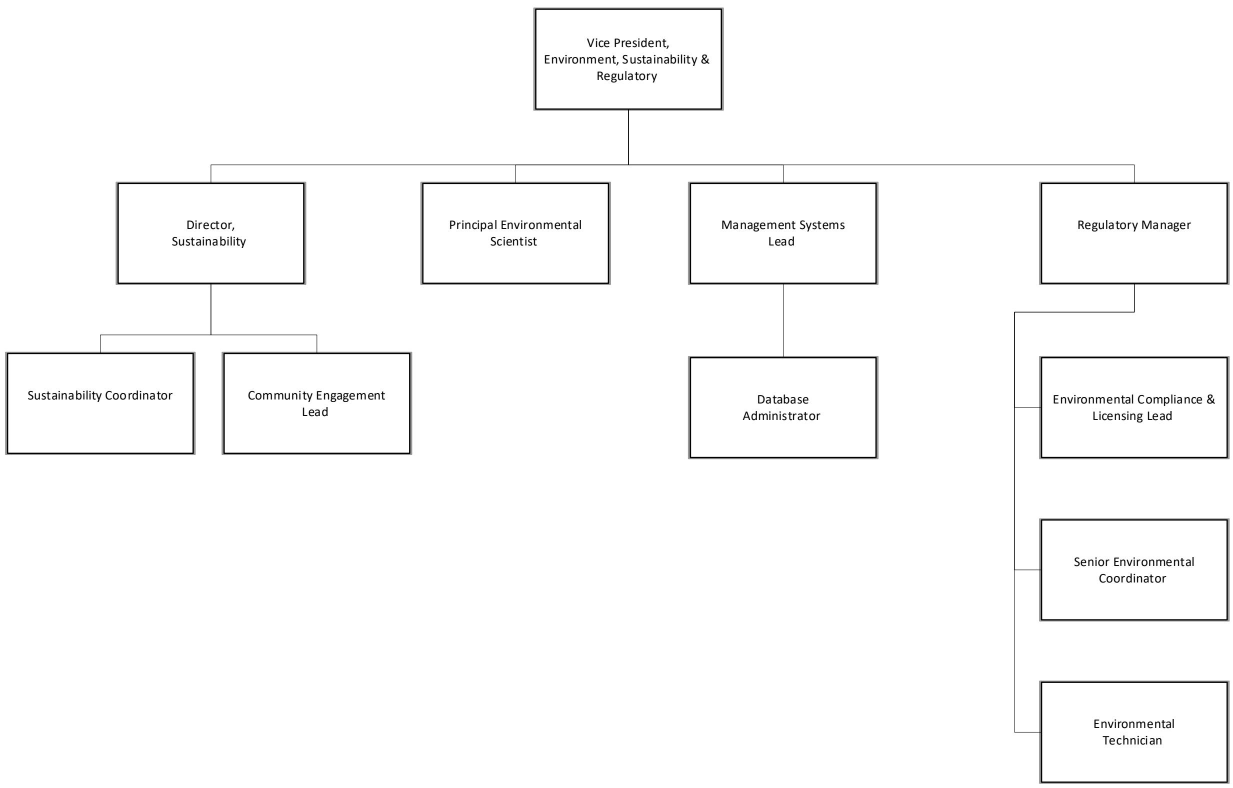


Figure 4 Environment, Sustainability, Regulatory Group

Vice President, Environment, Sustainability & Regulatory

Responsible for overall project permitting and licensing, including adherence to management system programs, environmental program, as well as public and Indigenous engagement.

Director, Sustainability

Oversees public and Indigenous engagement and ESG reporting.

Sustainability Coordinator

Responsible for ESG reporting.

Community Engagement Lead

Responsible for community engagement with communities of interest and stakeholders.

Principal Environmental Scientist

Provide scientific knowledge and lead environmental policy implementation.

Management Systems Lead

Responsible for the Management System Program.

Database Administrator

Responsible for the administration of Denison databases related to environment, health & safety, document control, compliance tracking module.

Regulatory Manager

Responsible for CNSC & SMOE licensing, as well as oversight of the Environmental Monitoring Program.

Senior Environmental Coordinator

Assist with SMOE licensing and permitting for the project and ancillary facilities.

Manage consultants and assist with collection of baseline environmental data.

Environmental Technician

Conduct field work duties of the environmental monitoring program.

Assist with regulatory reporting.

Environmental Compliance and Licensing Lead

Responsible for CNSC licensing.

2.5.4 Technical Services and Project Evaluation

The Technical Services Group is responsible for providing technical aspects of the Wheeler River Operations wellfield.

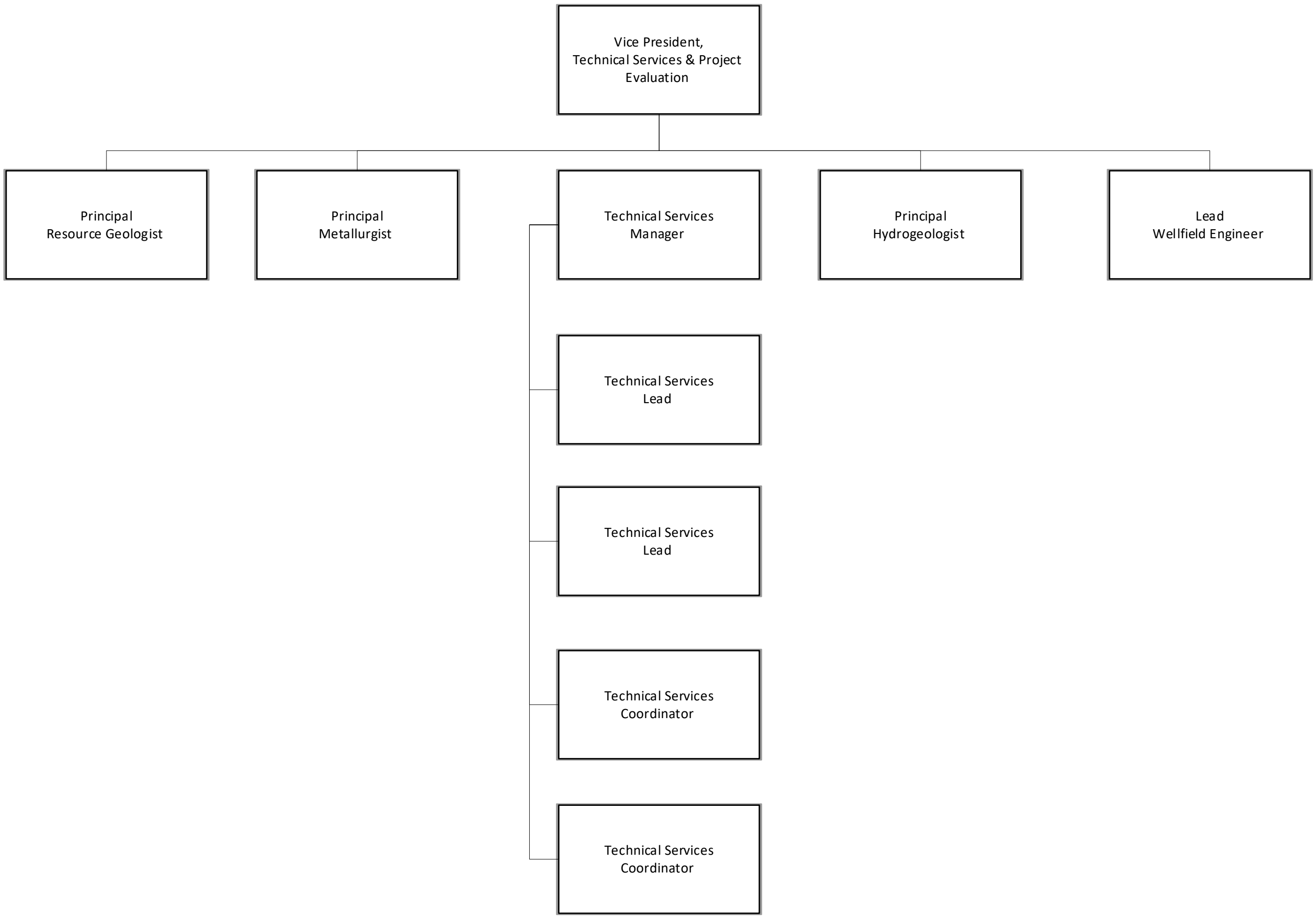


Figure 5 Technical Services and Project Evaluation Group

Vice President, Technical Services and Project Evaluation

Provides technical oversite of the construction and operation of the wellfield.

Principal Resource Geologist

Responsible for providing mineral resource models and geological oversight for Wheeler River and data collection in support of technical studies, mine designs and productive decisions.

Principal Metallurgist

Responsible for metallurgical oversight of Wheeler River, including test work to support process design and optimization.

Technical Services Manager

Responsible for managing assessment of development stage and technical services for assessment of mining method for Wheeler River.

Technical Services Lead

Responsible for executing program to assess development stage and technical services for assessment of mining method for Wheeler River.

Technical Services Coordinator

Responsible for collecting field data to assess development stage and technical services for assessment of mining method for Wheeler River.

Principal Hydrogeologist

Responsible for hydrogeological oversight of Wheeler River, including test work, modeling to support process design and optimization.

Lead Wellfield Engineer

Responsible for the design of the wellfield and associated equipment that satisfies the requirements of the technical services team.

2.5.5 Supply Chain

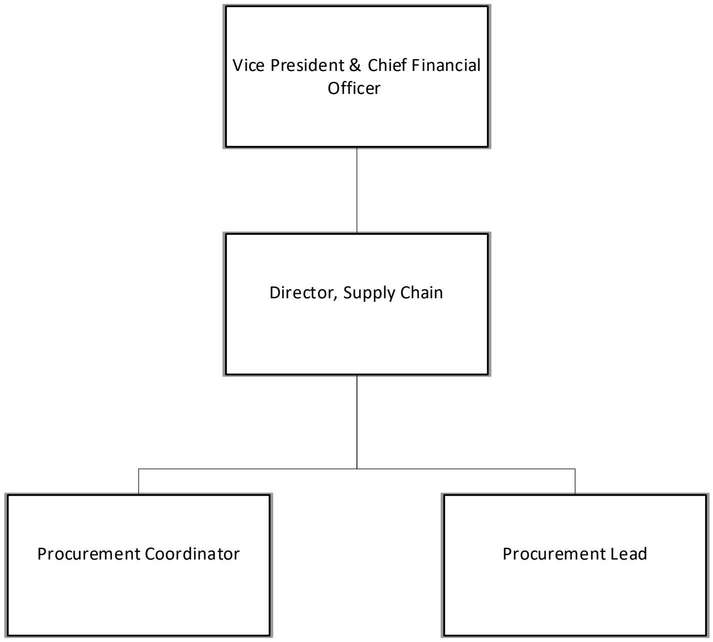


Figure 6 Supply Chain Group

Vice President, Finance & Chief Financial Officer

Ensures the project has the adequate resources to achieve desired outcomes.

Director, Supply Chain

Responsible for the procurement and delivery of materials and services, in addition to logistics and materials management, within the established project budget and schedule. Oversight of Denison's supply chain group.

Procurement Lead

Responsible for development and release of RFP packages, creating purchase orders, negotiating terms and contracts, strategic sourcing of goods and services.

Procurement Coordinator

Responsible for the development of supply chain reports and analysis, coordination of NDAs, issuing of purchase orders, setting up vendors, strategic sourcing of goods, expediting.

3 Plan

3.1 Objectives and Targets

Objectives and targets consistent with strategic plans, EHHS policy and the management system are developed and documented to support alignment of activities.

Objectives are specific, measurable, achievable, relevant, time-bound, evaluated, and reviewed (SMARTER). Targets and associated processes are developed where required to support objectives and mitigate associated risks.

Progress is monitored, measured, and key performance indicators (KPIs) are developed and adjusted as required for critical indicators to mark progress toward completion.

Processes related to objectives and targets are described in the procedure *Objectives and Targets*.

3.2 Resources

The Operation provides, manages, and assesses workers, equipment, facilities, and supporting services required to conduct activities in a safe, reliable manner that protects workers and the environment. Financials are managed to provide assets and competent workers to meet Operation obligations and objectives.

Resources to support the Management System are required by the Operation to ensure the effective and efficient application of the policies, processes and procedures used to achieve its objectives.

3.2.1 Roles and Responsibilities

The roles and responsibilities of workers are defined to provide for alignment with the requirements to safely and efficiently execute the duties and expectations.

Denison management is responsible for:

- Promoting and supporting a safety culture throughout operation activities;
- Providing resources needed to comply with requirements; and
- Following and promoting the requirements of the management system.

Operation management is responsible for:

- The effectiveness of the management system;
- Establishing processes and practices so that workers take responsibility for their safety and safety of others;
- Fostering a healthy safety culture;
- Verifying workers have access to tools, equipment, and required training for performing tasks; and
- Establishing that workers conducting licensed activity are provided with equipment, devices, clothing and procedures in accordance with requirements.

Operation supervisor is responsible for:

- Supervising workers in the area of responsibility in a manner that conforms to management system requirements;

- Promoting and supporting the expectation established by Operation management;
- Assigning tasks to competent workers;
- Require that every person at the site of the licensed activity uses equipment, devices, clothing and procedures in accordance with requirements; and
- Verifying quality of work conducted in their area of responsibility.

Workers and contractors are responsible for:

- Adhering to the management system, legal and other requirements;
- Adhering to Operation training requirements;
- Mitigating the effects of an incident or deviation, if safe to do so;
- Reporting incidents and deviations to supervisor as soon as practicable;
- Performing work safely to protect self and others;
- Checking work inputs, processes and outputs for conformance to requirements and quality of product; and
- Using equipment, devices, clothing and procedures in accordance with requirements.

3.2.2 Legal and Other Requirements

Denison is committed to complying with all applicable legal and other requirements. Internal and external requirements applicable to the Operation are identified, assessed, and managed. External requirements include legal, regulatory, and other requirements with which the Operation chooses to comply. Internal requirements that arise from the management system process requirements and stakeholders (e.g., workers, contractors).

Requirements are regularly monitored, reviewed, and identified changes are managed through the change management process. Legal and other requirements, including identified changes, are communicated to those responsible for managing conformance and compliance.

Processes associated with identifying, assessing, and managing legal and other requirements are described in the procedure *Legal and Other Requirements*. Processes associated with change management are described in the procedure *Change Management*.

3.3 Risk Identification and Assessment

Risks are systematically identified and assessed to prepare appropriate mitigation and control measures. Risk is managed to acceptable levels in alignment with Denison's EHSS Policy and other Corporate Policy expectations.

3.3.1 Hazard and Risk Identification and Analysis

A systematic approach to hazard and risk identification is applied to all licensed activities. Actual and potential hazards and risks are identified using a variety of methods including, but not limited to:

- Use of experience;
- Audits and inspections;
- Process identification and description;
- Incident reporting and cause analysis;
- Workplace observation reporting;

- Monitoring and measurement processes; for example:
  - Noise monitoring;
  - PPE effectiveness monitoring;
- Formal methodologies which may be applied:
  - Job hazard analysis (JHA);
  - Field level hazard assessment (FLHA);
  - What-if analysis;
  - Hazard and operational study (HAZOP); and
  - Failure mode and effects analysis (FMEA).

Following identification, hazards and risks are analyzed in a systematic manner to determine the risk ranking. Risk rankings are numeric values which represent the priority of the risk. Risk ranking are determined using a risk matrix which considers the likelihood and severity of an actual or potential occurrence. The results of this identification and assessment are documented in a risk registry.

3.3.2 Risk Registry

Identified hazards and risk are documented in a risk registry that includes a record of identified controls to mitigate the risk to an acceptable level. The risk registry is a controlled record, updated regularly, and maintained in accordance with the records management process.

The risk registry is consulted during management decision-making, analysis of proposed changes, and to assist in identification of opportunities for improvement.

Processes related to risk registry and risk management are described in the procedure *Risk Management*.

3.4 Work Planning

Work is planned to maintain the health of the Operation including the protection of the health and safety of workers and the environment. A series of approved Programs with supporting documentation describe the processes and controls used to manage work. The programs describe the processes followed for licensed activities at the Operation.

Work is planned to conform to the management system and regulatory requirements. Work plans include a description of the work, requirements for completion, materials, tools, resources, critical steps, plus sequencing, and scheduling. Approved work plans are assigned to trained competent workers and completed using approved processes, resources, and material. The final product of this work is verified as acceptable prior to the work being considered complete.

The *Management System Program* establishes the basis to which all other safety and control area programs are planned to ensure a consistent and efficient application of program elements. The objectives of each program are summarized in the following subsections.

3.4.1 Training Management Program

The *Training Management Program* and associated processes confirm workers are competent and qualified to perform required duties through use of a systematic approach to training (SAT).

The Program establishes and maintains documented procedures for identifying the training needs of the company, provides training to personnel performing activities affecting quality management, qualifies personnel performing specific assigned tasks based on appropriate education, documents and maintains appropriate training and qualification records, and verifies that all workers have been trained to ensure they are fully qualified to perform their duties in accordance with the current regulatory requirements.

3.4.2 Facilities and Equipment Management Program

The *Facilities and Equipment Management Program* ensures that work activities are identified, planned, and controlled, and to ensure that design, selection, procurement, onboarding, and maintenance of site facilities and equipment are carried out under controlled, optimized conditions in a consistent manner.

The Operation confirms that required equipment, facilities, infrastructure, and supporting services are adequate and assessed to verify conformance to quality requirements. Processes related to facilities and equipment include, but are not limited to:

- Asset control;
- Supply chain management;
- Facilities management;
- Equipment management;
- Construction management;
- Commissioning management;
- Design control; and
- Contractor management.

3.4.3 Security Management Program

The *Security Management Program* defines the requirements and framework to promote employee safety, property protection and effectively manage security risks of workers, the public, and the environment.

The Program integrates Denison's security measures into a documented, managed, and auditable process. Key approaches include:

- Identifying, mitigating, and managing security risks;
- Identifying, implementing, and maintaining controls of security risks; and
- Maintaining a safety culture focused on continual improvement of the Program.

3.4.4 Health and Safety Management Program

The *Health and Safety Management Program* defines the requirements, processes, and framework used to promote the health and safety of workers and establish a strong safety culture. The Program integrates Denison's health and safety measures and processes into a documented, managed, and auditable process.

The Program promotes a risk-based, systematic approach to managing risk and occupational health and safety hazards at the Operation.

3.4.5 Emergency Preparedness and Response Program

The *Emergency Preparedness and Response Program* provides processes and structure for overall crisis planning efforts. It further provides a framework for development of the site emergency response plan, processes, work instructions, and further supporting documentation. The EPRP also identifies the plans, outlining specific requirements for emergency response, Wheeler River transportation emergency response, and corporate crisis management.

3.4.6 Fire Protection Program

The *Fire Protection Program* establishes the fire protection goals and associated safety performance criteria. The Operation is designed, operated, inspected, tested, and maintained so that the fire protection goals, and safety performance criteria are achieved.

The Program adheres to a defense-in-depth principle which is used to achieve a high degree of fire protection by providing redundancy, diversity, and balance in fire protection measures.

3.4.7 Environmental Management Program

The *Environmental Management Program* describes and documents Denison's framework for environmental protection in a systematic and effective process which promotes improved environmental performance. It utilizes a risk-based approach to identify environmental protection measures, which is informed by and commensurate with the nature and complexity of the potential interactions of the Operation with the environment.

The Program encompasses:

- Identifying and managing environmental risks;
- Identifying, implementing, and maintaining pollution control activities;
- Effluent and emissions monitoring; and
- Environmental monitoring.

3.4.8 Radiation Protection Program

The *Radiation Protection Program* defines the requirements, and framework to promote radiation safety and effectively manage radiation risks of workers, the public, and the environment.

This Program integrates Denison's radiation protection measures into a documented, managed, and auditable process. Key approaches include:

- Identifying, mitigating, and managing radiation risks;
- Identifying, implementing, and maintaining controls on radiation exposure;
- Keeping exposures in the workplace and the environment ALARA considering social and economic factors;
- Ensuring that workers have the necessary tools, qualifications, and training to perform their work safely in a manner that protects the environment; and
- Maintaining a safety culture focused on continual improvement of the *Radiation Protection Program*.

3.4.9 Waste Management Program

The *Waste Management Program* describes and documents Denison's waste management which governs the waste management practices and proposes effective strategies for minimizing waste generation, improving waste segregation, and implementing sustainable waste management techniques.

The primary goal of this program is to establish a practical roadmap that effectively mitigates the environmental consequences associated with waste, optimizes resource allocation, fosters recycling and reuse initiatives, and improves overall waste management efficiency.

3.4.10 Public and Indigenous Information Program

The *Public and Indigenous Information Program* outlines Denison's policy, principles, and plan to communicate with Indigenous groups and members of the public in support of the development and maintenance of meaningful relationships in relation to the Operation, while also ensuring that information related to the health, safety and security of persons and the environment, and other issues associated with the lifecycle of nuclear facilities are effectively communicated more broadly. The Public Disclosure Protocol is defined within this Program.

The Program will be commensurate with the public perception of risk and the level of public interest in the Wheeler River Operation.

3.4.11 Human Performance Management Program

The *Human Performance Management Program* outlines and describes processes and frameworks for verifying and upholding active workforce participation, regulatory compliance, and continual improvement while creating a workforce culture of support.

Management of human factors within this Program includes, but is not limited to:

- Employee performance and evaluation;
- Discipline processes;
- Fitness for duty;
- Staffing complement;
- Absenteeism; and
- Administration of time-off.

4 Do

4.1 Risk Management

Risks and hazards are identified and managed through the application of controls which reduce the risk of real and potential harm to acceptable levels. Controls are applied using a graded approach which aligns the level of control with the level of risk (safety significance and complexity of work).

The level of risk is quantified using a risk matrix to assign values of likelihood and consequence to determine the risk ranking before and after assignment of controls. Controls serve to reduce the risk ranking to an acceptable level.

Controls are categorized in order of most to least preferred from:

- Elimination;
- Substitution;
- Engineering;
- Administrative; and
- Personal protective equipment.

The risk registry is reviewed at regular intervals to evaluate the risk ranking and the effectiveness of controls.

Processes associated with documenting risks and controls are further described in the *Risk Management* procedure.

4.2 Work Control

Planned and approved work is assigned to trained, competent workers and is completed using approved processes, resources, methods, and controlled documents (e.g., plans, procedures, work instructions and forms). Workers use materials, software, and tools that conform to and were acquired in accordance with management system requirements.

4.3 Change Management

Change from established processes, components, structures, systems, requirements, or organizational structure is managed in a systematic manner following the change management process. The change management process includes identifying the change and providing the reason for the change. Subject matter experts then review the justification, the plan to accomplish the change, and if needed, identify controls for any risks created. Changes are approved and assessed for associated regulatory requirements prior to implementation. Following implementation, the change is reviewed to verify that it is effective and does not create any unforeseen risk.

Change is managed to protect workers, the environment, and property, and to ensure that regulatory requirements are met.

Processes associated with managing change are described in the procedure *Change Management*.

4.4 Document Management

Documents generated for, or as a result of, licensed activities or to support the management system are identified, assigned a unique designation, and controlled in a systematic manner. Controlled documents include, but are not limited to:

- Licenses;
- Policies;
- Programs;
- Plans;
- Procedures;
- Work instructions;
- Forms; and
- Other instructional information.

Documents are controlled to verify current versions are properly presented, accurate, adequate, secure, accessible where and when needed, and confirm obsolete versions are archived. Controlled documents are approved and posted for accessibility. The creation of documents follows a process that includes authoring, reviewing, and approving prior to addition of the document as a controlled document. A database of the documents identified as part of the management system is maintained.

Processes associated with document management are described in the procedure *Document Management*.

4.5 Records Management

Records generated as a result of licensed activities or management system requirements are controlled and protected so that the records are, and remain, readable, complete, and identifiable. Records are traceable to the work activity or item associated with the record. Managed records are retrieved as needed during the specified retention period. Records relevant to licensed activities are made available to regulators as required.

A database of records identified as important to the management system is maintained.

Records are managed in accordance with the processes described in the procedure *Records Management*.

4.6 Communication Management

Communication processes confirm that the appropriate information is shared with appropriate recipients in a timely manner. This information is shared with internal and external stakeholders as required with consideration of confidentiality, business, and regulatory concerns. Incoming and outgoing communication with real or potential impact on licensing, business, and regulatory issues is managed, and a record of the communication is maintained following the records management process.

Workers are made aware of the relevance and importance of their work as it relates to objectives established for the Operation.

Communication with the public and the indigenous communities is managed as outlined in the *Public and Indigenous Information Program*, as well as the procedure *Communications.*

4.6.1 Regulatory Reporting

Regulatory reporting is a specialized communication between the Operation and regulatory bodies. This communication is largely prescribed by regulation. Regulatory communication is a crucial aspect of compliance with licensing requirements.

Processes associated with regulatory reporting are described in the procedures *Communication*, and *Regulatory Reporting*.

4.7 Non-Conformance Reporting and Management

Non-conformances include identified incidents, near misses, and opportunities for improvement. Non-Conformances are identified, documented, and classified so that action is taken to address the problem, eliminate the same or similar incident causes, or address the opportunity for improvement.

Workers and visitors are required to immediately report non-conformances to a supervisor. Non-conformances may result in unwanted outcomes, including, but not limited to, injury, illness, radiation exposure, unplanned discharge to the environment, damage to assets or infrastructure, disruption to work, failure to comply with a regulatory requirement, or a security breach.

When a near-miss, non-conformance, or deviation from the management system, legal or other requirement is identified and if safe to do so, the situation is controlled to the extent possible and reported to a supervisor or management representative. Data collection, and preliminary investigative details are collected and followed by investigation, if needed, to determine the cause and develop the appropriate preventive or corrective actions. Preventive and corrective actions are evaluated to ensure effectiveness in addressing causes of the incident prior to closing an incident report.

A record of each incident is initiated as soon as practicable and updated with relevant information throughout the incident management process. In addition, data from incident records is used for trend analysis to support continual improvement. Records of the incident and associated actions are maintained as described in the procedure *Records Management*.

Regulatory requirements for reporting specific types of incidents to regulatory bodies are managed through the regulatory reporting process as described in the procedure *Communication*.

Processes related to non-conformance reporting and management are described in the Non-Conformance Procedure. Processes related to non-conformance investigations are described in the work instruction *Investigation*.

4.8 Construction, Commissioning, and Turnover

The processes for control of construction and commissioning of structures, systems, and components are established and described in the *Facilities and Equipment Management Program*. Construction and commissioning outputs are controlled to confirm design requirements are met.

The turnover of structures, systems, components, and supporting documentation to the Operations phase is controlled following processes described in the *Facility and Equipment Management Program*.

4.9 Contractor Management

Management system processes apply to contractors working for the Operation on licensed activities. Contracted services are controlled using the graded approach to align with the risk and complexity of the tasks being performed.

The processes associated with contractor management are described in the *Facility and Equipment Management Program* and the *Contractor Management Plan*.

4.10 Supply Chain

The supply chain process applies to procurement of materials and services required for safe, reliable production, support, and management functions.

The processes and controls for the procurement of goods and services and supply chain management are described in the *Facility and Equipment Management Program* and the *Supply Chain Management Plan*.

The processes associated with supplier audits are described in the procedure *Audits* and *External Audits*.

4.11 Training and Competence

Training processes are implemented to provide workers with the required training to support safe and efficient completion of assigned work. Training records are maintained in accordance with the *Records Management Procedure.*

Training processes follow the SAT standards and use the analysis, design, development, implementation, and evaluation (ADDIE) model.

Processes associated with training activities are outlined in the *Training Management Program.*

4.12 Design Control

Initial design control occurs in the early stages of project development including site selection, and is addressed through feasibility studies, environmental assessments, licensing, and permitting processes.

Subsequently, processes are followed to establish design inputs, define requirements, and carry out design. The creation and maintenance of design documents used during construction, commissioning, operation, and decommissioning are managed in accordance with the *Facility and Equipment Management Program* and the *Engineering Design Control Plan*.

5 Check

5.1 Monitoring and Measurement

Monitoring and measurement of the management system processes are conducted on a continuous basis to verify the processes are implemented, operating efficiently and in accordance with requirements and objectives.

Monitoring and measurement processes serve to assess the effectiveness of the management system and identify areas that may benefit from change or improvement.

Monitoring and measurement testing activities and outputs are of value to management and regulatory bodies to verify that processes are operating effectively and to the expected standard, particularly as it may impact safety of workers and protection of the environment.

Monitoring of structures, systems, and components includes performance monitoring, periodic testing, inspection, calibration, and verification. Monitoring and measurement activities specific to construction, commissioning, procurement, maintenance, and contractor management are described in the *Facility and Equipment Management Program*, *Supply Chain Management Plan,* and *Contractor Management Plan*. Other Programs include specific monitoring and measurement activities, for example, radiation monitoring and environmental monitoring are described in the *Radiation Protection Program* and *Environmental Management Program* respectively.

Key performance indicators may be developed for monitoring and measurement of critical indicators, particularly, but not limited to, areas such as safety of workers, environmental protection, high-risk activities, and regulatory interest.

Processes associated with monitoring and measurement are described in the procedure *Monitoring and Measurement*.

5.2 Inspections

Inspections are conducted by internal and external groups to assess conformance to management system requirements and compliance to legal and other requirements.

External inspections include regulatory inspections conducted on behalf of regulatory agencies to assess activities for level of compliance. Other external inspections may be initiated by customers, associations of which the Operation is a member, and potentially international agencies.

Internal workplace inspections are conducted to assess compliance with regulatory requirements and conformance to management system requirements. Inspection schedules, plans, and findings are recorded. Inspection findings are recorded in the incident reporting system and investigated and addressed accordingly following the corrective actions process.

Processes associated with inspections are described in the procedure *Inspections*.

5.3 Audits

Audits are used to monitor and verify conformance to management system requirements, effectiveness of the management system, and compliance to legal and other requirements, as well as identify opportunities for improvement.

Audits may be initiated:

- Internally to provide an independent assessment on behalf of management to confirm the management system process meets requirements and is effective; or
- Externally on behalf of regulators, customers, registrars for recognized organizations, or groups to verify compliance to requirements.

Auditors are provided access to the work site, the work, documents, and records.

Internal audits are planned and conducted following a documented audit plan, which includes the schedule and scope of audits to be conducted. Audit plan considerations include, but are not limited to, regulatory requirements, management system requirements, and risks associated with licensed activities.

Audits are conducted by auditors independent of processes being audited and follow the audit process and protocols as described in the procedure *Audits* and *External Audits*.

Internal audits may be conducted by specialists within the organization or may be contracted following the supply chain process. External audits may be conducted by auditors representing customers, regulators, or other associations to which the Operation chooses to belong.

Regarding supply chain processes, the Operation conducts audits of suppliers to confirm the initial and ongoing acceptability of suppliers' management systems. If supplier audits are conducted by a third party, the Operation audit process owner is responsible to verify audit results are acceptable, and the process conforms to the procedure *Audits* and *External Audits*.

Workers are required to cooperate with auditors during the audit process.

Audit findings are recorded in the incident reporting system and addressed accordingly through the corrective action process. The responsible party initiates the corrective action process to resolve identified deficiencies or address opportunities for improvement.

Processes and protocols associated with audits are described in the procedure *Audits* and *External Audits.*

5.4 Self-assessment

Workers conduct self-assessments to confirm that approved processes are followed, and their work meets established requirements.

Management is responsible for conducting self-assessments to identify opportunities for improvement and confirm that the work meets management system requirements.

Processes associated with self-assessment and management review are described in the procedure *Self-assessment and Management Review*.

5.5 Management Review

At regular intervals, management reviews management system operations to determine its continuing suitability, adequacy, effectiveness, and alignment with Operation objectives.

Management reviews include, but are not limited to, monitoring and measurement results, change management processes, incident reports and trends, opportunities for improvement, customer and supplier interactions, resources, and risk management activities.

The review is documented, and outputs include, but are not limited to, identified opportunities for improvement, change recommendations, and resources adjustments.

Processes associated with self-assessment and management review are described in the procedure *Self-assessment and Management Review*.

6 Act

6.1 Preventive and Corrective Action

Preventive and corrective actions are determined based on the outcomes of reporting, analyzing, and investigation of incidents, near misses, and opportunities for improvement.

Corrective and preventive actions are taken to:

- Prevent injuries and illness to workers, contractors, and visitors;
- Protect the environment;
- Prevent and mitigate damage to equipment and property; and
- Achieve efficient process and optimize its costs.

Processes associated with preventive and corrective actions are described in the procedure *Preventative and Corrective Action.*

6.2 Use of Experience

Experience gained from activities at the Operation or from outside sources is documented and reviewed by Operation subject matter experts to determine whether there is value in applying this experience to prevent a problem or improve efficiency of a process. If it is determined the application of the experience is of value, action is taken to initiate the improvement.

Experiences that are not considered confidential or sensitive are made available to others.

Processes associated with use of experience actions are described in the procedure *Use of Experience and Continual Improvement*.

6.3 Continual Improvement

Ongoing efforts are made to seek opportunities to improve the suitability, adequacy, and effectiveness of the management system. This effort includes, but is not limited to consideration of:

- Trend analysis of incidents and identified causes;
- Audit, and inspection findings;
- Changes in the business environment;
- Benchmarking the performance and experience of comparable operations; and
- Periodic assessments against the planned outcomes and objectives.

Results of this evaluation and analysis indicate needs and opportunities for improvements that are addressed through the continual improvement process. If it is determined an improvement action is to be initiated, the change management process is used to implement the change in a systematic and controlled manner.

Processes associated with continual improvement are described in the procedure *Use of Experience and Continual Improvement*.

Outputs from the Act elements form inputs to the Plan elements of the Plan-Do-Check-Act cycle to systematically address recommendations and improve the operation of the management system.

6 References

6.1 Internal

Document Name
Audits (procedure)
Change Management (procedure)
Communication (procedure)
Contractor Management Plan
Document Management (procedure)
Emergency Preparedness and Response Program
Engineering Design Control Plan
Environment, Health, Safety, and Sustainability (EHSS) Policy
Environmental Management Program
External Audits (procedure)
Facilities and Equipment Management Program
Fire Protection Program
Health and Safety Management Program
Incident and Deviation Management (procedure)
Incident and Deviation Management (procedure)
Inspections (procedure)
Investigation (procedure)
Legal and Other Requirements (procedure)
Monitoring and Measurement (procedure)
Objectives and Targets (procedure)
Preventative and Corrective Action (procedure)
Process Identification (procedure)
Public and Indigenous Information Program
Radiation Protection Program
Radiation Protection Program
Records Management (procedure)
Regulatory Reporting (procedure)
Risk Management (procedure)
Risk Matrix (procedure)

Document Name
Risk Registry (Form)
Security Management Program
Self-assessment and Management Review (procedure)
Supply Chain Management Plan
Training and Performance Management Program
Use of Experience and Continual Improvement

6.2 External

6.2.1 Federal

Canadian Nuclear Safety Commission (CNSC). REGDOC-2.2.1, Management Systems

CSA 286-12 Management system requirements for nuclear facilities

General Nuclear Safety and Control Regulations

Nuclear Safety and Control Act

6.2.2 Provincial

The Saskatchewan Employment Act

8 Denison Mines Corp. Wheeler River Operation, Health and Safety Management Program, Version 1, July 2023

Denison Mines Corp.

Wheeler River Operation

Health and Safety Management Program

Document # 12

Version 2

March 2025

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
1	26-Sept-2023	For CNSC Review			

Revision History

Version	Date	Description of Revision
1	26-Sept-2023	For CNSC Review
2	13-March-2025	1.3 Safety Culture – *revised wording, added reference.* 1.5 Compliance with Regulatory Requirements – *corrected reference.* 2.9 Emergency Management – *added detail.* 3.1.4.4 Procedures – *added detail.* 3.1.7 GHS/WHMIS – *added section.* 3.1.7 Return to Work – *added section.*

Table of Contents

Figures

1 Introduction

The *Health and Safety Management Program* (the Program) is one of the Program documents that comprise the Management System for the Wheeler River Operation (the Operation). The *Health and Safety Management Program* is preceded by the *Management System Program* within the document framework for the Operation as shown in Figure 1. Consistent with all other Program documents, the *Health and Safety Management Program* is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

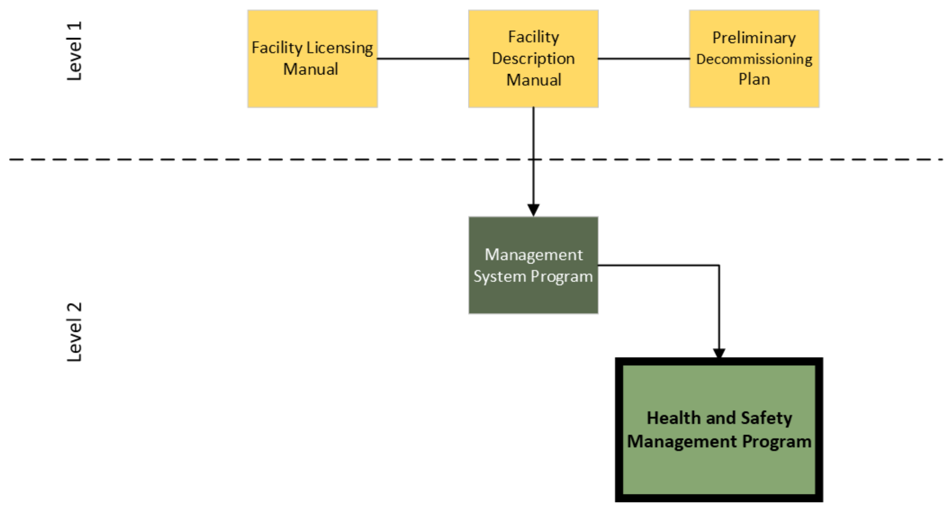


Figure 1: Program shown within Document Framework for the Wheeler River Operation

1.1 Purpose

This Program defines the requirements, processes, principles, and framework used to promote the health and safety of workers and a strong safety culture for the Operation. The Program is a management tool that is used to integrate Denison's health and safety measures and processes into a documented, managed, and auditable process.

The Program utilizes a risk-based, systematic approach to managing risk and occupational health and safety hazards at the Operation.

1.2 Scope

The Program is established to ensure compliance with regulations and company policy and principles for establishing safe work practices at the Operation.

Occupational health risks arising from ionizing radiation fall within the scope of the *Radiation Protection Program*. To protect overall worker health, this Program and the *Radiation Protection Program* operate in concert, wherever practicable.

1.3 Safety Culture

Denison is committed to building a strong health and safety culture that empowers workers to be health and safety promoters at the Operation. Assessments of the culture provide feedback and contribute data to safety key performance indicators (KPIs) and safety audit results. Safety culture shall be influenced as described in the *Management System Program* including utilizing strong leadership at all levels of the organization. Leaders will improve current safety climate utilizing *DMC-HS-164-Field Leadership* which over time will positively affect safety culture.

Additionally, the safety culture:

- Encourages and values worker and contractor input during daily, weekly, and monthly safety discussions;
- Fosters and promotes proactive prevention of workplace incidents utilizing leading indicator reporting of hazardous conditions and near misses; and
- Supports continual improvement by meeting cross functionally with various levels of leadership.

1.4 Program Principles and Denison's Environment, Health, Safety & Sustainability Policy

Denison recognizes the importance of worker health and safety to achieve Operation outcomes of safety and reliability, while fostering the approach to preventing workplace injury, illness, and disease.

Denison's commitment to health and safety is communicated in its corporate *Environment, Health, Safety, and Sustainability Policy*, applicable to all its facilities. The *Health and Safety Management Program* is based on the principles outlined in that policy and can be found in the *Management System Program*.

1.5 Compliance with Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act (SC 1997, c.9)* and associated regulations, including the *General Nuclear Safety and Control Regulations (SOR/2000-202), The Uranium Mines and Mills Regulations (SOR2000-206).* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.1.2, *Safety Culture,* and REGDOC 2.8.1 *Conventional Health and Safety.*

Additionally, the Program meets provincial requirements including *The Saskatchewan Employment Act, S-15.1,* and the *Occupational Health and Safety Regulations, 2020.*

1.6 Terminology

1.6.1 Definitions

Term	Definition
As low as reasonably achievable (ALARA)	A principle of radiation protection that holds that exposures to radiation are kept as low as reasonably achievable, social, and economic factors taken into account.
Field level hazard assessment (FLHA)	A process of hazard identification and control (mitigation) in work planning conducted by all workers involved in performing a task. An FLHA is conducted in the field.

Job hazard analysis (JHA)	A hazard identification and control process used to describe each task of a job, the associated hazards, and controls required to mitigate the risk of each hazard and keep workplace exposures to hazards ALARA.
Key performance indicator (KPI)	A quantifiable measure used to evaluate the success of a process or organization in meeting performance objectives. A KPI must be consistently measurable, comparable to a target, and display change over time (i.e., trending).
Licensed activities	Operation activities within the scope of Canadian Nuclear Safety Commission (CNSC) licensing. Operation site-based activities that may be outside the scope of CNSC licensed conditions are subject to the integrated management system on a risk-informed basis (i.e., where the consequence of human error poses a risk to the environment, the health and safety of people, or to the security of Operation facilities).
Personal protective equipment (PPE)	Includes equipment an individual must use to minimize hazards associated with doing a particular task. This includes safety glasses, gloves, hard hats, safety boots/shoes, coveralls, respirators, harnesses, etc.
Prime contractor	Contractor, under contract directly with Denison, who is responsible for the completion of a defined project and who directs the work of multiple sub-contractors to do the same.
Safe work practice	A governing document outlining the foundation for the safe execution of a specific type of work or job by providing a mandatory set of minimum standards for the work to be done. Safe work practices are commonly referred to as the "Do's and Don'ts" around a job.
Work instruction	A document that sets out the sequential steps for completing a particular task in a safe manner.
Worker	Any person working for Denison, including contractors.

1.6.2 Acronyms and Abbreviations

Acronym or Abbreviation	Term
ALARA	as low as reasonably achievable
FLHA	field level hazard assessment
JHA	job hazard analysis
KPI	key performance indicator
PPE	personal protective equipment

2 Plan

2.1 Risk Management

Risk management identifies, assesses, and controls risks to workers, the environment, systems, facilities, and equipment associated with a task or process. The operation adopts a consistent and integrated approach to risk management to identify, manage, and mitigate risk.

This process includes identifying health and safety hazards that can affect workers, the environment, or the public, determining the significance of any associated risks, and mitigating the risks to acceptable levels by applying controls.

2.1.1 Hazard Identification

Health and safety hazards are conditions or agents that can potentially cause harm in the form of physical injury, illness, or disease from differing work environments, conditions, circumstances, or the characteristics of physical, chemical, biological, or psychosocial agents.

Hazards are identified using appropriate types of assessment which are documented and tracked. Typical assessments include job hazard analyses (JHAs) and field level hazard assessments (FLHAs).

Procedures or processes involving identification and control of ionizing radiation are discussed in the *Radiation Protection Program*.

2.1.2 Hazard and Risk Assessment

Hazards are initially assessed using tools including JHAs and job observations. Once controls are in place for the known hazards, an FLHA is used to identify daily changes in conditions and assess hazards specific to the work location.

Risks to worker health and safety are assessed considering:

- Potential injury;
- Potential health exposure;
- The severity and frequency of exposure;
- Duration of exposure to the hazard; and
- Workers potentially at risk.

Risk matrices for the type of assessment performed are used to correlate the frequency, duration, and severity of each health and safety risk.

Results of the risk assessment process are used to identify and develop appropriate controls to mitigate risks to acceptable levels.

2.1.3 Risk Register

Denison uses a risk register to proactively identify and address significant health and safety aspects, prioritize resources, and continuously improve its health and safety practices. The risk register is a central repository for recording and tracking information related to the significant health and safety aspects.

The risk register can include information such as: risk identification, risk assessment, risk analysis, risk evaluation, risk prioritization, risk mitigation, risk monitoring and review. Further details on the risk register are provided in the *Management System Program*.

2.2 Objectives and Targets

Objectives and targets of this Program will be measurable, documented, and tracked. Performance against the objectives and targets will be communicated at regular intervals (i.e., during Management Review), and opportunities for continual improvement will be identified.

Health and safety and Safety Culture objectives and targets can better control existing significant risks and continual improvement of current practices. These objectives and targets are tracked using KPIs.

The process for setting overall objectives and targets is outlined in the *Management System Program* and supporting procedure.

2.3 Resources

Denison is committed to providing the necessary resources to support effective development, implementation, maintenance, and continual improvement of the Program, including achievement of its objectives and to encourage and grow an acceptable and strong health and safety culture.

2.3.1 Roles and Responsibilities

This subsection outlines the specific roles and responsibilities within the Program, including Site Management, Health and Safety Management, Site Supervision, Site Workers, and Occupational Health and Safety Committee, and other workers with various levels of responsibility.

For effective implementation of this Program, workers are informed of their roles and responsibilities and are accountable for comprehending and performing them. Executive and Leadership level roles and responsibilities are included in the *Management System Program*.

<u>Site Management</u>

- Promoting an environment that safety is a main consideration influencing decisions and actions at all levels of the Operation;
- Approving annual Program objectives and targets;
- The integration of Program requirements into various processes and phases of the Operation;
- Ensuring the effectiveness of this Program;
- Communicating the importance of effective management and of conforming to Program requirements;
- Allocating adequate and appropriate resources to fulfill Program implementation;
- Developing proper documentation and tools to implement this Program effectively;
- Controlling health and safety incidents and deviations and directing corrective action when required;
- Participating in the management review process;
- Ensuring oversight of processes with inspection and auditing activities; and
- Identifying, developing, and taking opportunities for continual improvement.

Health and Safety Management

- Overseeing development, implementation, and compliance to this Program;
- Communicating with the applicable regulatory agencies (e.g., CNSC, LRWS) on behalf of the Operation;
- Setting objectives and targets, monitor performance, and prepare internal and external reports regarding activities and outcomes of the Program;
- Managing resources confirming legal compliance with regulatory needs and standards, and conformance with Program requirements;
- Confirming workers have the training, and awareness of health and safety to perform their duties;
- Audit worker competency as determined by site supervision;
- Working with all departments to confirm those with specific responsibilities are qualified to fulfill their roles within the Program;
- Communicating with external stakeholders, if needed;
- Providing oversight through inspections, audits, and monitoring;
- Reporting to management on functioning and effectiveness of the Program;
- Facilitating management review of the Program; and
- Evaluating the Program to promote, identify, and support continual improvement.

Site Supervision

- Understanding and following the requirements of this program;
- Supporting objectives and targets;
- Demonstrating and promoting attitudes where safety is a main consideration at all levels of the Operation;
- Oversee their departmental functions and verify conformance to program requirements by their crew members;
- Conforming to program procedures and training needs;
- Supporting crew members in planning work activities to eliminate or mitigate health and safety risks;
- Participating in training workers to perform a task or carry out a duty while under close and competent supervision during their training;
- Assigning competent workers to perform work;
- Participating in inspections, investigations, and audits;
- Communicating and coordinating with other department workers, where activities can interconnect, to facilitate effective implementation of this Program;
- Communicating with and direct contractors, as necessary;
- Identifying and supporting scenarios for continual improvement; and
- Participating in management reviews, when required.

Site Workers

- Developing and demonstrating a positive health and safety culture/attitude;
- Understanding and following all health and safety processes and procedures;

- Recognizing, identifying, and promptly communicating any occupational health and safety hazards;
- Working towards fulfilling objectives and targets in their areas of responsibility;
- Adhering to applicable use, care, and maintenance procedures for occupational injury and exposure controls;
- Using equipment, devices, facilities intended for protecting their health and safety as outlined in procedures and training programs;
- Adhering to processes established to protect workers and promote health and safety;
- Co-operating with investigators, inspectors, auditors, and regulators;
- Taking all reasonable precautions to maintain the health and safety of themselves and other workers, including stopping and refusing any work deemed to be unsafe;
- Participating in risk assessment processes for health and safety hazards, including various occupational exposure monitoring programs; and
- Identifying and communicating opportunities for improvement to prevent injury, illness, and disease to themselves or other workers.

Occupational Health Committee

- Representing the workforce by contributing to this Program's development, improvement, and implementation including, but not limited to, hazard identification, risk assessment, and controls activation;
- Promoting a positive health and safety culture;
- Participating in incident investigations, as per regulatory requirements;
- Communicating health and safety concerns to support general awareness of hazards and the mitigation of associated risks; and
- Partnering with health and safety workers to prevent and minimize occupational injury, illness, and disease.

2.3.2 Facilities and Equipment

Facilities and equipment to support the effective implementation of the Program and its related practices are provided to Program staff and applicable workers. Facilities are designed, constructed, operated, and maintained with consideration for worker health, safety, wellbeing, and compliance with legal requirements. Physical infrastructure (e.g., change rooms, laundry), preparation and storage areas (e.g., PPE cleaning and storage areas), and equipment that supports Program implementation and its associated processes are provided to workers.

The Operation provides required fixed and portable equipment and personal protective equipment (PPE) to prevent, eliminate, or reduce occupational injury, illness, and diseases, including:

- Guards, fences, and interlocks;
- Ventilation systems;
- Fire prevention and suppression systems;
- Area and personal gas monitoring systems;
- Airborne dust monitoring and suppression systems; and
- Relevant PPE.

Equipment and buildings meet relevant provincial and federal health and safety standards, codes, and regulations.

The Operation provides monitoring equipment to collect samples and analyze data on physical, chemical, and biological hazards. Monitoring equipment is operated, calibrated, and maintained by qualified workers according to manufacturer instructions and specifications.

2.4 Legal and Other Requirements

Denison is committed to complying with all applicable legal and other requirements related to health and safety management. Types of legal requirements applicable to the Operation include:

- Federal and provincial acts and regulations;
- Environmental assessment commitments and follow-up monitoring; and
- Licensing obligations and commitments.

The process for managing legal and other requirements is outlined in the *Management System Program*. Denison has established procedures to ensure compliance with these requirements and that compliance obligations are regularly reviewed. Any changes relevant to health and safety compliance obligations are monitored and evaluated to determine if updates to the *Health and Safety Management Program* and its supporting Plans, Procedures, and Work Instructions are required.

2.5 Training and Competence

A systematic approach to training (SAT) is used to educate, train, and qualify workers and contractors to perform assigned work. Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely. Program-specific training requirements are defined in the *Training Management Program*.

Records of training activities and competencies will be maintained as outlined in the *Training Management Program*.

Workers and visitors must participate in site orientation. This orientation includes the health and safety policy, introduces applicable procedures, information on camp policies, and personal conduct expectations while at the site.

As per Part 5 of Occupational Health and Safety Regulations, 2020 personnel will be trained to meet the requirements set out in Table 9 *Summary of First Aid Personnel Requirements*. First aid kits will meet CSA Z1220-17, *First aid kits for the workplace*. A first aid register will be maintained accordingly.

2.6 Documentation and Records Management

Denison will establish and maintain documented plans, procedures, and work instructions to ensure effective implementation of the Program. Documentation will be controlled, reviewed, and updated as necessary in accordance with the requirements in the *Management System Program*.

Documents and records will be generated as a result of implementation of the Program and completion of licensed activities. Examples of some records generated specific to the Program can include:

- Health and safety plans, procedures, and work instructions;
- Safe work practices;
- Health and safety related and records (e.g., completed inspection forms, work permits, occupational health exposure monitoring data).

Documents and records are readily accessible to those who require them. Occupational exposure and health records are managed in accordance with applicable privacy legislation. Further information on documentation and records management is provided in the *Management System Program.*

2.7 Communication

Communication both with internal and external stakeholders is a critical element of the Program to promote a strong safety work culture. Information to update workers on safety issues can include, but are not limited to:

- Safety moments included in meetings and training courses;
- Safety-focused toolbox meetings;
- Monthly safety meetings;
- Health and safety information boards;
- Workplace health and safety posters;
- Graphs and charts displaying KPIs and safety statistics;
- Incident debriefings including corrective actions; and
- Town hall meetings.

Workers are informed of their duties and responsibilities in health and safety, any process changes, infrastructure changes, equipment changes, and worker changes that can affect them.

Internal and external communication principles and processes are further outlined in Denison's *Management System Program*. Avenues of internal communication will be established within the Health and Safety Department to ensure that the flow of information from the field and laboratories reaches those in supervisor or management roles and vice versa.

Communication with indigenous communities, local communities, and the public is managed as outlined in the *Public and Indigenous Information Program*.

2.8 Change Management

Change is managed at the Operation to protect workers, the environment, and property, and to ensure that regulatory requirements are met. The Operation's change management process is outlined in the *Management System Program.*

Examples of changes captured by the process can include, but is not limited to changes to the:

- *Health and Safety Management Program* and supporting plans, procedures, and work instructions;
- Structures, systems, and components;
- Health and safety related regulatory requirements;
- Emerging operational risks; and
- Organizational changes.

2.9 Emergency Preparedness and Response

Denison is committed to establishing, implementing, and maintaining a process to prepare for and respond to potential emergency situations.

Emergency preparedness and response for the Operation is within the scope of the *Emergency Preparedness and Response Program*. The Operation is committed to preparing for emergencies and having effective response measures in place to minimize potential impacts on worker health and safety during an emergency event.

Significant medical events that occur will involve adherence to the *Emergency Preparedness Response Program*. *Occupational Health and Safety Regulations, 2020* will be followed to determine the first aid personnel requirements based on a workplace first aid risk assessment and number of workers at the place of employment.

3 Do

3.1 Health and Safety Management and Risk Control

This Program provides guidance and direction on key controls required to maintain a safe and healthy work environment for workers and contractors involved in work activities at the Operation.

Controls identified during risk assessments are used to eliminate, prevent, or reduce the risk of injury, illness, or disease to workers. Controls corresponding to the level of risk are selected and implemented with consideration for the hierarchy of controls as illustrated in Figure 2. Examples of controls include guards, signage, equipment, processes, products, safe work practices, and PPE.

Where practicable and advisable, controls are used in combination to prevent or reduce risk to workers. Controls are used, operated, and maintained according to their design, limitations, training, and documentation.

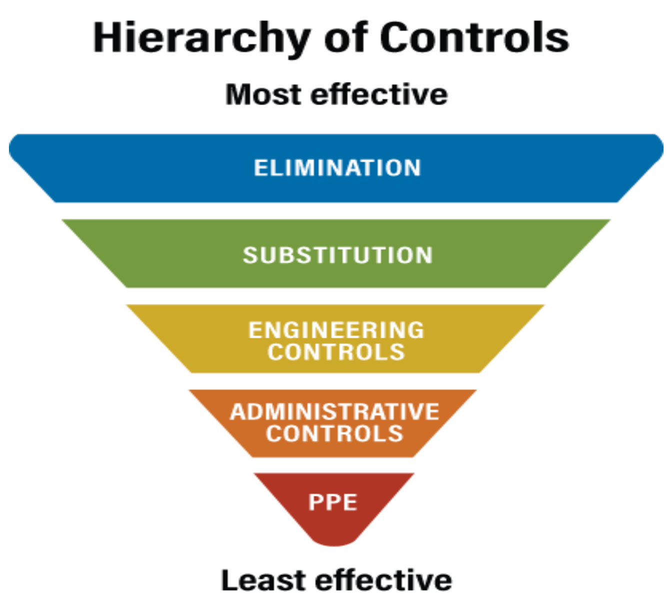


Figure 2: Hierarchy of Controls

3.1.1 Elimination

Wherever possible, hazards must be removed completely (e.g., assemble components at lower levels to eliminate working at height hazards).

3.1.2 Substitution

After a risk assessment, items can be replaced with less hazardous ones (e.g., using a non-toxic or less toxic chemical rather than a toxic one, using a weaker acid instead of a concentrated acid).

3.1.3 Engineering Controls

If eliminating or substituting a hazard is impractical, then risk can be mitigated with engineering controls. Engineering controls can include re-designing facilities and processes, equipment, or systems to reduce the exposure to the hazard (e.g., guards around moving parts, exhaust ventilation systems to remove gases or dust, interlocks). Design changes must go through the change management process as defined in the *Management System Program*.

3.1.4 Administrative Controls

Administrative controls include written safety procedures, processes, and rules, along with supervision, training, signage, and work permits. Administrative controls are usually implemented together with other types of controls (e.g., engineering, substitution, PPE).

3.1.4.1 Work Permits

Work permits are written controls detailing requirements for performing certain tasks in certain areas. Tasks requiring work permits include:

- Hot work (i.e. welding and cutting);
- Tasks with the potential for hazardous energy requiring lockout and tagout;
- Tasks performed in a confined space;
- Critical lifts; and
- Radiation work.

Work permits are valid only for the specific job for which they are issued and subject to cancellation if job conditions change.

3.1.4.2 Job Hazard Analysis

A JHA is completed for new or non-routine jobs that do not have documented hazard controls included in work instructions or are classified as critical jobs (e.g., welding in a confined space). The JHA process breaks a task down into its steps, identifies known hazards that are present or are reasonable to occur, and develops controls to maintain worker health and safety. The JHA is completed during the planning stages by site management, supervision, involved competent workers, and qualified persons, if required, in advance of the job start.

3.1.4.3 Field Level Hazard Assessment

An FLHA is performed and used by workers to identify hazards specific to the work location, workers performing the work, and those items that have not been identified during the JHA process. Task steps, hazards and controls identified are reviewed by the supervisor and later audited by the management team. Those that pose significant risk to health and safety are reported and documented and shall be subject to further risk assessment causing the JHA or work instruction to be updated, as required.

3.1.4.4 Procedures

Written and documented steps and controls for completing tasks associated with licensed activities shall be documented in the form of plans, procedures, safe work practices, and work instructions when directed by risk assessment results. Documentation from the planning and implementation process is subject to the document control process.

3.1.4.5 Signage

Signs indicating workplace hazards, requirements, and restrictions are posted at various applicable locations throughout the site. Examples include signs at entrances to work areas requiring specific PPE, confined spaces, and high radiation areas. (e.g., Noise level above 85dbA hearing protection is to be used, No entry to unauthorized persons). Consideration is given to size, visibility, legibility, and legal requirements when designing the signs. Procedures confirm signs are removed when no longer needed.

3.1.4.6 Alarms and Warning Devices

If practical or required by legislation, warning systems are installed using audible, visual, or odorous notification techniques to warn workers of situations that can affect their health and safety such as a change in the work environment or a change or malfunction in a piece of equipment. Examples of warning systems include fire alarms, high pressure alarms, and flashing beacons. Systems are tested periodically to ensure they are functional and reach the correct audience.

3.1.5 Personal Protective Equipment

PPE is vital to worker safety when other controls cannot mitigate a health and safety risk to an acceptable standard. Selection, use, and maintenance of general PPE is described in the procedure, DMC-HS-160 *Personal Protective Equipment*.

PPE is the last line of defense in the hierarchy of controls but can be used with other types of control. PPE is inspected periodically to check that it is not damaged or beyond its expiry date.

3.1.6 Emergency Management

Emergency response plans and further details on emergency management can be found in the *Emergency Preparedness and Response Program*. All plans will be documented, communicated, and posted in specific locations available to all personnel.

3.1.7 GHS/WHMIS

Workplace Hazardous Materials Information System 2015 (WHMIS 2015) is an internationally consistent approach to classifying chemicals and communicating hazard information and has been designed to give employers and workers information about hazardous materials used in the workplace.

For more information please refer to DMC-HS-171 *Workplace Hazardous Materials Information System* procedure.

3.2 Incident and Non-Conformance Reporting

Denison requires that workers, supervisors, and contractors report information relating to health and safety incidents and non-conformances in alignment with the DMC-QUA-105, *Non-Conformance Procedure*. Events are categorized with an actual and potential severity rating, which determines event reporting requirements internally and externally. These incidents include, but are not limited to:

- Near misses;
- Motor vehicle incidents;
- Property damage;
- Injuries whether or not treatment is provided;
- Potential and actual exposures to radiation above action and target levels; and

- Dangerous occurrences.

Incidents and non-conformances that meet or exceed legislated reporting limits are reported to applicable regulatory agencies within legislated timelines. Reporting follows the process outlined in the *Management System Program.*

3.3 Return to Work

In the event of a workplace injury the return-to-work process will be followed. The Return to Work (RTW) process is designed to provide workers who have sustained an occupational injury or illness with modified duties for the purpose of returning the employee to their regular duties within a defined time frame. RTW will be based upon medical restrictions with clear and specific limits as defined by a medical professional. These restrictions may arise from an event resulting from physical, cognitive and/or psychological injury. RTW is a planned process to manage the impact of disability in a workplace.

The documented processes are for the purpose of identifying and providing alternate or modified work (temporary or permanent) for injured workers, if necessary, with a progression to pre-injury work when appropriate. RTW is supported by Denison's *Human Performance Management Program*, Denison's Human Resources Group, and shall be implemented and monitored by the worker's line manager.

3.4 Planned Preventative Maintenance

Equipment and material procured and used for the Operation is subject to inspection and planned maintenance to confirm it is stored, calibrated, and maintained at a specified frequency in consideration of manufacturer and regulatory requirements. This is managed in accordance with the *Facility and Equipment Management Program.*

3.5 Contractor Management

Contractors performing work at the Operation are governed by this Program or an equivalent health and safety management program of their own which has been formally authorized by Denison for use at the Operation. The process for verifying contractors adhere to health and safety requirements, and the process for reviewing and accepting a contractor health and safety management program, is outlined in the *Contractor Management Plan* as part of the *Facility and Equipment Management Program.*

4 Check

4.1 Monitoring and Measurement

Health and safety performance is monitored and measured against established objectives and targets (identified in Section 2.2). Denison will monitor, measure, analyze, and evaluate its health and safety performance based on a defined process outlined in the *Management System Program*.

All monitoring and measurement activities must also meet defined quality assurance and quality control requirements outlined within relevant Plans as part of this Program.

The results of monitoring and measurement activities are communicated internally and externally and documented as part of the WRE-QUA-101 *Records Management* outlined in the *Management System Program.*

4.2 Performance Indicators

The KPIs that result from monitoring show whether the Program is meeting or beating legislated limits on areas such as noise levels, airborne dust concentrations, noxious gas concentrations, radiation levels, chemical concentrations and other materials that can have a deleterious effect on worker health.

4.3 Workplace Exposure and Monitoring

Where occupational exposure monitoring is required for chemical, physical, or biological agents, established sample collection and analysis methods are used to quantify exposure risk. Results from personal occupational exposure and workplace monitoring are collected, maintained, stored, and communicated with the workforce or individual involved.

Review and analysis of personal exposure and workplace monitoring results are performed to identify trends or abnormal results and to take appropriate corrective actions. Exceedances of established internal or external regulatory limits are reported as required. Investigations are initiated and corrective actions implemented in accordance with the corrective action process.

Occupational health assessments are performed as required to evaluate changes to worker health due to exposure to industrial hygiene or occupational health hazards. Work related changes in worker health status that indicate a lack of exposure controls, inappropriate use of controls or factors outside of the workplace that can be affecting the same areas of the body (e.g., noise exposure causing noise-induced hearing loss) must be addressed and corrected in a timely manner.

Occupational health assessments benefit the worker by providing knowledge of occupational health hazards and the appropriate protection from these hazards. Results from occupational health assessments are collected, maintained, stored, and communicated with the worker involved.

4.4 Inspections and Audits

Denison will conduct internal audits of the *Health and Safety Management Program* to assure compliance with the requirements set out in the Program and to determine if the Program is effectively implemented and maintained.

The internal audits will follow the process and procedures outlined in the *Management System Program*.

Inspections and compliance or conformance audits are performed regularly to determine the effectiveness of the Program. Audits are performed by a competent person not involved in the work being assessed.

Workplace inspections are conducted by workers, supervisors, and managers to determine progress of the Program and to facilitate risk management.

Monitoring and inspection activities can include and are not limited to:

- Physical condition inspections;
- Job observations;
- Field level hazard assessment;
- Planned maintenance inspections;
- Daily pre-use equipment checks;
- Safety audits;
- Management of external inspections by regulatory agencies and other third-party auditors;
- Housekeeping inspections; and
- Monitoring of workplace contaminants.

These inspection activities monitor the effective and efficient use of hazard controls and identify any deviations in processes or non-compliance with regulatory standards. Details of how inspections will be performed are outlined in the *Workplace Inspections* procedure.

These audits, inspections and observations also determine the presence and growth of safety culture within the Operation.

4.5 Management Review

The *Health and Safety Management Program* will be reviewed by Denison management in accordance with the defined frequency to determine if the defined Program is meeting its objectives or needs adjustment. Examples of the types of items related to radiation protection that Denison management will review can include, but is not limited to:

- Suitability, adequacy, and performance of program objectives and targets;
- Upcoming or new legislation related to health and safety requirements;
- Recent or planned changes in facility operations;
- Results of monitoring in relation to meeting performance objectives and targets;
- Results of audits and inspections in relation to meeting performance objectives and targets;
- Results of health and safety culture monitoring and assessments;
- Results of occupational exposure monitoring results;
- Identified opportunities for improvement based on trends in injuries, exposures, incident reports and other sources;
- Communications from interested parties;
- Adequacy of resources; and
- Any needs for Program adjustment.

Denison management will identify opportunities for improvement and establish action plans to implement change in accordance with the process outlined in the *Management System Program*.

5 Act

5.1 Corrective Action

Non-conformities or areas for improvement are identified following the process outlined in the *Management System Program* and the supporting procedures. Deviations from this Program and examples of other non-conformities can be found in Section 3.2 and include environmental incidents, near-misses, and deviations from the *Health and Safety Management Program.* Non-conformities can also be identified during inspections and audits.

Responses to identification of non-conformities include investigation of cause, and corrective action if appropriate. Corrective actions are planned, implemented, and reviewed for effectiveness in reducing the risk level. A new hazard and risk assessment is performed once the corrective action is in place.

Corrective actions process is further detailed in the *Management System Program*.

5.2 Continual Improvement

Opportunities for improvement of this Program will be identified and addressed to enhance health and safety performance. The continual improvement process for this Program follows the overall continual improvement process outlined in the *Management System* and the supporting procedures. Continual improvement shall also include updating Program objectives and targets based on changing circumstances or new information. Improvement can involve benchmarking performance against other similar projects and facilities. Any changes identified through the continual improvement process will be implemented in a systematic and controlled manner.

With respect to health and safety management, opportunities for continual improvement shall be identified through workplace inspections, incident investigations, lessons learned, and review of training suitability, adequacy, and effectiveness for the Operation.

6 References

6.1 Internal

Document Number	Document Name
41	Contractor Management Plan
	Emergency Preparedness and Response Program
	Facility and Equipment Management Program
DMC-HS-164	Field Leadership
	Field Level Hazard Assessment
	Human Performance Management Program
	Job Hazard Analysis
DMC-QUA-105	Non-Conformance Procedure
DMC-HS-160	Personal Protective Equipment
	Radiation Protection Program
	Training Management Program
DMC-HS-171	Workplace Hazardous Information Management System
	Workplace Inspection Procedure

6.2 External

Canadian Nuclear Safety Commission (CNSC). *Nuclear Safety and Control Act*

Canadian Nuclear Safety Commission (CNSC). REGDOC 2.1.2, *Safety Culture.*

Canadian Nuclear Safety Commission (CNSC). REGDOC 3.1.2, *Reporting Requirements.*

The Saskatchewan Employment Act

The Occupational Health and Safety Regulations, 2020

The Mines Regulations, 2018

9 Denison Mines Corp. Wheeler River Operation, Facility and Equipment Management Program, Version 2, May 2025

Denison Mines

Denison Mines Corp.
Wheeler River Operation

Facility and Equipment Management Program

Document # 7

Version C

September 2023

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
Version 1	15-Sept-2023	For CNSC Review			

Revision History

Version	Date	Description of Revision
Version 1	15-Sept-2023	For CNSC Review

Table of Contents

Figures

Introduction

The *Facility and Equipment Management Program* (the Program) is one of twelve Program documents that comprise the Management System for the Wheeler River Operation (the Operation). The *Facility and Equipment Management Program* is preceded by the *Management System Program* within the document framework for the Operation as shown in Figure 1. Consistent with all other Program documents, the Program is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

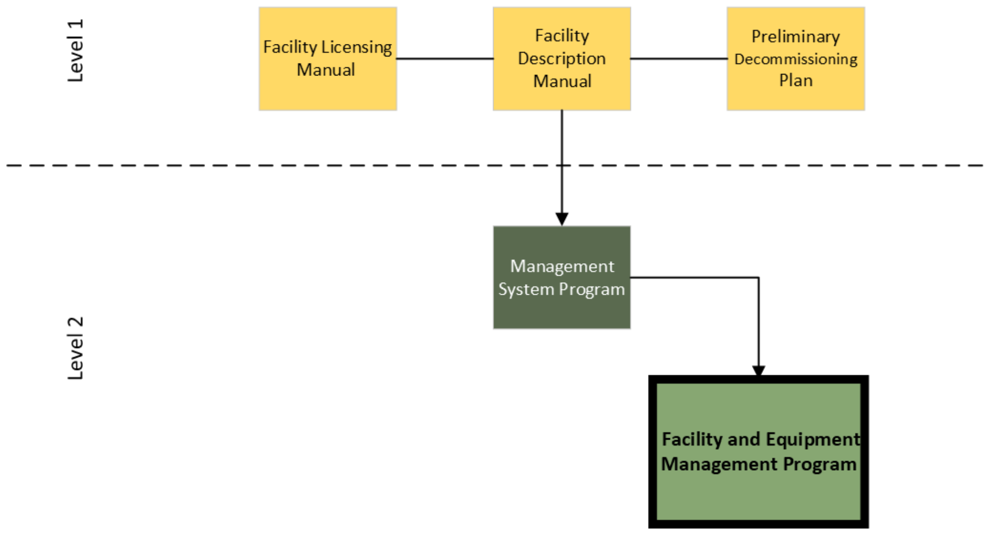


Figure 1: Program shown within Document Framework for the Wheeler River Operation

1.1 Purpose

The purpose of this Program is to ensure that work activities are identified, planned, and controlled, and to ensure that design, selection, procurement, onboarding, and maintenance of site facilities and equipment are carried out under controlled, optimized conditions in a consistent manner.

1.2 Scope

A risk-based, scaled approach to program implementation is taken for all physical assets owned, leased, constructed, commissioned, or operated by the Operation.

Physical assets included in this Program may include constructed or purchased goods, buildings, structural elements, mobile and fixed plant equipment, tools, inventory, and other physical infrastructure. Inventory is defined to include maintenance spare parts, consumables, reagents, and related components.

Leased land, non-physical (knowledge) assets, and financial assets are excluded from the scope of this program.

Contractor purchased and maintained equipment is not within the scope of this program. Contractors may be required to demonstrate a management system meeting the requirements of the appropriate regulations.

1.3 Program Overview and Principles

This Program is designed to align with Denison's overall goal of protecting and promoting the health, safety, well-being of people, and environment through all phases of the project.

Work conducted at the Wheeler River Operation is planned. Routine work conducted at the Wheeler River Operation is performed as documented in established procedure and work instructions. The procedures and work instructions indicate "what" the work activity is, "when" the work activity is to occur and at what frequency, "who" is responsible to complete the work activity, and "how" the work is to be performed.

The procedures and work instructions identify the resources (e.g., tools, materials, PPE) that are required for the work activity, the critical tasks of the work activity that are required to be verified (including verification methods and acceptance criteria), and other documents that are required or referenced for the work activity.

1.4 Compliance with Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act* and associated regulations, including the *General Nuclear Safety and Control Regulations,* the *Uranium Mines and Mills Regulations.* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.5.1, *General Design Considerations: Human Factors,* REGDOC 2.5.4, *Design of Uranium Mines and Mills: Ventilation Systems,* and REGDOC 2.6.3, *Aging Management.*

Additionally, the Program meets provincial requirements including the *Occupational Health and Safety Regulations,* and *The Mines Regulations, 2018.*

1.5 Terminology

1.5.1 Definitions

Term	Definition

1.5.2 Acronyms and Abbreviations

Acronym or Abbreviation	Term

Plan

2.1 Risk Management

All assets are assigned an asset importance ranking, establishing the risk posed by a potential failure. The ranking is based on a matrix of probability and consequence of failure and is assigned by subject matter experts knowledgeable in the design and operation of the system of assets.

The consequence of failure considers both direct impacts arising from the failure as well as impacts related to the resulting downtime of assets and systems.

The probability of failure is assessed based on criteria specific to asset-type. Criteria may include:

- Maintainability, defined as the ability to prevent or mitigate potential failures;
- Serviceability, defined as the ease and ability to recover from failures that have already occurred;
- Whether the equipment represents a "single point of failure" of a system;
- The equipment age and condition; and
- Any related factors.

The results of the asset importance ranking process are used to inform the maintenance methods employed for the asset. A comprehensive, risk-based strategy is developed by equipment subject matter experts (SME), as outlined in the *Maintenance Strategy Procedure*. The maintenance strategy includes the following escalation ranking:

- Assets with a "Low" importance ranking may be maintained in consideration of manufacturers' recommendations or run to failure and replaced.
- Assets with a "Moderate" importance ranking are be maintained in consideration of manufacturers' recommendations. Additional tools, including predictive maintenance inspections, may be used to improve reliability for certain assets or groups of assets.
- Assets with a "High" importance ranking are assessed by a panel of SMEs using a formal process such as failure modes and effects analysis. This assessment first considers the ability to lower the asset importance ranking through engineered controls, then recommends maintenance tools, processes, and schedules to control the residual risk. Tools deployed may include predictive or preventative maintenance methods, procurement and management of critical spare parts, or operating procedures.

Maintenance plans are developed for all moderate and high ranked assets in compliance with the risk-based strategy and all regulatory requirements as outlined in the *Work Management Procedure.*

2.1.1 Risk Register

Denison uses a risk register to proactively identify and address significant facility and equipment management risk aspects, prioritize resources, and continuously improve its risk management practices. The risk register is a central repository for recording and tracking information related to the significant facility and equipment management aspects.

The risk register may include information such as: risk identification, risk assessment, risk analysis, risk evaluation, risk prioritization, risk mitigation, risk monitoring and review. Further details on the risk register are provided in the *Management System Program*.

2.2 Objectives and Targets

Objectives and targets of this Program will be measurable, documented, and tracked. Performance against the objectives and targets will be communicated at regular intervals (i.e., during Management Review), and opportunities for continual improvement will be identified.

Objectives and targets related to facility and equipment management can better control existing significant risks and continual improvement of current practices. These objectives and targets are tracked using KPIs.

The process for setting overall objectives and targets is outlined in the *Management System Program* and supporting procedure.

2.3 Engineering Design

Engineering design at Denison, or completed by contractors on Denison's behalf, is managed in accordance with the requirements of *The Engineering and Geosciences Professions Act*, including the regulatory bylaws and code of Ethics. Engineers responsible for approving and validating work at Denison will be registered as Professional Engineers with APEGS.

Engineering management, including risk and hazard assessment and design review standards, is further detailed in the *Engineering Design Control Plan*. Denison is accountable for upkeep of the plan, ensuring work is completed by licensed professionals with sufficient experience for the work scope, and supervision of engineering work at Denison. Responsible Members are assigned by the permit holder to each major discipline in sufficient numbers to oversee professionals under their area of responsibility.

All engineers completing design work for the Wheeler River Operation are responsible to:

- Follow the *Engineering Design Control Plan* and ensure professionals under their direction are trained in it;
- To participate in quality control and assurance processes for engineering work they are involved in, under the direction and accountability of the responsible member;
- Authenticate and validate engineering and geoscience work in accordance with APEGS standards;
- Maintain good-standing Professional status; and
- Monitor and report any non-conformance to the responsible member.

2.3.1 Human Factors Engineering

Denison considers human factors in facility design, to help assure that interfaces between humans and structures, equipment, or substances during licensed activities occur without unacceptable impacts on workers, the public, or the environment. The *Engineering Design Control* procedure includes requirements for a project-specific human factors engineering plan for new facility construction. This plan includes, at a minimum:

- Constraints, limitations, and assumptions made in plan development;

- Criteria and rational for areas of consideration and program boundaries;
- Roles and responsibilities, including training needs;
- Technical basis (plant design information);
- Technical elements to be reviewed (human-machine interfaces to be assessed);
- Method of assessment for technical elements; and
- Technical guides and policies based on assessment outcomes.

Implementation and verification of human factors engineering plans will be managed in accordance with the *Management System Program*.

2.4 Asset Selection

Asset selection begins during the design process, with the goal of maintaining safety of workers and the environment, complying with regulatory requirements, and supporting reliable system operation. It may include comparative evaluations of potentially suitable assets using a standardized assessment tool. Consideration will be given to worker health, safety, environmental protection, life cycle costs, social considerations, and expert input. Asset selection is managed as outlined in the *Engineering Design Control* procedure.

Asset selection is the process of finalizing asset specifications, including:

- Make, model of purchased equipment;
- Procurement and QA requirements; and
- Performance criteria.

2.5 Asset Onboarding

A systematic approach is used prior to and during asset fabrication and procurement processes to capture relevant data to enable safe and reliable asset operation. At a minimum, this approach includes the following steps:

- Identifying and labelling assets in a consistent manner;
- Assessing operational and maintenance training needs in accordance with the *Training Management Program*; and
- Cataloging all relevant asset data in the operational document management system, in accordance with document management process as outlined in the *Management System Program.*

Asset data may include, but is not limited to:

- Drawings;
- Technical specifications;
- Commissioning reports;
- Equipment manuals;
- Bill of materials;

- Equipment setpoints; and
- Baseline measurements.

The asset onboarding process is described in the *Operation Commissioning Plan* as well as the *Asset Onboarding* procedure.

2.6 Resources

Denison is committed to providing the necessary resources to support effective development, implementation, maintenance, and continual improvement of the Program, including achievement of its objectives and targets.

2.6.1 Roles and Responsibilities

This section outlines the specific roles and responsibilities within the Program, including senior management, site supervisor, and other workers with varying levels of responsibility.

For effective implementation of this Program, workers are informed of their roles and responsibilities and are accountable for comprehending and performing them. Executive and Leadership level roles and responsibilities are specified in the *Management System Program*.

Senior Management

- Responsible for the overall operation of maintenance, engineering, procurement, and inventory management functions, and safe execution of required work to maintain safe, reliable functioning of Wheeler River Facilities;
- Establishing direction, targets, and objectives; and
- Provide resources required for safe execution of these functions.

Supervision

- Responsible for the direct supervision of the various workers, including engineering and trades, required for execution of the Program;
- Accountable for safe execution of maintenance activities;
- Understanding and coaching direct reports in the requirements of this program;
- Communicating and coordinating with other departments to promote safe execution of work; and
- Confirming personnel under their supervision are trained, equipped, and coached as required to perform safe work.

Workers

- Execute safe work in accordance with job plans and instructions, and specialized knowledge and training; and
- Recognizing and communicating hazards associated with their work areas or equipment.

2.6.2 Facilities and Equipment

Facilities and equipment to support the effective implementation of the Program and its related practices are provided to Program staff and applicable workers. The facilities and equipment used for construction, inspection, and maintenance will be of sufficient size and quantity for the work performed and maintained in good working order.

Examples of facilities and equipment used and maintained specific to this Program include, but are not limited to:

- Workshops, including lifting devices suitable for equipment to be maintained;
- Construction shops;
- Heated storage when required for equipment or parts; and
- Specialized tools and equipment required by installation, inspection, or maintenance plans.

2.6.3 Legal and Other

Denison is committed to complying with all applicable legal and other requirements related to facility and equipment management. Types of legal requirements applicable to the Operation include:

- Federal and provincial acts and regulations; and
- Licensing obligations and commitments.

The process for managing legal and other requirements is outlined in the *Management System Program*. Denison has established procedures to ensure compliance with these requirements and that compliance obligations are regularly reviewed. Any changes relevant to training compliance obligations are monitored and evaluated to determine if updates to the *Facility and Equipment Management Program* and its supporting Plans, Procedures, and Work Instructions are required.

2.7 Training and Competence

A systematic approach to training (SAT) is used to educate, train, and qualify workers and contractors to perform assigned work. Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely.

Records of training activities and competencies will be maintained as outlined in the *Training Management Program*.

2.8 Documentation and Records Management

Denison will establish and maintain documented Plans, Procedures and Work Instructions to ensure effective implementation of the Program. Documentation will be controlled, reviewed, and updated as necessary in accordance with the requirements in the *Management System Program*.

Documents and records will be generated as a result of implementation of the Program and completion of licensed activities. Documents and records are readily accessible to those who require them.

Further information on documentation and records management is provided in the *Management System Program.*

2.9 Change Management

Change is managed to protect workers, the environment, and property, and to ensure that regulatory requirements are met. Maintenance work may result in a change to assets if the work results in a change to equipment specifications, operating set points, or work procedures. Work is assessed during the planning process to determine if it qualifies as a change to equipment. Changes to equipment are managed to ensure the change is clearly defined, risks are assessed and managed, and resulting changes to documentation and/or training are completed.

The Operation wide change management process including steps to follow is outlined in the *Management System Program*. Management of changes involving design and installation of new assets are described through the *Engineering Design Control* procedure.

2.10 Vendor management

The purpose of the supply chain management activities is to ensure that safety critical items and services required for various construction and maintenance activities are procured and arrive at the right location in a timely manner.

Vendors are prequalified and categorized into two vendor categories (Approved or Rejected). A controlled list of approved suppliers is maintained. Vendors are selected for request for quotation (RFQ) based on prequalification, previous experience, and compliance with the work requirements.

Vendors are supplied with requests for quotation for safety critical items. Where applicable, information provided may include:

- Scope of supply;
- Performance specifications;
- Applicable codes, standards, and specifications, including jurisdictional requirements;
- Packaging and delivery requirements;
- Documentation requirements and timing;
- Reporting and corrective action requirements;
- Management system standard and applicable requirements;
- Sub-supplier requirements; and
- Required inspection, testing, and acceptance criteria.

The proposals received from the vendors are collected and distributed to the project managers/requisitioners for technical and commercial evaluation.

Bid evaluations consist of a commercial and technical evaluation. Evaluation criteria and weighting are dependent on the specific assets and project requirements. The result of the bid evaluation is to recommend the successful vendor to be awarded the contract.

2.11 Contractor Management

Contractors are responsible for ensuring work adheres to the requirements and standards established by Denison in this Program, as well as the *Health and Safety Management Program*, *Radiation Protection Program*, and any other documentation identified in their contract. Denison is responsible for providing this information to all contractors, and to verify compliance with these requirements. This process is described in the *Contractor Management Procedure.*

Contractors performing maintenance work, including equipment inspections, engineering, or work execution, are subject to the requirements of this Program.

Contractors are responsible to ensure that any equipment, facilities, or other assets owned by or under the control of the contractor are operated and maintained in a manner that maintains safety of the contractor and other workers, and protection of the environment. Contractor equipment is not subject to the requirements of this program but may be audited by Denison to ensure that sufficient processes are in place to maintain the equipment in safe operating condition.

Do

3.1 Asset Maintenance

Asset maintenance broadly refers to actions taken to keep assets in safe operating condition, extend their reliable lifespan, or return them to safe operation following a failure. The workflow is fully described in the *Asset Maintenance* procedure.

3.1.1 Work identification

Work identification refers to the processes by which required maintenance work is identified and documented. Maintenance work at the Operation is identified through the following processes:

- **Preventative maintenance** is work aimed at preventing breakdowns, extending asset life, and keeping assets running in optimal condition. It is identified through a maintenance plan that is automatically scheduled based on calendar, operating hours, or other operational metrics.
- **Predictive maintenance** includes inspection and testing work performed to gauge the current and future health of an asset, and is automatically scheduled based on calendar, operating hours, or other operational metrics.
- **Corrective maintenance** is work identified during predictive or preventative maintenance, during routine operations, or by other SMEs which is required to maintain the assets in safe operating condition and prevent breakdowns.
- **Breakdown maintenance** is work required to repair non-functional assets.
- **Non-routine maintenance** refers to equipment modifications, additions, or removals that are performed by the maintenance team or by contractors through maintenance processes and workflow.
- **Emergency Work** is work that is deemed time critical as a result of a safety or production risk and follows an expedited path through to execution.

3.1.2 Work Approval

Work approval involves both financial and subject matter expert approval of work to be performed. Work approval processes vary according to the work identification type.

For preventative and predictive maintenance, work approval occurs at creation of the asset maintenance plan, with consideration for the Maintenance Strategy. Plans are approved at the long-range level, and individual tasks generated accordingly.

Work notifications are used by workers or supervisors to create requests for corrective, breakdown, or non-routine maintenance work for approval.

The approval process considers both technical, commercial, and operational aspects. Approval of work is the joint responsibility of the maintenance and area operations managers.

3.1.3 Maintenance Work Planning

Maintenance planning ensures that maintenance tasks to be executed include sufficient level of detail to ensure safe, consistent execution.

Work plans are completed for all work to be executed. Level of detail will consider the skills and experience of the personnel assigned to execute, as well as the time available to plan. Depending on the complexity of work, job plans may contain but are not limited to:

- The qualifications and estimated hours of personnel required to complete the work;
- Sufficient description of the work to be performed to allow safe and consistent performance of the task;
- Parts, consumables, and any speciality tools required to complete the work;
- Requirements for area shutdown if applicable, including coordination with area operation personnel;
- Manuals, drawings, or work instructions relevant to the work;
- PPE or specialized equipment requirements;
- Area specific permit or safe work requirements; and
- Requirements (if applicable) for post-work inspection and testing.

3.1.4 Maintenance Work Scheduling

Maintenance scheduling involves sorting and prioritizing approved work requests for execution. Priorities are developed based on the importance ranking of the involved assets, the type of work to be performed, the requirements for area or plant outages, and the input of involved subject matter experts.

Maintenance scheduling requires a joint commitment between maintenance and operations/area owners to prioritize work, turnover assets, and systems for maintenance at agreed on times and perform quality work and return to operations.

Asset maintenance required to maintain regulatory compliance is identified on the schedule and communicated to both maintenance and area owner supervision. Examples of work required for regulatory compliance include refrigeration equipment, fire detection and fighting systems, boilers and pressure vessels, and others.

3.1.5 Work Execution

Maintenance supervisors are accountable to ensure that, prior to executing a job, those reporting to them are set up to execute safe, quality work. This includes ensuring that:

- Parts are on hand, tools are available, and equipment is prepared for service before the worker arrives;
- Work plans include sufficient detail for the task, and that the plan and all related documentation are provided to the worker sufficiently in advance of the task;
- Personnel are appropriately trained and have the skills and knowledge necessary for the tasks given, as outlined in the Training Management Program; and
- Personnel are equipped to work safely and given the time and tools to do so.

All work performed on the assets is executed by qualified personnel, working with appropriate tools, equipment, and parts to an established plan and schedule.

3.2 Aging Management

The *Aging Management* plan identifies routine inspection and remediation requirements for all fixed assets that have been commissioned at the Operation site, potentially including but not limited to:

- Structural support systems for tanks, vessels, piping, electrical, and equipment;
- Buildings, including structural frames, roof and wall systems, and other elements;
- Foundations, including footings, piles, or other anchorages;
- Platforms, grating, stairs, handrail, and related structural supports; and
- Any other assets not included in a maintenance plan.

Structural assets are assessed and added to the management plan after being commissioned and turned over for routine operation. Inspections are completed on these assets on a frequency that considers risk and consequence of failure. Based on the assessed risk, a combination of visual inspections, third party SME reviews, and non-destructive examination are identified for asset inspection. Any findings from the inspection are prioritized and added to an action log and documented in the maintenance portion of the *Document Management* procedure.

The inspection program, once developed, is managed through the maintenance system, including both scheduled inspections and open action items. A copy of all inspection requirements and current action logs is maintained through processes outlined in the *Management System Program*.

3.3 Asset Type Specific Plans

Specialized plans may be implemented on groups of assets that meet any of the following criteria:

- Pose a specific set of risks that benefit from a common assessment and management approach;
- Require specialised (contract) resources to assess, which provides a cost benefit to managing as a batch inspection; or
- Have specific regulatory implications, including recordkeeping, inspection, maintenance, and/or reporting requirements.

Items managed through an integrity program follow the assessment and maintenance processes as described in this program. They may include asset-specific risk criteria, action logs, and maintenance strategy in addition to or replacing the tools used for other assets. Maintenance plan documentation is managed such that inspection schedules, history, and action log items originating with an asset type plan are specifically identified for search and retrieval.

A prioritized action list is generated to document necessary repairs and improvements after scheduled inspections are completed for an asset type integrity plan. Any action items requiring maintenance team execution are input into the maintenance system and tagged with the originating action plan number.

Examples of asset type specific plans include:

- Environmental containment
- Ventilation
- Rigging and lifting equipment
- Pressure vessel

- Atmospheric tank and vessel
- Pipeline integrity

3.4 Construction & Commissioning Management

The construction plan and commissioning plan provide a framework used to effectively and consistently manage these activities to achieve design requirements of the facilities.

Denison is responsible for the construction, commissioning, and operating organizations, which may be internal to Denison or from a contracted organization.

Construction and commissioning activities are carried out in accordance with Denison's Management System, including this program, the *Management System Program*, the *Health and Safety Management Program*, the *Radiation Protection Program*, the *Training Management Program*, and all other related program documentation.

Throughout construction and commissioning activities, Denison's management is accountable to:

- Confirm all facilities are built in accordance with design basis, regulatory requirements, and applicable codes and standards;
- Maintain accountability for safe construction and operation of all facilities, including those constructed, commissioned, or operated by contractors on Denison's behalf;
- Provide a single point of contact for communication with CNSC and other regulators for all matters pertaining to construction;
- Ensure construction safe work plans and procedures are established;
- Ensure all inspections, tests, and verification required by design basis or regulators are performed, documented, evaluated, and reported on as required; and
- Maintain a listing of regulatory oversight requirements, including jurisdictional boundaries and responsibilities.

3.4.1 Construction

A readiness review will be completed prior to start of major construction, to verify management systems, planning, procedures and training, and hazard identification and control measures have been completed and are sufficient for control of construction activities.

Construction planning, scheduling, and sequencing is completed prior to construction, and includes provisions for witness and hold points for internal review and verification, as well as regulatory inspection where required.

Construction management is further detailed in the *Construction Management Plan*.

3.4.2 Commissioning

Denison oversees the organization, planning, execution, and assessment of commissioning activities at the Wheeler River site, whether performed by Denison or by contractors.

During commissioning:

- The construction organization will verify that all structures, systems, and components have been constructed as per design and quality assurance requirements are satisfied;

- The commissioning organization will test all structures, systems, and components important to safety and verify the facility is ready for safe operation; and
- The operating organization will satisfy itself that the systems transferred are safe to operate and will accept responsibility for operation and maintenance of transferred facilities in accordance with the design intent.

Commissioning management is further detailed in the *Commissioning Management Plan*.

3.4.3 Construction and Commissioning Contractors

Denison is accountable for management of Contractors and subcontractors to ensure they meet contractual obligations. Denison maintains records detailing its oversight activities, and reports on incidents or deviations that affect, or have the potential to affect, quality of construction, or current or future operational safety.

Contractors and vendors are managed in accordance with sections 2.8 & 2.9 of this program. Vendors and contractors for safety-sensitive work are chosen from the controlled list of approved suppliers. Vendor performance is tracked and used to inform future procurement decisions. Contractor-purchased equipment is subject to the same requirements as outlined in section 2.8.

3.4.4 Construction Security

Site security is managed to prevent both intentional and unintentional unauthorized acts directed at construction activities, that could impact current and future operational safety. Security requirements are reviewed on an ongoing basis, and controls put in place to address current site risks. Factors that are considered in review include:

- Current measures in place;
- Presence of nuclear material onsite;
- Change in facility control, including turnover to operations;
- Access control;
- Scheduled and random inspections and patrols;
- Screening of personnel and contractors, both pre-employment and on arrival;
- Cyber security controls; and
- Response capability.

Security of facilities turned over to operation are managed in accordance with the *Security Management Program.*

3.5 Inventory Control

Inventory refers to parts, consumables, bulk reagents, spare assets, and assemblies required for safe, reliable operation of the facilities.

3.5.1 Goods Receipt

Denison is responsible for handling and receiving goods. Items requiring special care and/or special handling methods are identified in the procurement documentation and treated accordingly. All items are received and inventoried onsite, with additional inspections and verifications completed based on procurement requirements. Documents from the supplier are kept, as well as inspection documentation where required. All other goods, including general freight, are received, inspected for quality, stored, and issued efficiently; the entire process is documented.

3.5.2 Inventory Management

Inventory stock levels are determined based on maintenance and operational requirements, lead time, and risk posed by equipment failure. Decisions on stocking levels are subject to an approval process based on risk and cost and are reviewed on a routine basis to maintain appropriate levels. Routine cycle counts are completed to verify inventory levels.

Inventory stored onsite is maintained in controlled areas to prevent damage, degradation, or loss of inventory. Procurement requirements outline storage requirements for incoming goods, including temperature or weather control.

Any required maintenance tasks to keep inventory in good working condition are logged and added to the maintenance schedule, utilizing the process outlined in section 3.1.

3.5.3 Critical Spare management

Items may be identified through the Maintenance Strategy procedure as critical spares if they are infrequently used but necessary to reduce the impact of failure of important assets. Critical spares will be maintained for as long as identified in the maintenance strategy and maintained in reliable operating condition.

Check

4.1 Work Closeout

The following section applies to assets in operation. Assets in construction will instead follow the commissioning process outlined in section 3.4.

Closeout and work verification is completed with safety as the paramount consideration guiding all decisions and actions. Required inspections and checkpoints are identified in the plan and carried out during work and at close-out as required. A competent worker must be assigned to perform verification of activities. Verification records are kept with the work order history.

Any information requiring update is recorded on the work order and returned to planning. Examples include bill of materials errors, incorrect jobs steps or equipment requirements, or suggested improvements to the job plan. The planning department is accountable to ensure that this information is recorded and assessed for improvements to future work or standard job plans.

4.2 Monitoring and Measurement

Performance relevant to this Program is monitored and measured against established objectives and targets (identified in Section 2.2). Denison will monitor, measure, analyze, and evaluate its health and safety performance based on a defined process outlined in the *Management System Program*.

All monitoring and measurement activities must also meet defined quality assurance and quality control requirements outlined within relevant Plans as part of this Program.

The results of monitoring and measurement activities are communicated and documented as part of the *Records Management* process outlined in the *Management System Program.*

4.2.1 Asset Based Targets

The maintenance manager is accountable for drafting relevant KPIs related to the health of the maintenance system, and their implementation at Wheeler River. KPIs adhere to the following guiding principles:

- They are relevant to the current state of the asset management program and will change over time as the program evolves;
- They provide clear line-of-sight to organization targets and KPI's and are tied to operational targets established as part of the management review process; and
- They include targets for required areas of regulatory compliance.

Performance monitoring KPI's are used to inform program improvement opportunities and included in targets and objectives for future years.

4.2.2 Vendor Performance Feedback

Performance reviews and audits of key vendors for goods and services are performed, with audit requirements based on the importance and risk of supplied goods and services. Vendor performance is recorded by end-users, and past performance is used to inform future purchasing decisions for all safety critical goods and services.

Vendors are evaluated during and after the completion of work, in accordance with the *Vendor Management Procedure.* Vendor deficiencies are identified and documented using the non-conformance process outlined in the *Management System Program*. The supplier must perform corrective actions to resolve the non-conformances. Failure to resolve the non-conformances results in the vendor's status being removed from the approved supplier listing.

4.2.3 Inventory Assessment

Site inventory is routinely assessed for shelf life and inventory turns. Assessment results are used to inform changes in stocking levels, prevent deterioration of goods in storage, and maintain necessary levels of parts and consumables.

Goods identified as critical spares are not subject to inventory turn assessments and are maintained in good working condition or replaced as required by the maintenance strategy.

4.3 Inspections and Audits

Denison will conduct internal audits of the *Facility and Equipment Management Program* to determine if Denison is complying with the requirements set out in the Program and to determine if the Program is being effectively implemented and maintained.

The internal audits will follow the process and procedures outlined in the *Management System Program.*

4.4 Management Review

The *Facility and Equipment Management Program* will be reviewed by Denison management in accordance with a defined frequency to determine if the defined program is meeting its objectives, is effective or needs adjustment. Relevant Program items that Denison management will review may include:

- Suitability, adequacy, and performance of Program objectives and targets;
- Upcoming or new legislation related to asset protection;
- Recent or planned changes in facility operations;
- Results of monitoring in relation to meeting performance objectives and targets;
- Results of audits and inspections in relation meeting performance objectives and targets;
- Communications from interested parties;
- Adequacy of resources; and
- Any needs for program adjustment.

Denison management will identify opportunities for improvement and establish action plans to implement change in accordance with the process outlined in the *Management System Program.*

4.5 Reporting

Denison will routinely report both internally and externally on the performance of the *Facility and Equipment Management Program*. External reporting can include reporting to regulators, the public, and Indigenous and local communities.

External reports to regulators will be produced in accordance with regulatory requirements.

Act

5.1 Corrective Action

Non-conformities or areas for improvement are identified following the process outlined in the *Management System Program* and the supporting procedures. These non-conformities can include incidents, near-misses and deviations from the *Facility and Equipment Management Program.* Non-conformities can also be identified during the inspections and audits.

Responses to identification of non-conformities include investigation of cause, and corrective action if appropriate. Corrective actions are planned, implemented, verified, and reviewed for effectiveness based on the process identified in the *Management System Program.*

5.2 Continual Improvement

Opportunities for improvement of the *Facility and Equipment Management Program* will be identified and addressed to enhance operational performance. The continual improvement process for this Program follows the overall continual improvement process outlined in the *Management System Program* and the supporting procedures. Continual improvement may also include updating Program objectives and targets based on changing circumstances or new information. Any changes identified through the continual improvement process will be implemented in a systematic and controlled manner.

Breakdown and failure information is trended to identify systems and equipment having an adverse effect on safety and reliability. Failure trends are routinely reviewed by reliability engineering subject matter experts. Based on failure trends, changes may be recommended at the design level (change in assets) or at the maintenance strategy level (changes in maintenance plans and tools).

5.3 Asset Disposal

Asset disposal is the process for removal of existing facilities, equipment, or inventory items from service or from the Wheeler River Operation.

Asset disposal includes change management to ensure the removal does not affect safety or reliability of site assets. Once approval for disposal is obtained, the asset disposal process includes archiving of maintenance records and plans, disposition of obsolete inventory, and disposal of assets in keeping with the requirements of the *Waste Management Program*

References

6.1 Internal

Document Name
Engineering Design Control Plan
Asset Identification
Asset Onboarding
Construction Management Plan
Commissioning Management Plan
Contractor Management Procedure
Vendor Management Procedure
Maintenance Work Management Procedure
Aging Management Plan

6.2 External

10 Denison Mines Corp. Wheeler River Operation, Change Management Procedure, July 2023

Purpose:

The purpose of this element is to ensure the Management System is continuously assessed for effectiveness and is improved using several methods.

Experience and lessons learned from activities that have occurred at the Wheeler River Operation and other businesses are documented and reviewed to prevent a problem from occurring or improve the efficacy of a process.

Applicable To:

- Wheeler River Operation personnel

Procedure:

Continual Improvement

The following list includes several ways Denison will achieve continual improvement.

1. The Plan-Do-Check-Act (PDCA) concept is used by the Wheeler River Operation to achieve continual improvement. All Level 2 Programs use the PDCA format.

PLAN –will establish the processes to deliver results.

DO – implement the processes as planned.

CHECK – monitor and measure the processes and report the results.

ACT – take actions to continually improve the processes.

2. Management will demonstrate leadership and commitment to the Management System by promoting continual improvement. This is done in part by having an EHSS policy which includes a commitment to continual improvement.
3. Risks and hazards are assessed periodically to reduce undesired effects, thus achieving continuous improvement. This is achieved by performing any of the following:
   - Planned task observations;
   - Senior Leadership Engagement;
   - Process identification and description;
   - Incident reporting and cause analysis;
   - Workplace inspections and observations;
   - Monitoring and measurement processes;
   - Job Hazards Analysis;
   - Field Level Hazard Assessment; and

- Hazard and operational study (HAZOP).

4. The Preventive and Corrective Action process and Management Review processes will also provide an opportunity for continual improvement.
5. Trends of incidents including causes and problems will be completed periodically throughout the year.
6. Audits will be completed on the Management System at planned intervals to evaluate and provide information on the effectiveness of the Management System.
7. The Management System documents will be reviewed at minimum every three years to determine if revisions are necessary. Changes to the program elements may be made prior to the three-year period if they are identified sooner.
8. Benchmarking the performance and experience of others where practicable, this will be achieved by Denison's involvement of the Saskatchewan Mining Association and other committees Denison may be involved with. Provincial Regulators will periodically provide Denison with statistics collected from across the province. Mining accidents such as: first aid, medical incidents, lost-time accidents, frequency, and severity of the events are shared.
9. Maintaining the awareness of changes in its business environment, this will be achieved through Management Review, as well as changes through Legal & Other Requirements.
10. Denison will set companywide internal objectives & targets.

Use of Experience

1. Following an incident, Denison will complete an investigation and implement preventative and corrective actions.
2. Denison will verify the effectiveness of the preventative and corrective actions by confirming the actions are functioning as intended and the causal factor of an incident was addressed or eliminated.
3. Denison will learn through experience in the uranium mining and milling business and through its involvement in committees and communication from regulatory agencies.
4. Denison employs experienced workers in management roles who bring knowledge and learnings to the team.

Records:

Record Name	Retention Time
TBD	

References:

WRE-QUA-103, Audits

WRE-QUA-104, Inspections

WRE-QUA-106, Legal & Other Requirements

WRE-QUA-109, Self-Assessment & Management Review

WRE-QUA-110, Objectives & Targets

WRE-QUA-111, Change Management

WRE-QUA-112, Risk Management

Health & Safety Management Program

Author:

Senior Coordinator, Environment & QMS	**Tracy Gaudry**
Title	**Name**

Approver:

Director, HSE & Regulatory	**Janna Switzer**
Title	**Name**

11 Denison Mines Corp. Wheeler River Operation, Human Factors Engineering Procedure, May 2025

Purpose:

This procedure supports the Engineering Design Control Plan and provides guidelines to establish a systematic process for integrating human factors into the design, construction, operation, and maintenance of nuclear facilities in accordance with CNSC REGDOC-2.5.1, *General Design Considerations: Human Factors*. This ensures personnel performance supports safety and environment and reduces the likelihood of human error.

Scope:

This procedure describes the elements to be followed to ensure human factors are considered for the licensed facilities of the Wheeler River Operation. Typical criteria used for determining areas of consideration for Human Factors Engineering (HFE) include industrial circuits with complex equipment requiring a high-level of physical and/or mental interaction with a process or system. The need for HFE is considered for the following activities:

- New plant designs;
- Control room upgrades;
- Maintenance and operations procedures;
- Human-Machine interfaces (HMI);
- Training and staffing strategies; and
- Facility design modifications.

This procedure also describes elements to be followed to validate effectiveness of the designs with regards to the health and safety of employees and environmental protection.

Qualification Pre-requisites:

Human Factors Engineering (HFE) activities are to be performed as an HFE team with relevant combined qualifications and experience as follows:

- Accredited Professional Engineers with a minimum of 5 years operating experience in mining/milling operations or personnel with 10 years or more of operating experience in mining/milling operations.
- Minimum of 5 years of staff supervision
- Minimum of 2 years in Uranium mining/Milling facility.

Procedure:

Activities applicable to HFE for the Wheeler River Operation are separated into 3 main steps:

1. Determining the requirements for Human Factors Engineering.

2. Completing Human Factor Engineering.
3. Validating effectiveness.

1. HFE Assessment Tools for New Facility Design

As outlined in the *Engineering Design Control Plan*, a variety of tools are utilized to ensure appropriate controls are in place to ensure the health and safety of employees and visitors, as well as environmental protection. The main tools utilized during engineering phases to determine HFE requirements are listed below.

1.1. Hazard and Operability Study (HAZOP)

For new facility designs a HAZOP shall be conducted to evaluate operational risks and hazards and determine necessary mitigations required to reduce risk levels to As Low as Reasonably Practicable (ALARP), This HAZOP shall involve appropriate Subject Matter Experts (SME) to ensure all human interventions within the licensed facility are understood.

Should HAZOP results prescribe the need for additional HFE, a team shall be onboarded, and an HFE implementation plan created, tailored to the project scope and risk.

1.2. 3D Model Reviews

For new facility designs, 3D model reviews shall be completed to validate all aspects of designs, including but not limited to:

- Constructability Reviews; and
- Operability and maintainability reviews.

3D model reviews shall involve appropriate SMEs to ensure that all human interventions within the licensed facility are understood.

Should the 3D model reviews prescribe the need for additional HFE, a team shall be onboarded, HFE implementation plan created, tailored to the project scope and risk.

1.3. Training Program Design

For new facility designs, a training program shall be developed for each process, encompassing the following:

- Analyze plant functions to identify required human intervention;
- Allocate functions between humans and systems based on reliability, performance and safety considerations;
- Perform detailed job task analysis for operational, maintenance, and emergency tasks;
- Identify potential human errors and mitigate through design or procedures; and
- Develop user-centered operating, maintenance, and emergency procedures.

Should the training program development identify high risk tasks not previously identified in HAZOP or 3D model reviews, an HFE team shall be onboarded, and an HFE implementation plan created, tailored to the project scope and risk.

Human Factors plays a crucial role in the analysis, design, development, implementation, and ongoing evaluation of training and awareness programs within a facility. The goal is to ensure that training effectively equips personnel with the knowledge, skills, and attitudes necessary for safe, efficient, and reliable performance, taking into account human capabilities and limitations.

Denison's Training Management Program integrates key aspect of Human Factors as follows:

- Training Needs Analysis: Leverage the detailed task analyses (operational, maintenance, emergency) to identify the specific knowledge, skills, cognitive and physical demands for each task. This ensures training focuses on what personnel need to do.
- Design and Development of Training Materials and Delivery Methods: User-Centered Design Principles: Applying HFE principles to the design of training materials to ensure they are clear, concise, and easy to understand. This includes: clear language and terminology, effective visual aids, logical organization structure, and evaluating training materials with Subject Matter Experts.
- Effective Training Methods: Training methods are appropriate for the learning objectives and the target audience (i.e., Simulator, Hands-on, Classroom Instruction).

1.4. Human-Machine Interface (HMI) Design

For new facility designs the selected HMI shall conform to ISA101, *Human-Machine Interfaces* for HMI screens and ISA-18.2 for alarms.

Should the HMI not meet the required standards, additional reviews by a Senior Engineer must be completed and may determine the requirement for additional HFE. If additional HFE is required, an HFE team shall be onboarded, and an HFE implementation plan created, tailored to the project scope and risk.

1.5. HFE Requirements for Modifications to Facilities.

Modifications to facilities shall follow the *WRE-QUA-111, Change Management* procedure.

Human factors engineering requirements shall be determined during the management of change activities.

2. Completing Human Factor Engineering

If HFE requirements are determined as described above, the following steps are provided as guidance. Each HFE project will be managed based on risks to Personnel Health, Safety, and the Environment.

2.1. Planning and Management

- Establish an HFE team with qualified human factors professionals;

- Define roles, responsibilities, and lines of communication;
- Develop a Human Factors Engineering Implementation Plan (HFIP) tailored to project scope and risk; and
- Ensure coordination with safety analysis, design, and operational teams.

2.2. Functional Requirements Analysis and Function Allocation

Analyze plant functions to identify where human intervention is required. This allows for allocating functions between humans and systems based on reliability, performance, and safety considerations.

2.3. Task Analysis

- Perform detailed task analyses for operational, maintenance, and emergency tasks.
- Identify potential human errors and mitigate through design or procedures

2.4. Human-Machine Interface (HMI) Design

- Design controls, displays, alarms, and interfaces in accordance with ergonomic standards.
- Use iterative design methods (prototypes, mock-ups) for validation.
- Ensure the HMI supports situational awareness and operator performance.

2.5. Procedure Development

- Develop user-centered operating, maintenance, and emergency procedures.
- Involve end-users in validation and review.
- Ensure clarity, consistency, and alignment with cognitive demands.

2.6. Training Needs Analysis (TNA)

- Conduct a training needs analysis based on task and job requirements.
- Develop training programs incorporating simulator-based training if applicable.

3. Validation of Effectiveness

For the Wheeler River Operation, the main tool utilized for validating effectiveness of designs will occur during the commissioning phase of the Project during which the following will occur:

- Conduct integrated system validation using representative end-users and realistic scenarios;
- Validation that the system supports safe and effective human performance; and
- Validation that the training program is effective, through feedback loops between trainers, trainers and incorporation of continuous improvement and lessons learned as defined in the *Training Management Program*.

After commissioning activities are completed, human performance evaluation will continue to identify any continuous improvement opportunities which could require management of change. For more information, please refer to the *Human Performance Management Program.*

Records:

Record Name	Retention Time

References:
Engineering Design Control Plan
Human Performance Management Program
ISA101, *Human-Machine Interfaces*
ISA-18.2-2016*, Management of Alarm Systems for Process Industries*
REGDOC-2.5.1, *General Design Considerations: Human Factors*
Training Management Program
WRE-QUA-111, Change Management

Author:

Project Director	**Xavier Lu Dac**
Title	**Name**

Approver:

VP Operations	**Kevin Himbeault**
Title	**Name**

12 Denison Mines Corp. Wheeler River Operation, Establishing Engineering Controls for Radiation Protection, Version 1,

Purpose:

To support the Engineering design and control plan and establish how the Wheeler River Operation incorporates Engineering Controls for Radiation Protection. This procedure should be used to guide engineering design decisions during the engineering phase with emphasis on verification after implementation.

Applicable To:

- Engineering Group
- Radiation Protection Group

Procedure:

1. Consult the most current worker dose assessment and the Radiation Protection Plan to identify radiation hazards (sources) that are present within the area(s) in which engineering design is to be undertaken. The main sources of radiation present at Wheeler River include:
    - External gamma radiation received while in proximity to radioactive sources.
    - Long-lived radioactive dust (U-238, U-234, Th-230, Ra-226, Pb-210, Po-210).
    - Radon (Rn-222) and short-lived progeny (Po-218, Pb-214, Bi-214, Po-214).
2. Identify engineering controls that are already included (and accounted for) in the worker dose assessment for the area(s) in which engineering design is to be undertaken. Engineering controls generally use one or more of the following design principles:
    - Limiting time that workers are required to be near radiation sources.
    - Increasing the distance between the worker and radiation sources.
    - Providing shielding between the radiation source and the worker.
    - Ventilation, monitoring, and control of radioactive gases (Radon) or airborne radioactive particulate (Long Lived Radioactive Dust).
3. Identify routine and expected worker tasks and durations for that area. Consult applicable work instructions, operator rounds, PM schedules, historic or expected maintenance activities and subject matter experts.
4. Carry out engineering design and identify any instances where engineering controls can be implemented to lower worker dose As Low As Reasonably Achievable (ALARA). In considering what is reasonable, the expected reduction of dose due to the engineering control, as well as the cost, complexity, reliability, and practicality of the engineering control is evaluated.
5. Structured assessments can be used for complex design (commensurate with risk) to assist with the identification of radiation hazards and engineering controls (Steps 4 and 5) that can be used to

mitigate those hazards. The Engineering Design Control Plan describes these assessment methods further. Examples include:

- Hazard and Operations (HAZOP) Studies
- 3D Model Reviews
- Operability and Maintainability Reviews

6. When engineering is significantly advanced (above 60%) the worker dose assessment is reviewed and updated as necessary. If worker dose assessment shows results above the levels set forth in the Radiation Code of Practice, then additional engineering controls are to be evaluated, refer to step 4.
7. Validation of the effectiveness of the Engineering controls is completed after installation by monitoring in accordance with the Radiation Protection Program. If monitoring determines that higher worker doses are being recorded than predicted by the worker dose model, then adaptive management practices can be utilized. Validation of the effectiveness of engineering controls is summarized in the Radiation Hazards and Engineering Controls Checklist.

Note:

If a worker dose assessment has not been completed or cannot be completed due to lack of design definition or lack of information, then a preliminary design is to be created using industry best practices and the knowledge and experience of subject matter experts. If a comparative worker dose assessment or radiological model does not exist, then a worker dose assessment should be completed on this preliminary design that can be the basis for the detailed design and this procedure can then be followed.

Records:

Record Name	Retention Time
Engineering Design Documents	Indefinite

References:

- *22, Radiation Code of Practice*
- *23, Radiation Protection Plan*
- *38, Engineering Design Control Plan*
- *Radiation Hazards and Engineering Controls Checklist*

Author:

Operational Readiness Manager	**Tyler Moniuk**
Title	**Name**

Approver:

Project Execution Director	**Xavier Lu Dac**
Title	**Name**

13 Denison Mines Corp. Wheeler River Operation, Well Design Criteria, March 2025

The information in this reference document is subject to a request for confidentiality under rule 12 of the *Canadian Nuclear Safety Commission Rules of Procedure*. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca) for more information concerning confidentiality.

14 Denison Mines Corp. Wheeler River Operation, Civil Overall Site Drainage Collection and Diversion Plan, March 2025

NOTES:

1. ALL UNITS ARE IN METRIC. COORDINATES AND DIMENSIONS ARE IN METERS, UNLESS NOTED OTHERWISE AND REFER TO THE UTM ZONE 13 NAD 83 (CSRS98) GROUND GRID.
2. CONTOUR INTERVALS ARE 2.0m. CONTOURS ARE GENERATED FROM LIDAR DATA PROVIDED BY DENISON ON JAN. 15, 2021.
3. FOR DRAINAGE ZONING AND SITE LAYOUT REFER TO DRAWING 100382-3000-C-GAD-0002.
4. THE DRAINAGE AREAS INSIDE OF THE FACILITY/CONSTRUCTION AREAS, ARE ACCORDING TO DRAINAGE POST CONSTRUCTION/POST DEVELOPMENT.
5. THIS DRAWING PRESENTS POST CONSTRUCTION / POST DEVELOPMENT DRAINAGE PATTERNS AND DOES NOT COVER DRAINAGE DURING CONSTRUCTION. THE CONTRACTOR IS RESPONSIBLE TO PROVIDE CONSTRUCTION DRAINAGE NETWORK SYSTEM BASED ON POST CONSTRUCTION DRAINAGE PLAN.

LEGEND:

- CATCHMENT BOUNDARY
- NON CONTACT ZONE DITCH LINE (SEE NOTE 3)
- CONTACT ZONE DITCH LINE (SEE NOTE 3)
- NON CONTACT ZONE STORMWATER FLOW PATH
- CONTACT ZONE STORMWATER FLOW PATH
- ROOF DRAINAGE TO GRADE
- CULVERT
- UNDISTURBED
- NEWLY GRADED AREAS / GRAVEL
- IMPERVIOUS - LINED
- IMPERVIOUS - NON LINED
- SELF CONTAINED AREA
- SHEET FLOW TO ENVIRONMENT
- Z2_18 CATCHMENT ID

REV	DDMMMYY	REVISION / ISSUE DESCRIPTION	DRN BY	DSN BY	DWG CHK	DSN CHK	LEAD ENG DEPT MGR	PRJ MGR
B	07APR25	ISSUED FOR REVIEW	DP	[signature]	[signature]	[signature]	[signature]	
A	30JUL24	ISSUED FOR SQUAD CHECK	KC	KC	CJE	JK		

REFERENCES

REF	NUMBER	TITLE
1	3000-C-GAD-0002	SITE GENERAL LAYOUT PROJECT OVERALL SITE PLAN

STAMP/SEAL

NOT FOR CONSTRUCTION

APPROVED FOR

CLIENT PROJECT MGR

PROJECT PHASE: DETAIL ENGINEERING

PROJECT NO.: 100382

SCALE: 1:2500

	BY	DDMMMYY
PRJ MGR		
ENG MGR		
LEAD ENG / DEPT MGR		
DSN CHK		
DWG CHK		
DSN BY	K. CAPEWELL	30JUL24
DRN BY	K. CAPEWELL	30JUL24

Denison Mines

wood.

SUBJECT: CIVIL
OVERALL SITE
DRAINAGE COLLECTION AND DIVERSION PLAN

AREA: 3610 — WHEELER RIVER PROJECT
GENERAL SITE PREP, PONDS & LANDFILL

CLIENT DWG NO.

DRAWING NO.: 100382-3610-C-PLN-0001 REV B

ISO A1-594x841

SAVED: 07-Apr-25 8:57 AM PLOTTED: 07-Apr-25 8:58 AM USER: PATEL, DARSHANA

15 Denison Mines Corp. Wheeler River Operation, Radiation Protection Program, Version 1, September 2023

Denison Mines Corp.
Wheeler River Operation

Radiation Protection Program

Document # 11

Version 1

September 2023

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
Version 1	15-Sept-2023	Draft for CNSC Review			

Revision History

Version	Date	Description of Revision
Version 1	15-Sept-2023	Draft for CNSC Review

Table of Contents

Figures

1 Introduction

The *Radiation Protection Program* (the Program) is one of twelve Program documents that comprise the Management System for the Wheeler River Operation (the Operation). The *Radiation Protection Program* is preceded by the *Management System Program* within the document framework for the operation as shown in Figure 1. Consistent with all other Program documents, the *Radiation Protection Program* is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

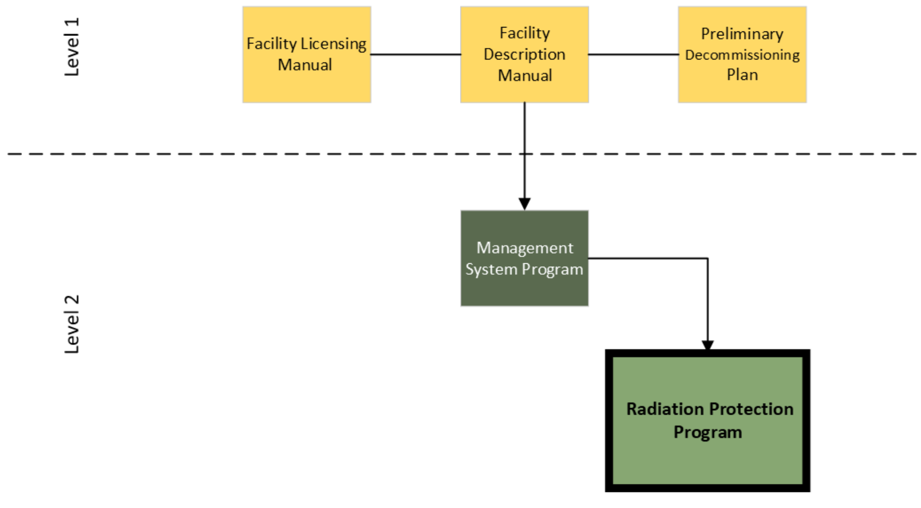


Figure 1: Program shown within Document Framework for the Wheeler River Operation

The *Radiation Protection Program* uses a risk-based approach to identify radiation protection measures, which are informed by and commensurate with the risk arising from potential radiation exposures related to the Operation, both in the workplace and in the environment.

1.1 Purpose

This Program defines the requirements, principles, and framework to promote radiation safety and effectively manage radiation risks of workers, the public, and the environment.

The Program is used to integrate Denison's radiation protection measures into a documented, managed, and auditable process. Key approaches include:

- Identifying, mitigating, and managing radiation risks;
- Identifying, implementing, and maintaining controls on radiation exposure;
- Keeping exposures in the workplace and the environment as low as reasonably achievable (ALARA) considering social and economic factors;
- Ensuring that workers have the necessary tools, qualifications and training to perform their work safely in a manner that protects the environment; and
- Maintaining a safety culture focused on continual improvement .

1.2 Scope

The *Radiation Protection Program* outlines approaches to protecting workers and members of the public from radiation effects, through managing radiation exposure and dose in the workplace, controlling radioactive contamination in the workplace, and controlling releases of radioactivity to the environment.

Environmental aspects of radiation protection, including monitoring and control of radioactive releases to the environment, monitoring of radioactivity in the environment, and assessment of public dose, are managed under the *Environmental Management Program*. Emergency preparedness and response aspects of radiation protection are managed under the *Emergency Management Program* and *Fire Protection Program*. Training aspects of radiation protection are managed under the *Training Management Program*.

1.3 Program Principles and Denison's Environment, Health, Safety & Sustainability Policy

Denison's commitment to radiation protection is communicated in its corporate Environment, Health, Safety & Sustainability Policy, applicable to all its facilities. The *Radiation Protection Program* is based on the principles outlined in that policy, and can be found in the *Management System Program* as well as at the following website:

https://denisonmines.com/about-us/corporate-governance/corporate-policies/

The Radiation Protection Program defines the requirements, principles, and framework to promote radiation safety and effectively manage radiation risks of workers, the public, and the environment.

Key principles of the Program include:

- A risk-based approach, which involves understanding the radiation risks related to Operation activities, and directing risk management effort where it is most needed to protect workers, the public and the environment; and
- The principle of keeping radiation exposures both within regulatory limits, and as low as reasonably achievable (ALARA), considering social and economic factors.

1.4 Compliance with Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act* and associated regulations, including the *General Nuclear Safety and Control Regulation),* the *Uranium Mines and Mills Regulations*, and the *Radiation Protection Regulations.* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.7.1, *Radiation Protection.*

Additionally, the Program meets provincial requirements including the *Occupational Health and Safety Regulations.*

1.5 Terminology

A list of common terms applicable to this Program and the *Management System Program* is available in the *Wheeler River Project Glossary*.

1.5.1 Definitions

Term	Definition
As low as reasonably achievable (ALARA)	A principle of radiation protection that holds that exposures to radiation are kept as low as reasonably achievable, social and economic factors taken into account. Section 4 of the *Radiation Protection Regulations* stipulates licensee requirements with respect to ALARA.
Dose limit	A maximum allowable radiation dose (effective dose or equivalent dose), as specified in the Radiation Protection Regulations, which are in place to minimize the risk of adverse health effects due to radiation exposure.
Dosimetry service	A prescribed facility for the measurement and monitoring of doses of radiation.
Effective dose	The sum of the products, in sievert, obtained by multiplying the equivalent dose of radiation received by and committed to each organ or tissue by the weighting factor of that item.
Equivalent dose	The product, in sievert, obtained by multiplying the absorbed dose of radiation of a given type by the weighting factor for that radiation type.
Nuclear energy worker	A person who is required, in the course of the person's business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in such circumstances that there is a reasonable probability that the person may receive a dose of radiation that is greater than the prescribed limit for the general public.

1.5.2 Acronyms and Abbreviations

Acronym or Abbreviation	Term
ALARA	As low as reasonably achievable
EIS	Environmental Impact Statement
LLRD	Long lived radioactive dust
LRWS	Saskatchewan Ministry of Labour Relations and Workplace Safety
NEW	Nuclear Energy Worker
PPE	Personal protective equipment
RSO	Radiation safety officer

2 Plan

2.1 Risk Management

Under the *Radiation Protection Program*, a risk management process is applied to protect workers, the public and the environment. The risk management process includes identification of potential radiological hazards, risk assessment of those hazards, and implementation of relevant radiation control measures to reduce the risks, where necessary.

2.1.1 Hazard Identification

This section outlines the types of radiation hazards associated with the Operation, including the radiation sources and the key exposure pathways. Hazard identification is the first step in risk assessment for a particular work activity or exposure situation.

The radiation hazards associated with the Operation include:

- External gamma radiation, received while in proximity to radioactive sources;
- Long-lived radioactive dust (LLRD) (ore dust or uranium concentrates dust); and
- Radon (Rn-222) and short-lived progeny (Po-218, Pb-214, Bi-214, Po-214).

Hazards anticipated relevant work areas are discussed further in the *Radiation Protection Plan*.

2.1.2 Risk Assessment

Risk assessment provides a basis for development of appropriate controls on radiation exposure of workers. The risk assessment process includes consideration of the anticipated hazards and exposure situations, estimating the magnitude, frequency, and duration of radiation exposures, and evaluating the need for exposure controls, as appropriate to the situation.

Estimation of radiation exposures involves prediction of radiation dose rates from identified sources, and of airborne concentrations of LLRD and radon and progeny, as appropriate to the situation, and calculation of resulting worker doses. Calculated doses are compared to action levels and administrative levels.

2.1.3 Managing to Control Risk

Radiation exposure controls are selected, as appropriate, based on results of risk assessment. Monitoring is used to confirm the actual levels of exposure and dose when the work is performed. If exposures are higher than anticipated, plans for additional controls may be implemented to ensure that radiation safety is not compromised.

This planning to assess and control risk applies to both routine and non-routine (unusual) exposure situations. For routine situations, the resulting monitoring and controls are built into standard operating procedures. For unusual exposure situations, the assessment and control will occur through a radiation work permit. This work permit process is detailed in the *ALARA Plan*.

Approaches to monitoring and exposure control are described in Sections 3.1 and 3.2.

2.1.4 Risk Register

Denison uses a risk register to proactively identify and address significant radiation protection risk aspects, prioritize resources, and continuously improve its radiation management practices. The risk register is a central repository for recording and tracking information related to the significant training aspects.

Anticipated radiation hazards, worker doses and controls as described by work area in the Environmental Impact Statement (EIS) will be documented in the risk register, and information will be updated on an ongoing basis as the Operation advances. For unusual exposure situations, the same information, developed through the work permit process, will be added to the risk register.

Further details on the risk register are provided in the *Management System Program*.

2.1.5 Worker Classification

Workers are classified as Nuclear Energy Workers (NEWS) or non-NEWs, based on risk assessment of their job category. Workers who have a reasonable likelihood of exceeding an effective dose of 1 mSv/y are classified as NEWs, and are subject to personal dose monitoring, reporting and information requirements under the *Radiation Protection Regulations.* Workers who do not work in radiation areas, or whose activities in these areas are controlled such that they are highly unlikely to exceed 1 mSv/y, are classified as non-NEWs, and while they are still monitored, they are not subject to the same requirements.

The dose monitoring, reporting and information requirements pertaining to NEWs include:

- Dose monitoring by a licensed dosimetry service, if they have a reasonable probability of receiving an effective dose above 5 mSv/y, or an equivalent dose to the skin above 50 mSv/y;
- Licensee reporting of NEW dose and personal information to the National Dose Registry; and
- information about radiation risks, dose limits, and rights of pregnant or breastfeeding workers, as per the *Regulations,* provided in writing to NEWs, and acknowledged in writing by NEWs.

Dose limits for NEWs under the *Radiation Protection Regulations* are:

- Effective dose: 50 mSv/y and 100 mSv/5y; 4 mSv for balance of pregnancy for NEWs who are pregnant or breastfeeding, after they have informed the licensee in writing (y=dosimetry year);
- Equivalent dose: 500 mSv/y to skin or to hands and feet, 50 mSv/y to eye lens (y=dosimetry year); and
- Dose limits for specific emergency control actions as per the *Regulations*.

Dose limits for non-NEWs under the *Radiation Protection Regulations* are:

- Effective dose: 1 mSv/y (y=calendar year); and
- Equivalent dose: 50 mSv/y to skin or to hands and feet, 15 mSv/y to eye lens (y=calendar year).

2.2 Objectives and Targets

Objectives and targets of this Program will be measurable, documented, and tracked. Performance against the objectives and targets will be communicated at regular intervals (i.e., during Management Review), and opportunities for continual improvement will be identified.

The objectives of the Radiation Protection Program are to:

- Protect people and the environment from harm due to radiation exposure; and
- Keep radiation exposures to workers and members of the public as low as reasonably achievable (ALARA), considering social and economic factors.

The targets of the Radiation Protection Program are to:

- Keep radiation doses in the workplace below regulatory limits and action levels;
- Keep releases of radioactivity to the environment below action levels (see *Environmental Management Program*);
- Keep radiation and radioactivity exposures in the workplace generally below administrative levels, and decreasing or not increasing over the long term;
- Keep releases of radioactivity to the environment generally below administrative levels, and decreasing or not increasing over the long term (see *Environmental Management Program*); and
- Keep the frequency of nonconformity with radiation protection processes and standards at a low level, and decreasing or not increasing over the long term.

The process for setting overall objectives and targets is outlined in the *Management System Program* and supporting procedure.

2.3 Supporting Plans

There are a number of supporting Plans under the Radiation Protection Program, including the *Radiation Protection Plan*, the *ALARA Plan*, and the *Radiation Protection Code of Practice*. Their scope is outlined below.

2.3.1 Radiation Protection Plan

The *Radiation Protection Plan* presents details on implementation of the Radiation Protection Program, with specific reference to Operation work areas and their hazards, area and worker monitoring requirements, equipment used, and processes followed.

2.3.2 ALARA Plan

The *ALARA Plan* describes the process for ensuring that radiation exposures in the workplace are as low as reasonably achievable, considering social and economic factors. The process involves an optimized selection of controls on exposure, which may in turn affect administrative and action levels.

2.3.3 Radiation Code of Practice

The *Radiation Code of Practice* describes the administrative and action levels that will be in place, and actions that will be undertaken when these levels are exceeded, in order to control workplace exposures.

2.4 Resources

Denison is committed to providing the necessary resources to support effective development, implementation, maintenance, and continual improvement of the Program, including achievement of its objectives and targets.

2.4.1 Roles and Responsibilities

This subsection outlines the specific roles and responsibilities within the Program, including Radiation Safety Officer (RSO), Radiation Protection Technicians, and other workers at various levels of responsibility.

For effective implementation of this Program, workers are informed of their roles and responsibilities and are accountable for comprehending and performing them. Executive and Leadership level roles and responsibilities are included in the *Management System Program*.

Radiation Safety Officer (RSO)

- Managing and monitoring effectiveness of the Radiation Protection Program;
- Ensuring compliance with radiation protection regulations and licence conditions;
- Identifying radiation protection problems and recommending corrective actions;
- Ensuring adequate training for radiation protection technicians and all workers;
- Ensuring that action levels and administrative levels are appropriate;
- Maintaining radiation protection documents and records;
- Ensuring radiation protection equipment is maintained;
- Tracking worker exposures and doses to ensure that they are ALARA;
- Reporting worker exposures and doses as required by regulation;
- Identifying radiation incidents and deviations, and recommending corrective actions;
- Reviewing and approving radiation work permits;
- Participating in the management review process; and
- Identifying and recommending opportunities for improvement.

Radiation Protection Technicians

- Performing radiation protection monitoring activities as directed by the RSO;
- Performing inspections and internal audits as directed by the RSO;
- Maintaining radiation protection equipment as directed by the RSO;
- Reporting any radiation protection incidents, deviations or near misses;

Other Workers (NEWs and non-NEWs)

- Performing duties safely with attention to approved radiation protection procedures;
- Reporting any radiation protection incidents, deviations or near misses.

2.4.2 Facilities and Equipment

Facilities and equipment to support the effective implementation of the Program and its related practices are provided to Program staff and applicable workers.

Facility design has incorporated features intended to reduce radiation exposure, including separate work areas with their own ventilation, negative pressure enclosure of dust-generating equipment, and shielding materials in tanks and piping.

Equipment for measuring radiation exposure, and procedures for use and maintenance of such equipment, are important in control of exposure. In addition, personal protective equipment, such as respirators, will be available for unusual situations that may require additional exposure control.

Monitoring and control of radiation exposure are described in Section 3.1 and 3.2.

2.4.3 Legal and Other

Denison is committed to complying with all applicable legal and other requirements related to radiation protection. Examples of types of legal requirements applicable to the Operation include:

- Federal and provincial acts and regulations;
- Environmental Assessment commitments and follow-up monitoring; and
- Licensing obligations and commitments.

The process for managing legal and other requirements is outlined in the *Management System Program*. Denison has established procedures to ensure compliance with these requirements and that compliance obligations are regularly reviewed. Any changes relevant to radiation protection compliance obligations are monitored and evaluated to determine if updates to the *Radiation Protection Program* and its supporting Plans, Procedures, and Work Instructions are required.

2.5 Training and Competence

A systematic approach to training (SAT) is used to educate, train, and qualify workers and contractors to perform assigned work. Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely.

Records of training activities and competencies will be maintained as outlined in the *Training Management Program*.

2.5.1 Program-specific Qualifications

This section describes the required qualifications for specific roles within the Radiation Protection Program, as defined in section 2.4.1. Required qualifications for the Radiation Safety Officer and Radiation Protection Technicians are as follows:

<u>Radiation Safety Officer</u>

- Minimum 2 years of related experience working in a uranium mine and mill or Class I nuclear facility or determined equivalent experience.

<u>Radiation Protection Technicians</u>

- Technical certification in radiation protection, or related field; or

- Successful completion of in-house training, and certification by an RSO.

2.5.2 Program-specific Training

Using the systematic approach to training, as outlined in the *Training Management Program,* Denison will ensure competency of radiation safety workers with respect to radiation protection, and ensure that all workers subject to occupational exposure have sufficient knowledge of radiation safety to perform their duties safely. The RSO will develop in-house training programs and materials for radiation protection staff, will present training courses, and will certify competence of staff, to ensure that all are competent to perform their duties related to radiation protection.

2.6 Documentation and Records Management

Denison will establish and maintain documented Plans, Procedures and Work Instructions to ensure effective implementation of the Program. Documentation will be controlled, reviewed, and updated as necessary in accordance with the requirements in the *Management System Program*.

Documents and records will be generated as a result of implementation of the Program and completion of licensed activities. Examples of some records generated specific to the Program may include:

- Radiation protection procedures and work instructions;
- Area monitoring results for specific work areas, as appropriate to identified hazards;
- Dosimetry records for individual workers (NEWs and non-NEWs);
- Documented hazard analyses and risk assessments;
- Radiation work permits;
- Completed inspection forms;
- Equipment inventories; and
- Equipment maintenance and calibration records.

Documents and records are readily accessible to those who require them. Dosimetry records are considered personal health information and managed in accordance with privacy legislation. Doses to NEWs will be reported to Health Canada's National Dose Registry.

Further information on documentation and records management is provided in the *Management System Program.*

2.7 Communication

Communication both with internal and external stakeholders is a critical element of the Program to promote a safe work culture that fosters radiation protection. Relevant information to inform workers of radiation protection duties, and any changes to personnel, processes, facilities, or equipment will be shared. Workers can also communicate radiation safety concerns to the RSO.

Communication principles and processes are further outlined in the *Management System Program,* and communication with indigenous communities, local communities, and the public is managed as outlined in the *Public and Indigenous Information Program.*

2.8 Change Management

Change is managed at the Operation to protect workers, the environment, and property, and to ensure that regulatory requirements are met. The Operation's change management process is outlined in the *Management System Program.*

Examples of changes captured by the process could include, but is not limited to changes to the:

- Radiation Protection Program and supporting plans, procedures, and work instructions;
- Structures, systems, and components;
- Regulatory requirements related to radiation protection;
- Emerging risks to workers; and
- Organizational changes.

2.9 Radioactive Releases

Emissions of uranium dust from the ISR Plant will be controlled by use of Venturi scrubbers in the stacks. Radon and short-lived progeny will be largely removed from uranium bearing solution at the wellfield and will be discharged through a stack on the recovered solution tank. The effectiveness of control on emissions will be verified by particulate monitoring around the ISR Plant, and monitoring of radon and progeny around the recovered solution tank. Details are described in the *Environmental Management Program* and supporting plans.

An industrial wastewater treatment plant will control discharge of radionuclides to receiving water. The effectiveness of control will be verified by monitoring of treated effluent as well as receiving water. Details are described in the *Environmental Management Program* and supporting plans.

Any potentially contaminated materials leaving the site will be checked and cleared for off-site release. The clearance process is described further in Section 3.2.7.

2.10 Emergency Preparedness and Response

Denison is committed to establishing, implementing, and maintaining a process to prepare for and respond to potential emergency situations.

The Wheeler River Operation prepares for potential emergency situations by anticipating radiological hazards, planning to monitor radiological impacts while restoring control, and planning to manage doses to emergency responders within emergency dose limits.

Denison's overall process for emergency management is outlined in the *Emergency Management Program* and *Fire Protection Program*.

3 Do

3.1 Monitoring of Worker Exposure

The monitoring of worker exposure under the *Radiation Protection Program*, includes monitoring of radiation exposure, worker dose, surface contamination, and bioassay monitoring (uranium in urine).

3.1.1 Radiation Exposure Monitoring

The type of exposure monitoring to be performed will be defined for each job category as appropriate to their identified hazards and risk assessments (exposure estimates). Exposure monitoring may include measurement of radon gas and radon progeny, LLRD, and gamma radiation in the work area. Results are compared to administrative levels. Monitoring equipment may include real-time warning systems, such as continuous air monitors and direct-reading dosimeters, enabling workers to respond to changing conditions to minimize exposure.

Types of monitoring by work area are discussed further in the *Radiation Protection Plan*. Work instructions on the type of monitoring to be conducted in each work area, and the methods, locations, and frequencies for that monitoring, are described in the *Radiation Exposure Monitoring Procedure*.

3.1.2 Worker Dose Monitoring

The type of dose monitoring to be performed will be defined for each job category as appropriate to their identified hazards and risk assessments. A licensed dosimetry service will be used to measure and monitor doses for all NEWs who have a reasonable probability of receiving an effective dose above 5 mSv/year, or an equivalent dose to skin, or to hands and feet, above 50 mSv/year. Doses for all workers will be recorded. Doses for all NEWs requiring licensed dosimetry will be reported to the National Dose Registry. Doses for individual workers will be compared to administrative levels and action levels, outlined in the *Radiation Code of Practice*.

Work instructions on the process for calculation and recording of individual worker doses over time, based on the relevant exposure measurements, are described in the *Worker Dose Calculation and Reporting Procedure*.

3.1.3 Contamination Monitoring

Surface contamination monitoring will be performed as appropriate for each contamination zone, including swipe tests for removable contamination, monitoring with a meter and pancake detector for total surface contamination, and calculation of fixed surface contamination. Results will be compared with administrative levels designed to keep clean areas from being impacted by contamination transport from other areas.

Contamination zones are described further in the *Radiation Protection Plan*. Work instructions on the contamination zones, and the methods, locations, and frequencies of surface contamination monitoring in each zone, are described in the *Contamination Monitoring and Control Procedure*.

3.1.4 Bioassay Monitoring

NEWs at the Operation will participate in a routine urine bioassay program. NEWs in work areas where there is risk of exposure to uranium ore concentrate participate in a targeted urine bioassay program.

Results will be compared to administrative levels indicative of abnormal intake. Doses are not ascertained from bioassay results except in the rare situation of an abnormal intake.

Work instructions on the methods and frequencies of urine collection and testing for the routine and targeted urine bioassay program are described in the *Urine Bioassay Monitoring Procedure*.

3.2 Radiation Exposure Controls

This section describes how controls are selected and applied in order to reduce radiation risks that have been identified through risk assessment as needing better control. Controls are selected in consideration of the following order of preference:

- Eliminate hazard or substitute with a lesser hazard;
- Engineer systems that reduce exposure;
- Define administrative (safe work) procedures and/or improve training; and
- Require personal protective equipment (PPE).

Controls may be used in combination to prevent or reduce radiation risk to workers, the public or the environment. For example, appropriate training is often critical to the effectiveness of other controls.

3.2.1 Elimination and Substitution

Neither elimination nor substitution of the hazard are feasible controls for the Operation, given its purpose to produce uranium concentrate, and given the radioactive nature of uranium. Elimination of an exposure pathway would typically involve engineering controls.

3.2.2 Engineering Controls

Engineering controls involve facility design features or equipment that serve to reduce or eliminate a pathway of exposure to the hazard. For example, ventilation is an important engineering control to reduce worker exposure to uranium dust or radon, negative pressure enclosure of dust generating equipment is a further control on dust exposure and shielding around source materials (e. g. in tanks and piping) reduces external radiation exposure. Details are discussed by work area in the *Radiation Protection Plan.*

3.2.3 Administrative Controls

Administrative controls include work practices and procedures, effective training to ensure they are understood, and effective supervision to ensure they are followed. Examples of administrative controls include procedures and work instructions, radiation work permits, signage and warning systems, and incident and deviation reporting. Work practices are developed with attention to managing time at distance from radiation sources. Further details are provided in the *Radiation Protection Plan.*

3.2.4 Personal Protective Equipment

PPE includes protective clothing, safety glasses, gloves, and respiratory protection devices designed to protect workers from radiation exposure. PPE is considered the last line of defense and is typically used in combination with other types of controls. Situations requiring PPE will be defined, and PPE will be provided for those situations. PPE is periodically inspected to verify it has not passed its date of expiry and is in good working condition. Further details are provided in the *Radiation Protection Plan.*

3.2.5 Contamination Control

Contamination is the introduction of radiological particulates into an area where they are not permitted. All areas of the Operation site, indoor and outdoor, are divided into contamination zones based on thresholds for allowable removable and fixed surface contamination within each zone. The contamination control process, via routine monitoring, verifies that particulate radiation from more contaminated zones is not routinely being tracked into areas with lower thresholds. PPE (protective clothing) and personal hygiene restrictions apply to workers moving between and within zones. Eating and drinking restrictions are applicable within designated areas. Contamination zones and control processes are detailed in the *Radiation Protection Plan a*nd the *Contamination Monitoring and Control Procedure.*

3.2.6 Managing Nuclear Substances and Radiation Devices

Nuclear substances such as uranium will be present and devices such as nuclear density gauges may be used during the Operation. These are radiation sources and must be controlled. All nuclear substances and radiation devices will be licensed and managed in accordance with the *Nuclear Substances and Radiation Devices Regulations*. A listing of nuclear substances and radiation devices licensed at the Operation site will be maintained. All licensed nuclear substances and radiation devices will be labelled as set out in the *Radiation Protection Regulations*. Only certified radiation devices are used at the Operation site.

Work instructions on the management and control of nuclear substances and radiation devices are described in the *Nuclear Substance and Radiation Devices Management Procedure*.

3.2.7 Clearance of Objects for Offsite Release

All objects from potentially contaminated work areas that need to be transported off-site as non-radioactive materials must be thoroughly cleaned and checked for contamination prior to release. Surface contamination criteria are contained in the *Packaging and Transport of Nuclear Substance Regulations*.

Work instructions on the clearance of objects for off-site release are described in the *Clearance for Off-site Release* Procedure. Objects will not be released if surface contamination exceeds the clearance limits defined in this procedure.

3.2.8 Packaging and Transport of Radioactive Materials

All materials leaving the site and classified as Class 7 Radioactive Materials under the *Packaging and Transport of Nuclear Substance Regulations*, will be further classified, packaged, labelled, and transported in compliance with the Regulations. Class 7 materials will not be transported off the Operation site unless they are in transit to a person or location licensed to receive them.

3.3 Contractor Management

Contractors performing work at the Operation site are subject to the requirements of this Program. The process for ensuring contractors adhere to requirements is outlined in the *Contractor Management Procedure* as part of the *Facility and Equipment Management Program*.

3.4 Equipment Procurement and Maintenance

All equipment to be used in the implementation of the *Radiation Protection Program* will be procured and maintained in accordance with defined procedures. All equipment used to monitor radiation is required to be calibrated before first use, then at regular intervals (at least once per year) and after any repair. Calibration and maintenance records are kept and made available to anyone who may request them. Nuclear density gauges or other sealed sources are leak tested regularly in accordance with the *Nuclear Substances and Radiation Devices Regulations*. All radiation measuring equipment is quality checked prior to use to verify proper equipment function.

Work instructions on checks, equipment calibration, and proper use are available for each piece of radiation measuring equipment, are described in the *Radiation Measurement Equipment Management Procedure*.

3.5 Incident and Deviation Reporting

Incidents include identified non-conformances, non-compliances, near misses, and opportunities for improvement. Workers and visitors are required to report information regarding health, safety, incidents (including near misses), and deviations. Radiation incidents and deviations include, but are not limited to:

- Radiation incidents (doses above action levels or regulatory limits);
- Unexpected dosimetry or monitoring results (above administrative levels);
- Contamination events (contamination above administrative levels for a zone); and
- Radiation near-misses (situations where a radiation incident could have occurred but was avoided).

Incidents or deviations that result in exceedances of federally or provincially legislated radiation reporting thresholds will be reported to the relevant regulatory agencies within legislated reporting timelines. Reporting requirements for exceedances of radiation action and administrative levels will follow requirements outlined in the *Radiation Code of Practice*.

Additional details on incident and deviation reporting can be found in the *Management System Program.*

4 Check

4.1 Monitoring and Measurement

Radiation protection performance is monitored and measured against established objectives and targets (identified in Section 2.2). Monitoring results (identified in Section 3.1) will be routinely evaluated against administrative and action levels (as per the *Radiation Code of Practice*) and evaluated over time by calculating indicators of performance for the *Radiation Protection Program*. Indicators for the Program will include, but is not limited to:

- Frequency of exceeding administrative and action levels; and
- Trend over time in exposure concentrations and worker doses.

All monitoring and measurement activities must also meet defined quality assurance and quality control requirements outlined within relevant Plans as part of this Program.

The results of monitoring and measurement activities are communicated internally and externally (see Section **Error! Reference source not found.**) and documented as part of the *Records Management* process outlined in the *Management System Program.*

4.2 Inspections and Audits

Denison will conduct internal audits of the *Radiation Protection Program* to assure compliance with the requirements set out in the Program and to determine if the Program is effectively implemented and maintained.

Workplace inspections will be performed as outlined in the *Health and Safety Management Program.* Effective use of radiation exposure controls will be monitored (e.g., to verify that radiation signage is effective and meets regulatory requirements).

Deviations, instances of regulatory noncompliance, and opportunities for improvement identified through inspections or audits are managed as outlined in the *Management System Program*.

4.3 Management Review

The *Radiation Protection Program* will be reviewed by Denison management in accordance with the defined frequency to assure the Program is meeting its objectives or needs adjustment. Examples of the types of items related to radiation protection that Denison management will review may include, but is not limited to:

- Suitability, adequacy, and performance of radiation protection objectives and targets;
- Upcoming or new legislation related to radiation protection;
- Recent or planned changes in facility operations;
- Results of monitoring in relation to meeting performance objectives and targets;
- Results of audits and inspections in relation meeting performance objectives and targets;
- Identified opportunities for improvement based on incident reports and other sources;
- Communications from interested parties;

- Adequacy of resources; and
- Any needs for program adjustment.

Denison management will identify opportunities for improvement and establish action plans to implement change in accordance with the process outlined in the *Management System Program*.

4.4 Reporting

Denison will routinely report both internally and externally on the performance of the *Radiation Protection Program*. External reporting can include reporting to regulators, the public, and Indigenous and local communities.

External reports to regulators will be produced in accordance with regulatory requirements.

External reports to the public or Indigenous communities on the performance of the Program will be tailored to the interests of these groups as identified through community engagement activities. Reporting, disclosure, and communication to the public and Indigenous and local communities is discussed in more detail in the *Public and Indigenous Information Program.*

5 Act

5.1 Corrective Action

Non-conformities or areas for improvement are identified following the process outlined in the *Management System Program* and the supporting procedures. These non-conformities can include exposure related incidents, near-misses, and deviations from the *Radiation Protection Program.* Non-conformities can also be identified during inspections and audits.

Responses to identification of non-conformities include investigation of cause, and corrective action if appropriate. Corrective actions are planned, implemented, verified, and reviewed for effectiveness based on the process identified in the *Management System Program*.

5.2 Continual Improvement

Opportunities for improvement of this Program will be identified and addressed to enhance radiation protection performance. The continual improvement process for this Program follows the overall continual improvement process outlined in the *Management System* and the supporting procedures. Continual improvement may also include updating Program objectives and targets based on changing circumstances or new information. Improvement may involve benchmarking performance against other similar projects and facilities. Any changes identified through the continual improvement process will be implemented in a systematic and controlled manner.

With respect to radiation protection, opportunities for continual improvement may be identified through review by the RSO of techniques, processes, and procedures for ensuring effective protection.

6 References

6.1 Internal

Document Name
Management System Program
Facility and Equipment Management Program
Training Management Program
Environmental Management Program
Health and Safety Management Program
Emergency Management Program
Fire Protection Program
Radiation Protection Plan
ALARA Plan
Radiation Code of Practice

6.2 External

Canadian Nuclear Safety Commission (CNSC). 2021a. Radiation Protection. REGDOC 2.7.1. Canadian Nuclear Safety Commission.

Canadian Nuclear Safety Commission (CNSC). 2021b. Radiation Protection Regulations. SOR/2000-203. Minister of Justice. Government of Canada.

Canadian Nuclear Safety Commission (CNSC). 2015a. Nuclear Substances and Radiation Devices Regulations SOR/2000-207. Minister of Justice. Government of Canada.

Canadian Nuclear Safety Commission (CNSC). 2015b. Transport of Nuclear Substance Regulations. SOR/2015-145. Minister of Justice. Government of Canada.

16 Denison Mines Corp. Wheeler River Operation, Radiation Protection Plan, Document # 23 Version 2, March 2025

Denison Mines Corp.
Wheeler River Operation

Radiation Protection Plan

Document # 23

Version 2

March 2025

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
1	19 Dec 2023	Submitted for CNSC review			

Revision History

Version	Date	Description of Revision
1	19 Dec 2023	Submitted for CNSC review
2	March 2025	Table 2-1 – *revised heading.*

Table of Contents

Tables

Acronyms and Abbreviations

Term	Definition
ALARA	As low as reasonably achievable
ALI	Annual limit on intake
CAM	Continuous air monitoring
DAC	Derived air concentration
EIS	Environmental Impact Statement
ISR	In-situ recovery
LLRD	Long lived radioactive dust
NEW	Nuclear Energy Worker
PPE	Personal protective equipment
RnG	Radon gas
RnP	Radon progeny
RSO	Radiation safety officer
UBS	Uranium bearing solution
WL	Working Levels
WTP	Water treatment plant

1 Introduction

1.1 Purpose

This *Radiation Protection Plan* for the Wheeler River Operation (the Operation) supports the *Radiation Protection Program*. The *Radiation Protection Plan* provides detail on the radiological hazards, exposure pathways, and how monitoring and control of worker exposure and dose occurs. It is intended to meet the expectations of the Canadian Nuclear Safety Commission (CNSC) with respect to radiation protection, as well as applicable regulatory requirements.

1.2 Regulatory Framework

Regulatory requirements with respect to radiation protection are outlined in the *Nuclear Safety and Control Act* (NSCA) and associated regulations, including the *General Nuclear Safety and Control Regulations*, the *Nuclear Substances and Radiation Devices Regulations*, the *Packaging and Transport of Nuclear Substances Regulations*, the *Uranium Mines and Mills Regulations*, and the *Radiation Protection Regulations* (CNSC, 2015a, 2015b, 2015c, 2017, 2021a). Guidance on radiation protection is provided by the CNSC in REGDOC 2.7.1 on Radiation Protection (CNSC, 2021b), and related guidance on dosimetry is provided in REGDOC 2.7.2 (CNSC, 2021c).

2 Context of the Plan

2.1 The Project Site and Facilities

The Wheeler River Operation will be an in-situ recovery (ISR) mining operation with on-site processing. The ISR operations involve a wellfield, where uranium is extracted from the ore body in a circulating lixiviant solution, and the ISR Plant, where uranium is precipitated out of solution to make the yellowcake product. The fresh yellowcake will be dried and then packaged for transport.

Workers engaged in the Wheeler River Operation will be occupationally exposed to radiation sources in several work areas in the process of drilling, lixiviant recovery, and processing to yellowcake. Expected exposure pathways are through inhalation of radioactive dust and radon, as well as external exposure to gamma radiation from process solids and liquids containing radionuclides of the U-238 decay chain.

2.2 Radiological Hazards and Exposure Pathways

Radon gas (RnG) and short-lived radon progeny (RnP) are of primary concern at the front end of the ISR process, where solutions and precipitates bearing Radium-226 (Ra-226) and daughter Radon-222 (Rn-222) are present. Gaseous Rn-222 grows in rapidly from decay of Ra-226. When uranium bearing solution (UBS) is initially brought from the ore body to surface, Rn-222 gas is supersaturated in the solution, and will off-gas rapidly when exposed to air. Within the ISR plant, Rn-222 in solution is supported by ingrowth from Ra-226, and Rn-222 gas can partition from open solutions or precipitates to indoor air.

Radon gas will also emanate from cores of uranium ore in the core shack, since the cores contain all the radionuclides of the U-238 series, including Ra-226. Short-lived progeny can grow in from airborne radon and will also be present in the air within the core shack.

Long-lived radioactive dust (LLRD) is of primary concern at the back end of the ISR process since the process is wet until the yellowcake product (uranium oxide) is precipitated out of solution and dried. The long-lived species of concern at that point are U-238 and U-234. Both species can be inhaled from air, mainly in the drying and packaging/loading areas.

Ore dust (another form of LLRD) is also of potential concern when handling and cutting cores of uranium ore in the core shack. The drilling process is wet, but cores may become dry. Since all the radionuclides of the U-238 series are present, all contribute to worker dose if dust is inhaled.

External gamma exposure is of potential concern throughout the ISR process, when workers spend time in close proximity to a source, particularly a large volume with high concentrations of U-238 series radionuclides.

2.3 Work Areas and Radiation Sources

The following work areas and associated key sources of radiation exposure are anticipated:

- **Wellfield (Well Collar):** Drillers on the wellfield are exposed to radiation from drill cuttings from the ore zone. The cuttings are temporarily stored in drums at the drilling location until they are moved to the special waste pad;
- **Wellfield (Header House and Storage Tank):** Workers here are exposed to external radiation from UBS in header house piping and UBS storage tank. In addition, UBS sample ports and instrumentation ports are local sources of radon to indoor air;
- **Wellfield (Wellfield Piping):** Workers here are exposed to external radiation from UBS in other wellfield piping;
- **ISR Plant (Process Precipitate Removal Area):** Workers here are exposed to external radiation from the UBS feed tank, the process precipitate thickener, and filter cake. In addition, the thickener and filter cake are local sources of radon to indoor air;
- **ISR Plant (Yellowcake Precipitation Area):** Workers here are exposed to external radiation from the precipitation tank and the yellowcake thickener. In addition, the thickener is a local source of radon to indoor air;
- **ISR Plant (Water Treatment Area):** Workers here are exposed to external radiation from the water treatment plant (WTP) clarifiers, which also serve as a local source of radon to indoor air (less than upstream sources);
- **ISR Plant (Drying Area):** Workers here are exposed to external radiation from the yellowcake in the drier. In addition, they are potentially exposed to radioactive dust in the air from the dried yellowcake product;
- **ISR Plant (Packaging/Loading Area):** Workers here are exposed to external radiation from drums of yellowcake product in the loading bay. In addition, they are potentially exposed to radioactive dust in the air from the dried yellowcake product;
- **Waste Pads and Ponds:** Equipment operators here may be exposed to radiation from the special waste pad (drill cuttings from the ore zone) and the process precipitate pond. In addition, they are exposed to radon in outdoor air from various sources, including the pond and wellfield; and

- **Core Shack:** Geologists and geotech staff here are exposed to external radiation from cores. In addition, the cores are a source of both ore dust and radon to indoor air.

For more information on the Operation layout please refer to the *Facility Description Manual*.

2.4 Worker Dose Calculations

The Environmental Impact Statement (EIS) (Appendix 10-C) identified radiation sources and predicted worker doses for each work area (i.e., job category). The dose predictions are based on design assumptions about source concentrations, volumes, geometry, and shielding materials, as well as worker exposure times in work areas and time at distance from key sources. Exposure and dose monitoring during commissioning will check on predictions.

As a basis for design of exposure and dose monitoring systems, the EIS predictions for the key components of worker exposure and effective dose by work area (those resulting in 1 mSv/y or more) are outlined below.

Table 2-1: Exposure Location and Total Predicted Effective Worker Dose

Predicted External Radiation Dose	
Wellfield (Well Collar)	10.16 mSv/y
ISR Plant (Precipitate Removal Area)	12.59 mSv/y
ISR Plant (Water Treatment Area)	1.70 mSv/y
Waste Pads and Ponds	5.68 mSv/y
Core Shack	2.02 mSv/y
Predicted Rn-222 Air Concentration and Dose (dose includes progeny contribution)	
ISR Plant (Process Precipitate Removal Area)	879 Bq/m^3, 2.27 mSv/y
ISR Plant (Yellowcake Precipitation Area)	613 Bq/m^3, 1.54 mSv/y
Core Shack	1248 Bq/m^3, 2.30 mSv/y
Predicted U-238 Air Concentration and Dose (dose includes progeny contribution)	
ISR Plant (Drying Area)	3.9 Bq/m^3, 11.7 mSv/y
ISR Plant (Packaging/Loading Area)	3.9 Bq/m^3, 11.7 mSv/y
Core Shack	0.20 Bq/m^3, 6.65 mSv/y

Monitored worker dose information will be recorded, tracked, and managed, on an individual basis, and by work area, as discussed in subsequent sections.

3 Worker Exposure and Dose

3.1 Monitoring of Worker Exposure and Dose

The plan for exposure and dose monitoring in each work area is informed by hazard identification and risk assessment (exposure/dose estimation), such that the main radiation exposure pathways are monitored. The EIS (Appendix 10-C) identified radiation sources and predicted worker doses for each work area (i.e., job category). Exposure and dose monitoring during commissioning will check on predictions, allowing for optimization of exposure and dose control systems. Results will contribute to the Risk Register, which will document hazards, exposures, doses, and controls for various exposure situations. Monitoring and control systems are subject to periodic review to ensure they are fit for purpose.

3.1.1 Radiation Exposure Monitoring

The type of exposure monitoring to be performed will be defined for each work area as appropriate to their identified hazards and risk assessments (exposure estimates). Exposure monitoring may include measurement of RnG, RnP, LLRD, and/or gamma radiation in the work area. Results are compared to administrative levels. Monitoring equipment may include real-time warning systems, such as continuous air monitors and direct-reading dosimeters, enabling workers to respond to changing conditions to minimize exposure.

External gamma radiation doses will be monitored in all work areas by means of:

- Personal dosimeters worn by all workers (dose recorded daily in µSv/day); and
- Hand-held meters used by radiation technicians to characterize key sources.

Radon exposure levels will be monitored in all work areas by means of:

- Air grab samples taken in all work areas (results in Working Levels (WL)); and
- Continuous air monitors (CAM) in key work areas (colour warnings indicate WL range).

LLRD exposure levels will be monitored in all work areas by means of:

- Air grab samples taken in all work areas (results as fraction of Derived Air Concentration (DAC)); and
- Dust pumps worn by workers in key LLRD work areas (results given as fraction of DAC).

The DAC is the air concentration for U-238 (Bq/m^3) corresponding to the annual limit on intake (ALI, Bq/y) which corresponds to 20 mSv/y for a reference worker (1.2 m^3/h for 2000 h/y). The ALI for U-238 in uranium oxide dust is greater than that for U-238 in uranium ore dust because more progeny are present in ore dust and the progeny inclusive dose coefficient is larger for U-238 in ore dust.

The *Radiation Exposure Monitoring Procedure* describes the methods, locations, and frequencies for each type of exposure monitoring. The monitoring results will be compared to administrative and action levels as outlined in the *Radiation Code of Practice*.

3.1.2 Worker Dose Monitoring

Worker effective dose will be calculated as the sum of three components: gamma radiation, radon, and LLRD. Worker equivalent dose to the skin and lens of eye will be determined from the gamma radiation measurements. A licensed dosimetry service will be used to measure and monitor doses for all nuclear energy workers (NEW)s who have a reasonable probability of receiving an effective dose above 5 mSv/year, or an equivalent dose to skin, or to hands and feet, above 50 mSv/year. Doses for all workers (NEWs and non-NEWS) will be recorded. Doses for all NEWs requiring licensed dosimetry will be reported to the National Dose Registry.

Personal dosimeter measurements will provide equivalent doses as well as the external component of effective dose, through use of appropriate filters to detect energy penetrating to different depths. The operational quantity Hp (10) represents whole-body effective dose, while Hp (0.07) represents skin dose. Workers are expected to be in uniform radiation fields, such that eyes are not closer to source than the body. Equivalent dose to lens of eye is essentially equal to effective dose for exposure to uranium oxide (U-238 and U-234) and approximately 1.6 times effective dose if all decay chain isotopes are present (uranium ore or UBS), based Microshield results. Thus, considering effective and lens dose limits, the dose to lens is never limiting. The dose to lens can be estimated from Hp (10) measurements.

The *Worker Dose Calculation and Reporting Procedure* describes how doses will be calculated from the exposure measurements and reported for individual workers. Doses will be compared to administrative levels and action levels, as outlined in the *Radiation Code of Practice*.

3.1.3 Contamination Monitoring

Zones of potential surface contamination will be defined, as a basis for understanding potential for radioactivity transport by workers between zones, and for design of access controls to prevent contamination of clean areas. In each zone, swipe tests for removable contamination will be conducted, and surface gamma readings will be taken using a meter with a pancake probe. Results for removable and fixed contamination will be recorded and compared with administrative levels, which are designed to keep clean areas from being impacted by transport from other areas.

The following work areas have potential for higher levels of surface contamination:

- Drying area – potential for deposition of LLRD (uranium oxide dust);
- Packaging/loading area – potential for deposition of LLRD (uranium oxide dust);
- Core shack – potential for deposition of LLRD (uranium ore dust);
- Process precipitate removal area – potential for contamination via handling of filter cake; and
- Wellfield drilling sites – potential for contamination via handling of drill cuttings.

The *Contamination Monitoring and Control Procedure* defines contamination zones, monitoring frequencies and methods, procedures for moving from one zone to another, and cleaning requirements. The monitoring results will be compared to administrative levels as outlined in the *Radiation Code of Practice*.

3.1.4 Bioassay Monitoring

NEWs will participate in a routine urine bioassay program. NEWs in work areas where there is risk of exposure to LLRD will participate in a targeted urine bioassay program, which includes special bioassay monitoring to investigate any known or suspected abnormal intake.

The following work areas have a risk of exposure to LLRD:

- Drying area – potential for deposition of LLRD (uranium oxide dust);
- Packaging/loading area – potential for deposition of LLRD (uranium oxide dust); and

- Core shack – potential for deposition of LLRD (uranium ore dust).

The targeted program in LLRD areas will include special urine bioassay testing for individuals whenever their personal LLRD exposures suggest that an abnormal intake may have occurred (e.g., LLRD exceeds the DAC, or a routine bioassay result exceeds the expected maximum for the LLRD area).

The *Urine Bioassay Monitoring Procedure* describes methods and frequencies of urine collection and testing, as well as criteria for participation in the routine and targeted urine bioassay programs.

3.2 Control of Worker Exposure and Dose

The plan for control of exposure and dose in each work area is informed by hazard identification and risk assessment (exposure/dose estimation), such that the main radiation exposure pathways are controlled. The EIS (Appendix 10-C) identified radiation sources and predicted worker doses for each work area (i.e., job category). Exposure and dose monitoring during commissioning will check on predictions, allowing for optimization of exposure and dose control systems. Results will contribute to a risk register, which will document hazards, exposures, doses, and controls for various exposure situations. Monitoring and control systems are subject to periodic review to ensure they are fit for purpose.

Controls are selected in consideration of the following order of preference (hierarchy of controls):

- Eliminate hazard or substitute with a lesser hazard;
- Engineer systems that reduce exposure;
- Define administrative (safe work) procedures and/or improve training; and
- Require personal protective equipment (PPE).

Controls may be used in combination to prevent or reduce radiation risk to workers, the public or the environment. For example, appropriate training is often critical to the effectiveness of other controls.

Elimination or substitution of the radiation hazards are not feasible controls for the Operation, given its purpose to produce uranium concentrate, and given the radioactive nature of uranium. Elimination of an exposure pathway would typically involve engineering controls.

Engineering controls have been incorporated into Operation design. They serve to reduce or eliminate a pathway of exposure to the radiation hazard. Key engineering controls include:

- Sparging to off-gas dissolved RnG from the UBS and vent it to atmosphere;
- Ventilation in all enclosed work areas (6 exchanges per hour) is a control on worker exposure to LLRD and to RnG and RnP;
- Negative pressure enclosure of key LLRD sources in the drying area and the packaging/loading area (drum loader); exhaust is separate from the room ventilation system; and
- Shielding around source materials serves to reduce external radiation exposure; includes steel in tanks and drums, HDPE in totes and piping, and berm around special waste pad.

Administrative controls include procedures and work instructions, radiation work permits for unusual exposure situations, signage and warning systems, and incident and deviation reporting (all discussed below), as well as effective training to ensure these systems are understood (Section 4.6) and effective supervision to ensure these systems are followed.

Personal protective equipment (PPE) includes protective clothing, safety glasses, gloves, and respiratory protection devices designed to protect workers from radiation exposure. PPE is considered the last line of defense and is typically used in combination with other types of controls. Situations requiring certain types of PPE are defined in the *Radiation Code of Practice*.

3.2.1 Procedures and Work Instructions

Written procedures describe work processes relevant to exposure and dose monitoring or control, or other aspects of radiation protection. They may be supported by detailed work instructions for specific tasks. Work instructions will detail how workers can reduce time near a radiation source and maximize their distance from it when completing a task. They enable workers to perform their duties in compliance with planned procedures, using PPE as needed, to ensure that worker exposures and doses are kept as low as reasonably achievable (ALARA).

The *Radiation Exposure Monitoring Procedure* describes the methods, locations, and frequencies for each type of exposure monitoring.

The *Worker Dose Calculation and Reporting Procedure* describes how doses will be calculated from the exposure measurements and reported for individual workers.

The *Contamination Monitoring and Control Procedure* defines contamination zones, monitoring frequencies and methods, procedures for moving from one zone to another, and cleaning requirements.

The *Urine Bioassay Monitoring Procedure* describes methods and frequencies of urine collection and testing, as well as criteria for participation in the routine and targeted urine bioassay programs.

The *Nuclear Substance and Radiation Devices Management Procedure* describes processes for managing nuclear substances and radiation devices (see Section 4.3.6).

The *Clearance for Off-site Release Procedure* describes processes for clearing materials to be transported off-site as non-radioactive materials (see Section 4.3.7).

3.2.2 Radiation Work Permits

The work permit process provides planned procedures for non-routine (unusual) exposure situations. The planning is based on anticipated radiation hazards, estimated worker exposures and doses, and selection of controls to optimize exposure and dose. The resulting work permit outlines the new task, and its anticipated hazards, exposures, doses, controls, associated monitoring to verify that exposures are as expected, and actions to be taken if they are not. On completion of the work, the information is added to the risk register to document the experience.

The *ALARA Plan* provides more detail on the radiation work permit process.

3.2.3 Signage and Warning Systems

Signage is used to delimit boundaries between contamination zones and to identify other potential radiation hazards in a particular work area that workers should be aware of such as higher levels of LLRD or radon. The signage may include safe practice reminders appropriate to the work area.

Warning systems include continuous CAM devices with automatic alarm systems in areas with potential for higher levels of LLRD or radon.

The work areas with potential for higher levels of LLRD include the drying area, and the packaging/loading area (both with uranium oxide dust) and the core shack with uranium ore dust. Work areas with potential for higher levels of radon include the core shack and the process precipitate removal area.

3.2.4 Personal Protective Equipment

Personal protective equipment (PPE) includes protective clothing, safety glasses, gloves, and respiratory protection devices designed to protect workers from radiation exposure. PPE is considered the last line of defense and is typically used in combination with other types of controls. Situations requiring certain types of PPE are defined in the *Radiation Code of Practice* – please refer to that document and the *Personal Protective Equipment Procedure* for further information.

3.2.5 Managing Nuclear Substances and Radiation Devices

A listing of nuclear substances and radiation devices licensed at the Operation site will be maintained. Only certified radiation devices are used at the Operation site.

Details on the management and control of nuclear substances and radiation devices are described in the *Nuclear Substance and Radiation Devices Management Procedure*.

3.2.6 Clearance of Objects for Off-site Release

Details on the clearance of objects for off-site release are described in the *Clearance for Off-site Release Procedure*. Objects will not be released if surface contamination exceeds the clearance limits defined in this procedure.

3.3 Equipment Procurement and Maintenance

Details on performing checks, equipment calibration, and proper equipment use are available for each piece of radiation measuring equipment as described in the *Radiation Measurement Equipment Management Procedure*.

3.4 Qualifications and Training

Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely.

Technicians and other applicable workers will be required to complete successful completion of in-house training, and certification by an RSO.

A systematic approach to training (SAT) of Radiation Protection personnel is detailed in the *Training Management Program*.

3.5 Communication

Avenues of internal communication will be established within the Health and Safety Executive Department to ensure that the flow of information from the field and laboratories reaches the RSO and vice versa. Venues and tools used for internal communication of radiation safety information will include but are not limited to; radiation safety review meetings, safety moments, radiation safety posters and hazard signage.

Communication principles and processes are further outlined in the *Management System Program* and communication with indigenous communities, local communities, and the public is managed as outlined in the *Public and Indigenous Information Program.*

4 References

4.1 Internal

Document Number	Document Name
	ALARA Plan
	Clearance for Off-site Release Procedure
	Contamination Monitoring and Control Procedure
	Management System Program
	Nuclear Substance and Radiation Devices Management Procedure
	Personal Protective Equipment Procedure
	Public and Indigenous Information Program
	Radiation Code of Practice
	Radiation Exposure Monitoring Procedure
	Radiation Protection Plan
	Radiation Protection Program
	Training Management Program
	Urine Bioassay Monitoring Procedure
	Worker Dose Calculation and Reporting Procedure

4.2 External

Canadian Nuclear Safety Commission (CNSC). 2015a. General Nuclear Safety and Control Regulations. SOR/2000-202. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2015b. Nuclear Substances and Radiation Devices Regulations. SOR/2000-207. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2015c. Packaging and Transport of Nuclear Substances Regulations. SOR/2015-145. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2017. Uranium Mines and Mills Regulations. SOR/2000-206. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2021a. Radiation Protection Regulations. SOR/2000-203. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2021b. Radiation Protection. REGDOC 2.7.1. Canadian Nuclear Safety Commission.

Canadian Nuclear Safety Commission (CNSC). 2021c. Radiation Protection. Dosimetry. Volume 1. Ascertaining Occupational Dose. REGDOC-2.7.2. Canadian Nuclear Safety Commission.

17 Denison Mines Corp. Wheeler River Operation, ALARA Plan, Version 1, December 2023

Denison Mines Corp.
Wheeler River Operation

ALARA Plan

Document # 21

Ver. 1

December 2023

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
1	19 Dec 2023	Draft for CNSC Review			

Revision History

Version	Date	Description of Revision
1	19 Dec 2023	Draft for CNSC Review

Table of Contents

Acronyms and Abbreviations

Term	Definition
ALARA	As low as reasonably achievable
EIS	Environmental Impact Statement
LLRD	Long lived radioactive dust
NEW	Nuclear Energy Worker
PPE	Personal protective equipment
RnG	Radon gas
RnP	Radon progeny
SAT	Systematic Approach to Training
RSO	Radiation safety officer

1 Introduction

1.1 Purpose

This *ALARA Plan* supports the *Radiation Protection Program* for the Wheeler River Operation (the Operation). The *ALARA Plan* defines the process of optimization that is followed to ensure that radiological doses received by workers and members of the public are as low as reasonably achievable (ALARA), considering social and economic factors. The *ALARA Plan* is intended to meet the expectations of the Canadian Nuclear Safety Commission (CNSC) with respect to radiation protection, as well as applicable regulatory requirements. REGDOC-2.7.1 *Radiation Protection* (CNSC, 2021b) provides guidance on the application of ALARA.

2 Management Controls over Work Practices

2.1 General Process

Radiological exposures are kept ALARA, through a process of work and exposure planning, optimizing controls, monitoring to assess their effectiveness, and reviewing to see if there are opportunities for improvement. The intention is to plan and control both workplace exposures and public exposures, the latter through planning and control of emissions to the environment. The process is further described in Section 3 with respect to workplace exposures (Section 3.1) and public exposures (Section 3.2).

The ALARA process (CNSC, 2021b) is ongoing and cyclical, involving for any given exposure situation:

- Evaluation of the exposure situation (hazard assessment, risk assessment, dose estimation);
- Identification of options for exposure control (e.g. engineering or administrative controls, PPE);
- Selection of the best option for control (considering social and economic factors);
- Implementation of the selected control (with monitoring to confirm effectiveness);
- Regular review of the situation to ensure control is optimized for prevailing conditions; and
- Corrective action and re-evaluation as needed to keep exposure and dose ALARA.

The ALARA process applies to both routine and non-routine exposure situations. The planning and control of exposure for these two types of situations are described in Sections 3 and 4, respectively.

Administrative controls often involve management of worker exposure time and/or distance from source, in accordance with written procedures. Worker training in safe work procedures, internal communication of dose outcomes and issues, and learning from experience are integral to the success of the ALARA process.

Selection of the best option for control is also called optimization. Optimization may be considered achieved without further evaluation if effective doses are shown to be less than 1 mSv/y for workers, or less than 0.05 mSv/y for members of the public. Otherwise, an optimization process must be followed to show that the selected controls produce doses below regulatory limits (Sections 13 and 14 of the Radiation Protection Regulations), and as low as reasonably achievable, considering social and economic factors (CNSC, 2021a). The process for optimization is outlined in Section 3.3, and consideration of social and economic factors is described in Section 3.4.

Safe work procedures, monitored exposure and dose results, incident and deviation reports, and reviews of performance with respect to exposure and dose control, all must be well documented as a basis for continuing improvement.

3 Planning and Control of Exposures

3.1 Workplace Exposures

The planning and control of a workplace exposure situation involves:

- Identification of radiation hazards;
- Assessment of likely exposures (dose/risk assessment);
- Consideration of options to control exposure;
- Selection of appropriate (optimized) controls;
- Design of monitoring to verify the effectiveness of control;
- Conduct work with selected controls and monitoring;
- Regularly review the situation to confirm control is effective; and
- Corrective action as needed to keep exposure and dose ALARA.

Planning for control of routine work situations was initiated during Project design and environmental assessment and will continue through licensing. Controls will be implemented during construction and commissioning and confirmed to be adequate. During operation, ongoing review of exposure and dose monitoring data will allow for adjustment of controls if needed.

Workers will be classified as nuclear energy workers (NEWs) or non-NEWs according to expected effective dose levels, as outlined in the *Radiation Protection Plan*. Total dose monitoring results for all workers will be tracked and compared to administrative levels and action levels, with associated mitigative/reporting actions if exceeded, in order keep doses at or below target levels, as outlined in the *Radiation Code of Practice*. Exceedance of an action level is considered to indicate loss of control and is an incident reportable to regulators. The RSO has responsibility for worker classification, dose tracking, mitigative action plans (in consultation with management) and reporting of dose incidents.

Workplace exposures to external radiation, radon progeny, and long lived radioactive dust (LLRD) are routinely monitored and compared to administrative levels and action levels, with associated mitigative/reporting actions if exceeded, as outlined in the *Radiation Code of Practice*. Bioassay monitoring is routinely conducted in high LLRD areas to identify any abnormal exposures that may be occurring, as outlined in the *Radiation Code of Practice*. Any abnormal exposure will trigger investigative and mitigative actions.

Work areas are routinely monitored for surface contamination with non-fixed radioactivity due to LLRD deposition. Work areas are classified as high or low contamination areas, and transition zones are defined, where personal decontamination procedures will be applied to prevent transfer of radioactivity from high to low contamination areas. Administrative levels for surface contamination, with associated mitigative/reporting actions, are outlined in the *Radiation Code of Practice*.

Access restrictions are applied to non-NEW workers and visiting members of the public, as well as pregnant or breastfeeding NEWs, to ensure that they do not have access to higher exposure areas. In addition, signage is used to identify Radiation Hazard Areas where NEWs will have limited access, in accordance with Section 21 of the *Radiation Protection Regulations* (CNSC, 2021a).

Details of the hazard assessment, dose/risk assessment, monitored exposures and appropriate exposure controls for each routine job category are maintained in the Risk Register. This provides a repository of information that can be utilized when considering new tasks, which encourages consistency in planning.

Planning and control of exposure for unusual worker exposure situations are described in Section 5 below.

3.2 Public Exposures

The planning and control of public exposure includes access restrictions for visiting members or the public, as noted above, as well as monitoring and control of contaminated materials transported off-site, and monitoring and control of radionuclides in effluents or emissions to the environment.

All objects from potentially contaminated work areas that need to be transported off-site as non-radioactive materials must be thoroughly cleaned and checked for contamination prior to release. Surface contamination criteria are contained in the *Packaging and Transport of Nuclear Substance Regulations (CNSC, 2015)*. Details on the clearance of objects for off-site release are described in the *Clearance for Off-site Release Procedure*. Objects will not be released if surface contamination exceeds the clearance limits defined in this procedure.

All materials leaving the site and classified as Class 7 Radioactive Materials under the *Packaging and Transport of Nuclear Substance Regulations (CNSC, 2015)*, will be further classified, packaged, labelled, and transported in compliance with the regulations. Class 7 materials will not be transported off the Operation site unless they are in transit to a person or location licensed to receive them.

The planning and control of radionuclides in effluents or emissions to the environment involves:

- Identification of radionuclides in the effluents or emissions;
- Assessment of likely public exposures (dose/risk assessment);
- Consideration of options to control the effluents or emissions;
- Selection of appropriate (optimized) controls;
- Design of monitoring to verify the effectiveness of control;
- Conduct release with selected controls and monitoring;
- Regularly review the situation to confirm control is effective; and
- Corrective action as needed to keep public exposure and dose ALARA.

Planning for control of routine effluents and emissions was initiated during Project design and environmental assessment and will continue through licensing. Controls will be implemented during construction and commissioning and confirmed to be adequate. During operation, ongoing review of effluent and emissions monitoring data and of resulting public exposure and dose will allow for adjustment of controls if needed. Details are provided in the *Effluent and Emissions Plan* within the *Environmental Management Program*.

3.3 Selection of Controls

Controls on worker exposure and dose are selected in consideration of the following order of preference (hierarchy of controls):

- Eliminate hazard or substitute with a lesser hazard;
- Engineer systems that reduce exposure;
- Define administrative (safe work) procedures and/or improve training; and
- Require personal protective equipment (PPE).

Elimination or substitution of the radiation hazards are generally not feasible, given the purpose of the Operation to produce uranium concentrate, and given the radioactive nature of uranium. Elimination of an exposure pathway would typically involve engineering controls.

Engineering controls have been incorporated into the design of the Operation. They serve to reduce or eliminate a pathway of exposure to the radiation hazard. Key engineering controls include:

- Sparging to off-gas dissolved radon gas (RnG) from the UBS and vent it to atmosphere;
- Ventilation in all enclosed work areas (6 exchanges per hour) is a control on worker exposure to LLRD and to RnG and radon progeny (RnP);
- Negative pressure enclosure of key LLRD sources in the drying area (dryer, calciner) and the packaging/loading area (drum loader); exhaust is separate from the room ventilation system; and
- Shielding around source materials serves to reduce external radiation exposure; includes steel in tanks and drums, HDPE in totes and piping, and a berm around the special waste pad.

Administrative controls include procedures and work instructions, radiation work permits for unusual exposure situations, signage and warning systems, incident and deviation reporting, as well as effective training to ensure these systems are understood, and effective oversight to ensure they are followed.

Personal protective equipment (PPE) includes protective clothing, safety glasses, gloves, and respiratory protection devices designed to protect workers from radiation exposure. PPE is considered the last line of defense and is typically used in combination with other types of controls.

There may be opportunity to add or enhance engineering, administrative and/or PPE controls if needed to keep doses ALARA. The review and selection process includes:

- Identifying options for additional control;
- Evaluating options in terms of benefit (dose reduction) and cost (financial and other impacts); and
- Selecting an option that is optimal (best) in consideration of benefit/cost trade-offs.

The comparison of options may be qualitative or quantitative. The selected (best option) controls for each exposure situation are documented with rationale in the Risk Register.

3.4 Consideration of Social and Economic Factors

In evaluating the benefit versus cost of control options, social and economic factors are considered, as applicable (CNSC, 2021b). For example, social factors such as perceived risk, cultural values, well being of local communities, and equitable allocation of risk and benefit, may influence the consideration benefit/cost trade-offs. While the company cost of implementing a new control is an obvious economic factor, other factors such as capital versus operating cost, and local or regional economic benefits of the operation, may also influence the consideration of benefit/cost trade-offs.

4 Planning for Unusual Exposure Situations

4.1 Performing a Radiation Hazard Analysis

Planning for an unusual (higher) exposure situation is intended to provide control over worker exposure in that new situation, such that exposure and dose are kept as low as reasonably achievable.

Radiation hazard analysis is a first step in risk assessment for an unusual planned exposure situation. The Risk Register is consulted to confirm that the new work situation is unusual, and to draw upon past experience with respect to likely hazards and successful controls. The Radiation Hazard Analysis identifies the work area and work to be performed, the key sources of external and internal radiation exposure, the radionuclides involved and the worker exposure levels.

4.2 Initiating a Radiation Work Plan

A Radiation Work Plan is developed for each new applicable work situation. Based on the hazard analysis a risk assessment is completed considering all pathways of exposure, resulting in an estimate of effective dose to the worker. Based on the risk assessment, controls are selected to minimize the dose. These may include use of shielding, management of worker time and distance, or used of PPE if needed. The Radiation Work Plan outlines the work area and the task, its anticipated hazards, exposure levels and doses, the exposure controls to be used, the associated monitoring to verify that exposures are within the expected range, and actions to be taken if they are not. The Radiation Work Plan is submitted to the RSO for review and approval.

Methods for calculating anticipated worker doses based on exposure levels are included in the *Worker Dose Calculation and Reporting Procedure*.

4.3 Issuing a Radiation Work Permit

Following review of the Radiation Work Plan the RSO will issue a Radiation Work Permit. This is derived from the Radiation Work Plan with modifications if deemed appropriate by the RSO. The Radiation Work Permit defines the work area and task to be performed, the anticipated hazards, exposure levels and doses, the exposure controls to be used, the associated monitoring to verify that exposures are as expected, and actions to be taken if they are not. A worker asked to perform the work must be provided this information and must agree to the conditions.

An area for which a Radiation Work Permit has been issued is a Restricted Area for any work not described in the permit and is identified as such by signage.

The permit can cover multiple entries into the same area for the same work. However, there is a limit on total dose to an individual worker under a Radiation Work Permit. This administrative limit is described in the *Radiation Code of Practice*.

The RSO will be responsible for tracking individual worker doses incurred under a Radiation Work Permit, will inform workers and their area managers when they approach this limit, and will exclude any worker from further participation who is likely to exceed this limit.

4.4 Use of the Risk Register

On completion of the work under a Radiation Work Permit, the information is added to the Risk Register to document the experience.

The Risk Register is used to track experience regarding new exposure situations. It documents the identified hazards, the controls used, and the exposures and doses received. The Risk Register facilitates use of past experience to inform future work.

4.5 Emergency Situations

In an emergency situation, any NEW who is not pregnant or breastfeeding may enter a Restricted Area without adherence to the Radiation Work Permit, in order to perform specific emergency actions as defined in Section 15 of the *Radiation Protection Regulations* (CNSC, 2021a). Event-based dose limits are applicable, as defined in the regulations. A post hoc dose assessment must be performed, and any exceedance of a limit is reportable to the regulators.

In an environmental emergency (a spill to the environment) the Environment Department must be informed immediately, to ensure adequate response to and reporting of the spill.

Emergency preparedness and response aspects of radiation protection are managed under the *Emergency Preparedness and Response Program*.

5 References

5.1 Internal

Document Number	Document Name
	ALARA Plan
	Clearance for Off-site Release Procedure
	Effluent and Emissions Monitoring Plan
	Emergency Preparedness and Response Program
	Environmental Management Program
	Management System Program
	Radiation Code of Practice
	Radiation Protection Plan
	Radiation Protection Program
	Worker Dose Calculation and Reporting Procedure

5.2 External

Canadian Nuclear Safety Commission (CNSC). 2015. Packaging and Transport of Nuclear Substances Regulations. SOR/2015-145. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2021a. Radiation Protection Regulations. SOR/2000-203. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2021b. Radiation Protection. REGDOC 2.7.1. Canadian Nuclear Safety Commission.

18 Denison Mines Corp. Wheeler River Operation, Radiation Code of Practice, Version. 2, March 2025

Denison Mines Corp.
Wheeler River Operation

Radiation Code of Practice

Document # 22

Ver. 2

March 2025

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
1	15 Dec 2023	Draft for CNSC Review			
2	March 2025	For CNSC Review			

Revision History

Version	Date	Description of Revision
1	15 Dec 2023	Draft for CNSC Review
2	March 2025	2.2 Action and Administrative Levels for Dosimetry and Associated Actions – *added detail.* Table 1 – *added clarification to heading.* 2.3 Result Tracking, Notification and Reporting of Exceedances – *added clarification.* Table 3 – *added footnote.*

Table of Contents

Tables

Acronyms and Abbreviations

Term	Definition
ALARA	As low as reasonably achievable
ALI	Annual limit on intake
AM	Area manager
APF	Assigned protection factors
CAM	Continuous air monitoring
CNSC	Canadian Nuclear Safety Commission
DAC	Derived air concentration
DIL	Derived investigation level
DRD	Direct reading dosimeter
ISR	In-situ recovery
LLRD	Long lived radioactive dust
LRWS	Labour Relations and Workplace Safety
NEW	Nuclear Energy Worker
OHC	Occupational Health Committee
PPE	Personal protective equipment
RnG	Radon gas
RnP	Radon progeny
RP	Radiation protection
RSO	Radiation safety officer
GM	General Manager
WL	Working level
LTPSC	License to prepare site and construct

1 Introduction

1.1 Background

This *Radiation Code of Practice* supports the *Radiation Protection Program* for the Wheeler River Operation. The *Radiation Code of Practice* defines dosimetry action levels and administrative levels for radiological exposure, and associated actions to be taken to control exposure and dose if those levels are exceeded. It also details the Radiation Work Permit process for control of new non-routine radiological exposure situations and criteria for use of respiratory protection devices.

This *Radiation Code of Practice* is intended to meet the expectations of the Canadian Nuclear Safety Commission (CNSC) with respect to radiation protection, as well as applicable regulatory requirements such as: REGDOC-2.7.1 (CNSC, 2021b) which provides guidance on use of action levels, administrative levels, and mentions Radiation Work Permits as an administrative control on exposure.

2 Action and Administrative Levels for Dosimetry

2.1 Purpose of Action and Administrative Levels for Dosimetry

Dosimetry action levels define the total dose for a worker which signify potential loss of control of the *Radiation Protection Program*. Total dose includes external radiation, long lived radioactive dust (LLRD), and radon components of effective dose, as applicable to the work area. Exceedance of an action level triggers corrective action to ensure that worker dose limits are not exceeded and triggers notification of regulatory authorities.

Dosimetry administrative levels are lower levels of total dose, which do not signify loss of control, and their exceedance does not trigger notification of regulatory authorities, but may still warrant certain actions, including internal notifications within the operating organization. Exceedance of an administrative level triggers action to ensure that doses are kept as low as reasonably achievable (ALARA) and that action levels are not exceeded.

2.2 Action and Administrative Levels for Dosimetry and Associated Actions

For Nuclear Energy Workers (NEWs), pregnant workers, and non-NEW workers dosimetry action and administrative levels and associated actions if they are exceeded, are outlined in **Table 1**. An exceedance is considered to occur at the time the dose value is calculated, and the radiation safety officer (RSO) becomes aware of the exceedance.

Table 1 is applicable to NEWs during the construction phase. Drilling within the ore body is planned to commence during the LTPSC phase. Potential radiological hazards have been identified in both the wellfield and the core shack. Workers assigned to these areas are expected to be classified as Nuclear Energy Worker (NEWs). Additionally, non-NEW Personnel, such as workers in non-radiological areas during construction will also be present during this phase. As activities progress into other stages, additional worker classification will be identified.

Table 1: Dosimetry Action and Admin Levels for workers (Total Effective Dose)

Admin Level	Dose Value (mSv)	Mitigative Action	Notifications
1(a) (monthly)	1.17 - NEW 0.3 - Pregnant NEW 0.08 - Non NEW	• Identify elevated worker dose through worker exposure review process; • Formally notify worker; • Initiate formal review; and • If twice in quarter, initiate formal review.	RSO Radiation Dept AM
1(b) (quarterly)	3.5 - NEW 0.9 - Pregnant NEW 0.23 - Non NEW	• Identify elevated worker dose through worker exposure review process; • Formally notify worker; and • Initiate formal review and devise action plan	As above plus GM OHC
1(c) **Action Level** (annual)	14 - NEW 3.6 - Pregnant NEW 0.9 - Non NEW	• Identify elevated worker dose through worker dose review process; • Formally notify worker • Initiate formal review and devise action plan; and • Follow up with full report in accordance with required timelines and report content (Section 2.3).	As above plus CNSC LRWS

Note: OHC = Occupational Health Committee, LRWS = Labour Relations and Workplace Safety (Saskatchewan)

The action level for NEW workers is below the 5-year average dose limit of 20 mSv/y. In reporting to regulators, any doses exceeding a dose limit will be specifically flagged as such.

For workers who are NEWs, and have reported they are pregnant or breastfeeding, their administrative levels will become 0.3 mSv/mo and 0.9 mSv/quarter for the balance of the pregnancy or breastfeeding period. Their action level will become 3.6 mSv for the balance of this period. Mitigative actions and notifications at each level are otherwise as outlined in **Table 1**.

2.3 Result Tracking, Notification and Reporting of Exceedances

The RSO will be responsible for daily recording of worker doses, flagging exceedances of administrative and action levels, tracking exceedance frequencies, notifying managers and regulators, working with management on mitigative measures, as needed, and regularly reporting dose information to workers.

Reviews and action plans will be documented and appropriately stored for future access and review.

Regulatory notifications and reports in response to action level exceedances as described above will be within required timelines and will include required content. Any worker doses exceeding their applicable dose limit, will be specifically flagged in reports. An internal non-conformance report is also filed whenever an action level is exceeded, in accordance with DMC-QUA-105 *Non-Conformance Procedure* within the *Management System Program*.

When dose limits are exceeded, section 16 and 17 of the Radiation Protection Regulation will be activated by the RSO.

Guidance on the format and content of initial and full reports to the CNSC (and Labour Relations and Workplace Safety (LRWS)) when action levels are exceeded is provided in REGDOC 3.1.2, Volume I CNSC (2022). The process for determining reporting requirements and timeframes, and for initiating and managing the reporting, is detailed in the DMC-QUA-105 *Non-Conformance Procedure* within the *Management System Program*.

3 Action and Administrative Levels for Exposure

3.1 Purpose of Action and Administrative Levels for Exposure

Action levels for exposure define the levels of short-term exposure for a worker which signify potential loss of control of the *Radiation Protection Program*. The exposure values monitored include external radiation, radon progeny (RnP), LLRD, and uranium in urine, as applicable to the work area. Exceedance of an action level triggers corrective action to ensure that exposure conditions do not persist that could lead to dose limit exceedances and triggers notification of regulatory authorities.

Administrative levels are lower levels of short-term exposure which do not signify loss of control, and their exceedance does not trigger notification of regulatory authorities but may still warrant certain actions, including internal notifications within the operating organization. Exceedance of an administrative level triggers action to ensure that exposures are kept ALARA and that action levels are not exceeded.

3.2 Action and Administrative Levels for Exposure and Associated Actions

Action and administrative levels for the various measures of short-term exposure and associated actions, if they are exceeded, are outlined in the following sections.

3.2.1 External Radiation Exposure

The relevant measures of external radiation exposure include ambient dose equivalent rates measured by the radiation protection department using a hand-held dose rate meter (average values for main work areas, 1 m above the floor), as well as personal dose equivalent rates recorded by real-time direct reading dosimeters (DRDs) worn by workers in higher gamma areas (where expected external dose is above 1 mSv/y).

The administrative levels for external radiation exposure and associated actions if they are exceeded are outlined in Table 2 and Table 3.

Table 2: Ambient Dose Equivalent Rate Action and Administrative Levels (for all areas)

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
2(a)	2.5 µSv/h	If reading is higher than expected, resample within 48 hours. If confirmed, determine cause, and mitigate if reasonably practicable.	RSO and RP department AM
2(b)	5 µSv/h	If reading is higher than expected, resample within 24 hours. If confirmed, determine cause, and mitigate if reasonably practicable.	RSO and RP department AM GM
2(c)	10 µSv/h	If reading is higher than expected, resample immediately. If confirmed, determine cause, mitigate if reasonably practicable. If readings are above 25 µSv/h, post "Gamma Radiation" signs and restrict access except for essential work under RWP.	RSO and RP department AM GM OHC

The 10 uSv/h value is a dose rate that, if it persists, could lead to a dose of 20 mSv/y. The 25 uSv/h value is a dose rate that, if it persists, could lead to a dose of 50 mSv/y.

Table 3: Individual Worker DRD Administrative Levels (for workers in higher gamma exposure areas)

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
3(a)	50 µSv/day	Worker to inform RP department and AM. Worker to record daily results until below this level for 7 consecutive working days.	RSO and RP department AM
3(b)	200 µSv/day	As for 4(a), plus notify GM and OHC. Worker to leave area until approved to return, based on RP review and finding of unlikely to exceed 400 µSv/week.	RSO and RP department AM GM OHC

3(c)	400 µSv/week	As for 4(b), plus RP/AM to develop action plan for worker to remain below 400 uSv/week, approved by GM, report outcome at next Radiation Safety Review Meeting.	RSO and RP department AM GM OHC

The 400 uSv/week value is an exposure level that, if it persists, could lead to a dose of 20 mSv/y.

DRD will be provided to any worker who enters an area where the dose rate exceeds 100 µSv/h.

3.2.2 Radon Progeny Exposure

The relevant measures of RnP exposure include air sampling by the radiation department and subsequent radiochemical analysis (RnP and radon gas (RnG)), as well as continuous air monitor (CAM) systems throughout the mill). The CAM system alerts workers when exposure levels exist that warrant exposure avoidance.

The administrative levels for RnP in air, and associated actions if they are exceeded, are outlined in Table 4 and Table 5.

Table 4: Radon Progeny Action and Administrative Levels based on Area Air Sample Results

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
4(a)	0.03 WL	If result is higher than expected, resample within 24 hours. If confirmed, determine cause, and mitigate if reasonably practicable.	RSO and RP department AM
4(b)	0.06 WL	If result is higher than expected, resample within 24 hours. If confirmed, determine cause, and mitigate if reasonably practicable.	RSO and RP department AM GM
4(c)	0.1 WL	Resample immediately to confirm result. If confirmed, determine cause and mitigate. Post "Airborne Radiation" signs and restrict access except for essential work under RWP. Resample every 24 hours until levels are persistently below 0.1 WL.	RSO and RP department AM GM OHC
4(d)	1 WL	As for 5(c), plus RP to notify CNSC and LRWS and follow up with full report in accordance with required timelines and report content (Section 3.3).	RSO and RP department AM GM OHC, CNSC, LRWS

The 0.1 WL value corresponds to 370 Bq/m^3 of RnG in full equilibrium (F=1) with short-lived progeny. With design ventilation (6 air exchanges/hour) only partial equilibrium is expected (F= 0.18).

Table 5: Radon Progeny Administrative Levels based on CAM Results (for all areas)

Admin Level	Colour (WL)	Mitigative Actions if Colour Seen	Notifications
5(a)	Green/Yellow (0.1 to <0.2 WL)	Workers investigate, mitigate if possible. If > 2h, workers inform RP department. RP sample air to confirm > 0.1 WL. If > 8h, or if confirmed > 0.1 WL, stop routine work (see 5(c)).	RSO and RP department AM GM
5(b)	Yellow (0.2 to <0.5 WL)	Workers investigate, mitigate if possible. If > 1h, workers inform RP department. RP sample air to confirm > 0.1 WL. If > 2h, or if confirmed > 0.1 WL, stop routine work (see 5(c)).	RSO and RP department AM GM OHC
5(c)	Yellow/Red (0.5 to 1.0 WL)	Workers investigate, mitigate if possible. If no obvious quick fix, workers inform RP department. RP sample air to confirm > 0.1 WL. If > 2h, or if confirmed > 0.1 WL, stop routine work (see 5(c)).	RSO and RP department AM GM OHC

3.2.3 Long-lived Radioactive Dust Exposure

The relevant measures of LLRD exposure include particulate activity concentrations measured in air samples collected by the radiation department, as well as personal activity concentrations measured using dust pumps worn by workers in higher LLRD areas (where expected LLRD dose is above 1 mSv/y). Results from both types of samples are expressed as a fraction of the Derived Air Concentration (DAC).

The administrative levels for LLRD exposure, and associated actions if they are exceeded, are outlined in Table 6.

Table 6: LLRD Action and Administrative Levels based on Area Air Sample Results

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
6(a)	0.05 fraction of DAC	If result is higher than expected, resample within 48 hours. If confirmed, determine cause and mitigate if reasonably practicable.	RSO and RP department AM
6(b)	0.10 fraction of DAC	If result is higher than expected, resample within 24 hours. If confirmed, determine cause and mitigate if reasonably practicable.	RSO and RP department AM
6(c)	0.20 fraction of DAC	If result is higher than expected, resample within 24 hours. If confirmed, determine cause and mitigate if reasonably practicable.	RSO and RP department AM GM OHC
6(d)	1.0 fraction of DAC	As for 7(c), plus Post "Airborne Radiation" signs and restrict access except for essential work under RWP, RP to notify CNSC and LRWS and follow up with full report in accordance with required timelines and report content (Section 3.3).	RSO and RP department AM GM OHC, CNSC, LRWS

The DAC represents an LLRD concentration that, if persistent, corresponds with 20 mSv/y for a given work area. It may be affected by the type of dust (uranium oxide or uranium ore) as well as the defined work hours per year for the work area. These considerations allow DAC to reflect a particular annual dose.

For a typical work year (2000 h/y) the DAC is defined as (CNSC, 2021):

DAC (BqU-238/m^3) = Annual dose limit (0.02 Sv/y) / DCF (Sv/BqU-238) / (2000 h/y x 1.1 m^3/h)

For uranium oxide (UO_4) in the in-situ recovery (ISR) Plant, a DCF of 2.6E-06 Sv/BqU-238 is taken from ICRP 137 (2017). This value assumes U-234 to be present in secular equilibrium with U-238. The last term in the DAC equation is modified by (4/8) in the drying and packaging areas because the work shift in these areas is limited to 4 hours. The selected DCF is conservative for UO_4 because values for Type M were utilized, which are higher than Type F/M recommended for UO_4. The DCF is sufficiently conservative to accommodate a mixture of dried and calcined product in the drying area. It exceeds the geomean of Type F and Type S values suggested by IAEA (2020) for dried and calcined product, respectively.

For uranium ore in the core shack, a DCF of 2.08E-05 Sv/BqU-238 is taken from ICRP 137 (2017). This value is a sum of DCFs over the decay chain, assuming all progeny to be present in secular equilibrium with U-238. The last term in the DAC equation is modified by (11/8) since the work shift in this area is 11 hours. The DCFs for individual radionuclides were either Type M values specifically recommended for the radionuclide in high grade uranium ore dust, or otherwise were Type M or Type S values recommended for unspecified forms.

Table 7: LLRD Action and Administrative Levels based on Dust Pump Results (for higher LLRD areas)

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
7(a)	0.10 fraction of DAC	Worker to inform RP department and AM. RP to review daily results; if higher than expected, investigate cause, RP/AM develop action plan for worker to reduce exposure.	RSO and RP department AM
7(b)	0.20 fraction of DAC	As for 8(a), plus RP to notify GM and OHC.	RSO and RP department AM GM OHC
7(c)	1.0 fraction of DAC	As for 8(b), plus action plan to ensure worker remains below DAC, approved by GM, report outcome at next Monthly Exposure Meeting.	RSO and RP department AM GM OHC

3.2.4 Uranium in Urine

Routine bioassay measurements of uranium in urine provide a check on internal exposure to uranium. The internal exposure is expected to be mainly through inhalation of uranium dust. Any hand to mouth exposure should be minimal assuming good contamination control and good hygiene; however, an abnormal urine bioassay result warrants investigation of both inhalation and hand to mouth pathways.

Uranium in urine is measured chemically (in µg/L). The chemical measurement can be readily converted to U-238 activity (Bq/L) since the uranium mass is primarily U-238 (0.012356 BqU-238/ugU).

The administrative levels for uranium in urine, and associated actions if they are exceeded, are outlined in Table 8 and Table 9.

Table 8: Administrative Levels for Uranium in Urine (for ISR Plant workers)

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
8(a)	10 µg/L	Resample to confirm the exceedance. If confirmed, RP department to investigate cause, RP/AM develop action plan for worker to reduce exposure if possible.	RSO and RP department AM
8(b)	100 µg/L	Resample to confirm exceedance. If confirmed, RP department to investigate cause, RP/AM develop action plan for	RSO and RP department AM GM OHC

		worker to reduce exposure. RP to notify GM and OHC.	

The value of 10 µg/L is a bounding value for the Derived Investigation level (DIL) in the ISR Plant. The DIL is a uranium in urine concentration that triggers investigation and corrective action if possible. For a typical full work year, it is calculated as follows (CNSC, 2010):

DIL (ug/L) = 0.3 x ALI (BqU-238/y) x (30/365) x Bq/d excreted per Bq Intake / 1.4 L/d / 0.012356 Bq/ug

The assumption is that an acute intake occurs at the beginning of the 30-day interval between samples and that the measurement of daily excretion occurs at the mid-point of the interval. This daily excretion is 4.3E-04 Bq/d per Bq intake of U-238 in uranium oxide (ICRP 78, Table A.10.8, Type M). The Annual Limit on Intake (ALI) is the annual dose limit (0.02 Sv/y) divided by the DCF (Sv/BqU-238).

For uranium oxide (UO_4) in the ISR Plant, a DCF of 2.6E-06 Sv/BqU-238 is taken from ICRP 137 (2017). This value assumes U-234 to be present in secular equilibrium with U-238 (see Section 3.2.3).

The value of 100 µg/L a bounding value for both the drying area and the packaging/loading area, which are the two high LLRD areas in the ISR Plant. Other areas in the ISR Plant are expected to be well below 10 µg/L.

Table 9: Administrative Levels for Uranium in Urine (for core shack workers)

Admin Level	Value	Mitigative Actions if Exceeded	Notifications
9(a)	1 µg/L	Resample to confirm the exceedance. If confirmed, RP department to investigate cause, RP/AM develop action plan for worker to reduce exposure if possible.	RSO and RP department AM
9(b)	10 µg/L	Resample to confirm exceedance. If confirmed, RP department to investigate cause, RP/AM develop action plan for worker to reduce exposure. RP to notify GM and OHC.	RSO and RP department AM GM OHC

The value of 1 µg/L is a bounding value for the Derived Investigation level (DIL) in the core shack. It is calculated as described above for the ISR Plant, but with a DCF for uranium ore.

For uranium ore in the core shack, a DCF of 2.08E-05 Sv/BqU-238 is taken from ICRP 137 (2017). This value is a sum of DCFs over the decay chain, assuming all progeny to be present in secular equilibrium with U-238 (see Section 3.2.3).

The value of 10 µg/L a bounding value for the core shack.

3.3 Result Tracking, Notification and Reporting of Exceedances

The RSO will be responsible for regular recording of monitored exposure levels as described above, flagging exceedances of administrative and action levels, tracking exceedance frequencies, notifying managers and regulators, working with management on mitigative measures as needed, and regularly reporting exposure information to workers.

Reviews and action plans will be written reports, maintained in radiation protection (RP) and manager files.

Regulatory notifications and reports in response to action level exceedances as described above will be within required timelines and will include required content. An internal non-conformance report is also filed whenever an action level is exceeded, in accordance with DMC-QUA-105 *Non-Conformance Procedure* within the *Management System Program*.

Guidance on the format and content of initial and full reports to the CNSC (and LRWS) when action levels are exceeded is provided in REGDOC 3.1.2 Volume I CNSC (2022). The process for determining reporting requirements and timeframes and for initiating and managing the reporting is detailed in DMC-QUA-105 *Non-Conformance Procedure* within the *Management System Program*.

4 Administrative Levels for Surface Contamination

4.1 Purpose of Administrative Levels for Surface Contamination

The purpose of contamination control is to minimize potential for abnormal intake of uranium by hand to mouth transfer of LLRD deposited on work surfaces. Administrative levels for surface contamination are intended to define upper levels of deposited radioactivity for work areas so that decontamination effort can be applied if these levels are exceeded.

4.2 Administrative Levels for Contamination and Associated Actions

Upper levels for non-fixed radioactive contamination in work areas are outlined in REGDOC 1.6.1 (CNSC, 2017) under the *Nuclear Substances and Radiation Devices Regulation*. For alpha emitting radionuclides, these levels are 3 Bq/cm^2 in areas where the substances are used or stored, and 0.3 Bq/cm^2 in all other work areas. In accordance with REGDOC 2.7.1 (CNSC, 2021b), lower levels should be defined for these areas if reasonably practicable based on operating experience. Transition zones between high and low LLRD areas will be established and personal decontamination procedures will be applied here to prevent transfer of radioactivity from high LLRD areas to other areas.

The relevant measure of non-fixed surface contamination is an activity measurement on a wipe that has been used to collect activity over a known area (100 cm^2 or less). A survey meter with a pancake probe or a benchtop instrument may be used for activity measurement. Guidance on sampling and instruments and activity measurement is provided in Appendix BB of REGDOC 1.6.1.

After an upper level of contamination for each work area is established by the RSO, the RP department will be responsible for monitoring surface contamination, informing area managers if upper levels are exceeded, and in that event, working with area managers to develop a corrective action plan.

5 Radiation Work Permits

5.1 Purpose of Radiation Work Permits

The purpose of radiation work permits is to provide planned control over new non-routine work situations such that exposures and doses are kept ALARA.

5.2 The Radiation Work Permit Process

The planning for new non-routine work is based on anticipated radiation hazards, estimated worker exposures and doses, and selection of controls to optimize exposure and dose. Based on this information, a Radiation Work Plan is produced for review and approval by the RSO, who then issues a Radiation Work Permit. The permit outlines the new task and its anticipated hazards, exposures, doses and controls, as well as associated monitoring to verify that exposures are as expected and actions to be taken if they are not. On completion of the work, the information is added to the risk registry to document the experience.

The risk registry is consulted during development of the Radiation Work Plan, so that any previous experience in similar situations can be considered.

Although Radiation Work Permits are for unusual exposure situations, they can cover multiple entries into the same situation. However, there is a limit on total dose to an individual worker under a Radiation Work Permit. This administrative limit is 5 mSv/y.

The RSO will be responsible for tracking individual worker doses incurred under a Radiation Work Permit and will inform workers and their area managers when they approach this limit, and will exclude any worker from further participation who is likely to exceed this limit.

6 Respiratory Protection Criteria

6.1 Purpose of Respiratory Protection Criteria

The purpose of respiratory protection is to enable essential work to be performed safely under conditions of Airborne Radiation hazard. Under the hierarchy of controls, use of respiratory protection is a control of last resort, after in-design and administration controls have been applied. The purpose of respiratory protection criteria is to specifically define the conditions under which respiratory personal protective equipment (PPE) may be used and to outline appropriate types of respiratory PPE for different types of Airborne Radiation hazard.

As Airborne Radiation hazard conditions are non-routine work conditions, work under these conditions will only be performed under a Radiation Work Permit, supported by hazard and risk assessment.

6.2 Criteria for Use of Respiratory Protection

The general criteria for use of respiratory PPE are:

- The work is deemed essential;
- The work is considered unsafe to perform without respiratory protection; and

The work must be performed under a Radiation Work Permit.

Table 10 outlines the conditions for use of specific types of respiratory PPE, considering the airborne radiation hazards at site, along with Assigned Protection Factors (APF) for each type of PPE. The APF values may be used in estimation of worker exposure when wearing PPE.

Table 10: Criteria for Use of Specific Types of Respiratory PPE

Respirator Type	RnP Range (WL)	LLRD Range (DAC)	RnG Range (Bq/m^3)	APF	Considerations
Filtering facepiece	n/a	n/a	n/a	n/a	May be used but no credit may be taken for exposure reduction.
Half-face elastomeric Air Purifying Respirator	0.2 - <1	1 - <2	n/a	10	Use for short duration tasks (<1h). Not used for protection from radon gas (RnG).
Full-face elastomeric Air Purifying Respirator	0.2 - <2	1 - <20	n/a	50	If radon progeny (RnP) < 1 WL time limitation may be used as an alternative. Device not used for protection from RnG.
Powered Air Purifying Respirator (Loose-fitting Hood)	0.2 - <2	1 - <10	n/a	25	If RnP < 1 WL time limitation may be used as an alternative. Device not used for protection from RnG.
Powered Air Purifying Respirator (Tight-fit facepiece)	2 - <20	10 - <50	n/a	1,000	Not used for protection from RnG.
Supplied Air Breathing Apparatus	2 - <20	10 - <50	20,000 or more	1,000	Assumes tight fit facepiece.
Self-contained Breathing Apparatus	20 or more	50 or more	20,000 or more	10,000	Assumes tight fit facepiece.

APF values are taken from CSA Z94.4-18 (CSA, 2018) and USNRC (2022). The values shown are the lowest among the two standards.

7 References

7.1 Internal

Document Number	Document Name
	Management System Program
	Radiation Protection Program
	ALARA Plan
	Radiation Code of Practice
DMC-QUA-105	*Non-Conformance Procedure*

7.2 External

Canadian Nuclear Safety Commission (CNSC). 2010. Designing and Implementing a Bioassay Program. Guidance Document GD-150. Canadian Nuclear Safety Commission.

Canadian Nuclear Safety Commission (CNSC). 2021a. Radiation Protection Regulations. SOR/2000-203. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2021b. Radiation Protection. REGDOC 2.7.1. Canadian Nuclear Safety Commission.

Canadian Nuclear Safety Commission (CNSC). 2017. *Licence Application Guide: Nuclear Substances and Radiation Devices*. REGDOC 1.6.1. Canadian Nuclear Safety Commission.

Canadian Nuclear Safety Commission (CNSC). 2022. Reporting Requirements, Volume 1: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills. REGDOC-3.1.2, Version 1.1. Canadian Nuclear Safety Commission.

Canadian Standards Association (CSA). 2018. Selection, care and use of respirators. Z94.4-18. Canadian Standards Association.

International Atomic Energy Agency (IAEA). 2020. Occupational Radiation Protection in the Uranium Mining and Processing Industry. Safety Report Series No. 100. International Atomic Energy Agency.

International Commission on Radiation Protection (ICRP). 2017. Occupational Intakes of Radionuclides: Part 3. ICRP Publication 137. Annals of the ICRP 46 (3/4). International Commission on Radiation Protection.

United States Nuclear Regulatory Commission (USNRC). 2022. Code of Federal Regulations. Title 10, Energy (revised as of January 1, 2022). Part 20 Standards for Protection Against Radiation. Appendix A, Assigned Protection Factors for Respirators.

19 Denison Mines Corp. Wheeler River Operation, Environmental Risk Assessment, December 2024

APPENDIX 10-A: ENVIRONMENTAL RISK ASSESSMENT FOR WHEELER RIVER

TECHNICAL SUPPORT DOCUMENT

REPORT PREPARED FOR:

DENISON MINES
230 22nd St. East, Suite 200
Saskatoon, SK, S7K 0E9

REPORT PREPARED BY:

Ecometrix Incorporated
www.ecometrix.ca
Mississauga, ON

Ref. 19-2638
20 December 2024

Ecometrix | Environmental INTELLIGENCE

APPENDIX 10-A: ENVIRONMENTAL RISK ASSESSMENT FOR WHEELER RIVER

TECHNICAL SUPPORT DOCUMENT

....

Langping Wu, Ph.D.
Environmental Modeller

....

Rina Parker, M.A.Sc., P.Eng
Technical Lead and Project Manager

....

Don Hart, Ph.D.
Project Principal and Reviewer

EXECUTIVE SUMMARY

The Wheeler River Project (the Project) proposes the development of the high-grade Phoenix uranium deposit as an in-situ recovery (ISR) mining operation with on-site processing. The Project is located approximately 35 km north-northeast of Cameco's Key Lake Operation and 35 km southwest of Cameco's McArthur River Operation in the eastern portion of the Athabasca Basin region in northern Saskatchewan.

The proposed Project is subject to both federal and provincial Environmental Assessment (EA) processes, and the Environmental Impact Statement (EIS) was prepared to support the EA. This environmental risk assessment (ERA) encompasses a human health risk assessment (HHRA) and an ecological risk assessment (EcoRA), which have been prepared to be compliant with Canadian Standards Association Group (CSA) N288.6-22 *Environmental Risk Assessments at Nuclear Facilities and Uranium Mines and Mills* (CSA, 2022). It also meets the requirements for an ERA outlined in Section 4.1 of Regulatory Document-2.9.1, *Environmental Principles, Assessments and Protection Measures* (CNSC, 2020).

The ERA focused on constituents of potential concern (COPCs) that exceeded screening values in air and water based on predicted atmospheric releases and aqueous releases (e.g., treated effluent and groundwater solute releases) from the Project. Based on the screening of atmospheric releases, no COPCs in air were advanced for further quantitative assessment in the ERA. Based on the screening of aqueous releases, arsenic, cadmium, chromium, cobalt, copper, molybdenum, selenium, uranium, vanadium, zinc, sulphate, and chloride were advanced for further quantitative assessment in the ERA. Radionuclides, including the uranium-238 series and radon, were included as COPCs because these constituents are of public interest.

An environmental transport and pathways model (IMPACT) was used to evaluate the effects of COPCs on the local environment including human and ecological receptors.

The ERA estimated dose and risk to human and ecological receptors during all Project phases and in the future centuries. The future centuries reflect the time period over which the highest constituent concentrations in groundwater are predicted to migrate towards and interact with surface water post-restoration (i.e. beyond the Project timeline of 0-38 years).

The selection of human and ecological receptors was informed by Indigenous and Local Knowledge.

The HHRA focused on members of the public potentially exposed to low levels of airborne or waterborne constituents. The selected human health receptor groups included a camp worker, seasonal resident, recreational fisher/hunter, and fisher/trapper. In the future centuries a hypothetical permanent resident was assessed at the former mine site instead of a camp worker.

The ecological receptors selected for the EcoRA were a subset of valued components identified for the EA so that the results from the ERA could be used in the effects assessments for fish, vegetation, wildlife, human health, Indigenous land and resource use, and other land and resource uses.

Non-radiological Human Health Risk Assessment

The potential effects on human receptors were evaluated by comparing the non-radiological exposures of receptors to recognized benchmarks, a dose-based toxicity reference value in the same units, for each COPC.

For assessment of non-carcinogens, risk was estimated based on Project total HQs (includes the Project risk in addition to the baseline risk) and Project incremental HQs (includes the Project risk only with baseline component removed). Project incremental HQs were compared to a benchmark HQ value of 0.2 because total background exposures (e.g., store-bought foods) were not included in the incremental HQ. This approach is consistent with Health Canada's guidance on human health preliminary quantitative risk assessment (Health Canada, 2021a).

The Project incremental HQ was predicted to remain below 0.2 for human receptors for all non-carcinogens and all pathways during all phases of the Project, with the exception of selenium for fisher/trapper at Russell Lake from the fish ingestion pathway. The traditional foods diet for the fisher/trapper is conservative as it assumes a high annual fish consumption rate of 183 kg/yr (approximately 1 to 2 servings per day) and assumes that all fish consumed in the diet is obtained from Russell Lake, whereas it is likely that someone would fish from many different lakes including those outside of the RSA. The diet of the fisher/trapper is representative of one person, who consumes a unique composition and quantity of traditional foods. Most people fishing, hunting, and trapping in the LSA and RSA would consume traditional foods more consistent with the average traditional foods consumer diet which was developed from the ERFN country foods study (CanNorth, 2017). However, it is recognized that the ERFN considers the fisher/trapper's use of the area as representative of current and future land users and expects that their relationship to the Project Area will be continued and strengthened through generations of future use.

During the future centuries there are no predicted exceedances of the HQ benchmark (HQ<0.2) for any human receptors, including the permanent resident, for any non-carcinogens.

For the assessment of carcinogens (arsenic), the incremental risk of developing cancer over a lifetime (ILCR) was estimated and compared against the cancer risk level of 1 in 100,000 recommended by Health Canada (Health Canada, 2021a). The ILCR was predicted to remain below the negligible cancer risk level of 1 in 100,000 for the camp worker, recreational fisher/hunter, and seasonal resident during the Project phases. The ILCR was predicted to be essentially equal to the negligible cancer risk level of 1 in 100,000 for the adult fisher/trapper at Russell Lake. These findings for the fisher/trapper are based on the conservative assumption of high consumption of traditional foods including fish and caribou in the LSA and RSA. As indicated above, the diet of the fisher/trapper is representative of one person, who consumes a unique composition and quantity of traditional foods. During the future centuries, the cancer risk was not predicted to exceed the negligible cancer risk level of 1 in 100,000 for any human receptor, including the permanent resident.

Radiological Human Health Risk Assessment

The incremental radiation dose to all human receptors during all Project phases is predicted to be below the regulatory public dose limit of 1 mSv/yr and the dose constraint of 0.3 mSv/yr during all Project phases and in the future centuries. The maximum incremental radiological dose is predicted to be 0.06 mSv/yr to the fisher/trapper at Russell Lake. The total incremental dose to the camp worker from all radionuclides in the U-238 decay chain including radon would be 0.16 mSv/year, which is below the dose limit for a non-NEW of 1 mSv/yr.

Overall, since the radiation dose estimates were predicted to be below the public dose limit, no discernable health effects would be anticipated due to exposure of human receptors to radioactive releases from the Project.

Non-radiological Ecological Risk Assessment

The potential for ecological effects was assessed by comparing exposure levels to toxicological benchmarks and characterized quantitatively in terms of HQs. An HQ greater than 1 indicates adverse effects may be possible for a given ecological receptor and further investigation would be warranted. Species at risk were either assessed directly or were represented by other more common species that have similar diets and exposure pathways.

No significant adverse effect on either aquatic or terrestrial populations or communities, as a result of releases from the Project, are predicted during the Project phases or during the future centuries. Estimated total HQs for the COPCs arsenic, cadmium, chromium, cobalt, molybdenum, selenium, uranium, vanadium, zinc, chloride and sulphate, for all ecological receptors are predicted to remain below the HQ benchmark of 1. Under baseline conditions as well as the future centuries, copper HQs for all aquatic organisms are less than 1 with the exception of predator fish in Whitefish Lake, and benthic invertebrates at all locations where HQs are above 1.

Using predicted operational site conditions for hardness and pH, copper HQs for all aquatic organisms are less than 1 at all downstream locations, indicating no adverse effects to aquatic organisms from facility related copper.

Species at risk were assessed using surrogate species. Since there are no total HQs above 1 for birds and mammals, individual species at risk would also be considered protected.

Radiological Ecological Risk Assessment

Radiation dose benchmarks of 9.6 milligrays per day (mGy/d) and 2.4 mGy/d (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in CSA N288.6-22.

There were no predicted exceedances of the 9.6 mGy/d radiation dose benchmark for aquatic biota, or the 2.4 mGy/d radiation dose benchmark for terrestrial and riparian biota during any Project phase or during the future centuries.

Since there were no predicted exceedances of the respective dose benchmarks for any of the aquatic or terrestrial receptors, individual species at risk would also be considered protected.

Monitoring and Follow-up

The ERA was developed based on the best available information for the Project, including baseline monitoring data, assumptions on source-terms, and Traditional Foods diet (intake rates and food types).

Monitoring would focus on collecting data to verify ERA model predictions as well as providing data to improve model predictions as the Project begins. Recommended monitoring would support Denison's environmental protection framework with the goal of reducing uncertainty over time through an iterative process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AAAQO	Alberta Ambient Air Quality Objectives
AAQC	ambient air quality criteria
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	bioaccumulation factor
BC MECCS	British Columbia Ministry of Environment and Climate Change Strategy
BC MOE	British Columbia Ministry of Environment
BLM	biotic ligand model
CAAQS	Canadian Ambient Air Quality Standards
CAC	criteria air contaminant
Cal OEHHA	California Office of Environmental Health Hazard Assessment
CCC	criterion continuous concentration
CCME	Canadian Council of Ministers of the Environment
CF	conversion factor
CNSC	Canadian Nuclear Safety Commission
COPC	constituent of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSA	Canadian Standards Association
CSM	conceptual site model
DCF	dose coefficient
DWWTP	domestic wastewater treatment plant
EA	Environmental Assessment
EC	effect concentration
EcoRA	ecological risk assessment
Eco-SSL	ecological soil screening level
ECOTOX	Ecotoxicology database
EIS	Environmental Impact Statement
ERA	environmental risk assessment
ERFN	English River First Nation
ESL	effects screening level
ESOD	erythrocyte superoxide dismutase
FEQG	federal environmental quality guidelines
FNFNES	First Nations Food, Nutrition and Environment Study
HC	Health Canada
HHRA	human health risk assessment
HQ	hazard quotient
IAEA	International Atomic Energy Agency
IC	inhibition concentration
ICRP	International Commission on Radiological Protection
ILCR	incremental lifetime cancer risk
IMPACT	Integrated Model for the Probabilistic Assessment of Contaminant Transport
ISQG	interim sediment quality guideline

ISR	in-situ recovery
IWWTP	industrial wastewater treatment plant
LC	lethal concentration
LEL	lowest effect level
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effect concentration
LSA	local study area
MECP	Ministry of the Environment, Conservation and Parks
MOE	Ministry of Environment
MATC	maximum acceptable toxicant concentration
NCRP	National Council on Radiation Protection and Measurements
NOAEL	No-observed adverse effect level
OAAQC	Ontario Ambient Air Quality Criteria
OF	occupancy factor
ORNL	Oak Ridge National Laboratory
PEL	probable effect level
PESC	Pacific Environmental Science Centre
PM	particulate matter
PM_{10}	particulate matter with a diameter of 10 microns or less
$PM_{2.5}$	particulate matter with a diameter of 2.5 microns or less
RAF	relative absorption factors
Rec F/H	Recreational Fisher/Hunter
REF	reference
RSA	regional study area
SAAQS	Saskatchewan Ambient Air Quality Standards
SAR	Species at Risk
SARA	Species at Risk Act
SEL	severe effect level
SEQG	Saskatchewan environmental quality guidelines
SKCDC	Saskatchewan Conservation Data Centre
TDI	tolerable daily intake
TF	transfer factor
TRV	toxicity reference value
TSP	total suspended particulates
UL	upper intake level
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USEPA	United States Environmental Protection Agency
VC	valued component
WHO	World Health Organization
WQO	water quality objective
YNLR	Ya'thi Néné Lands and Resources

Units of Measure

%	percent
µg/L	Micrograms per litre
µg/m^3	micrograms per cubic metre
µg/kg/d	micrograms per kilogram per day
Bq/g	becquerels per gram
Bq/kg	becquerels per kilogram
Bq/L	becquerels per litre
Bq/m^3	becquerels per cubic metre
dw	dry weight
fw	fresh weight
g/d	grams per day
g/m^2/yr	grams per square metre per year
h/yr	hours per year
kg/yr	kilograms per year
km	kilometre
km^2	square kilometre
L/d	Litre per day
m	metre
min	minute
m^3/h	cubic metre per hour
m/min	metres per minute
mg $CaCO_3$/L	milligrams of calcium carbonate per litre
mg/cm^2/30 days	milligrams per square centimetre per 30 days
mg/d	milligrams per day
mg/kg	milligrams per kilogram
mg/kg/d	milligrams per kilogram per day
mg/L	milligrams per litre
mGy/d	milligrays per day
mGy/h	milligrays per hour
mSv/yr	millisieverts per year

1.0 Introduction

1.1 Background and Regulatory Context

The Wheeler River Project (the Project) proposes the development of the high-grade Phoenix uranium deposit as an in-situ recovery (ISR) mining operation with on-site processing. Denison Mines Corp. (Denison) is the operator of the Wheeler River Joint Venture and holds a 90% interest (directly or through its subsidiaries). JCU (Canada) Exploration Company Ltd. owns the remaining 10% of the joint venture. The Project is located approximately 35 km north-northeast of Cameco's Key Lake Operation and 35 km southwest of Cameco's McArthur River Operation in the eastern portion of the Athabasca Basin region in northern Saskatchewan.

The proposed Project is subject to both federal and provincial Environmental Assessment (EA) processes, and the Environmental Impact Statement (EIS) was prepared to support the EA. This environmental risk assessment (ERA) encompasses a human health risk assessment (HHRA) and an ecological risk assessment (EcoRA), which have been prepared to be compliant with Canadian Standards Association Group (CSA) N288.6-22 *Environmental Risk Assessments at Nuclear Facilities and Uranium Mines and Mills* (CSA, 2022). It also meets the requirements for an ERA outlined in Section 4.1 of Regulatory Document-2.9.1, *Environmental Principles, Assessments and Protection Measures* (CNSC, 2020). The ERA has been developed with current science and current regulatory attitudes in mind.

The ERA is used to inform other EA disciplines and to support the conclusions made in the EIS. The regulatory and guidance documents applicable to the EIS are discussed in the EIS.

1.2 Objectives

The objectives of this ERA are to:

- Predict and assess the risk to representative human and ecological receptors resulting from exposure to radiological and non-radiological substances expected to be released throughout the Project Phases;
- Inform decision-making in the EIS; and
- Inform prioritization of monitoring and mitigation measures.

1.3 Scope

The scope of the ERA encompassed both human and ecological health risks, and radiological and non-radiological constituents of potential concern (COPCs).

The ERA used the expected sources of atmospheric and liquid releases to predict the transport of these constituents through the environment, exposure and dose to the public, and exposure and effects on representative ecological receptors.

1.3.1 Spatial Boundaries

The spatial boundaries of the ERA are generally consistent with the boundaries defined for the EIS for the aquatic and terrestrial environment. The study areas include the Project area, the local study area (LSA), and the regional study area (RSA). The spatial boundaries include the Icelander River drainage and major waterbodies along its course including Kratchkowsky Lake, Whitefish Lake, McGowan Lake, and parts of Russell Lake. The spatial boundaries for the ERA are shown on Figure 1-1.

The study areas for the ERA are defined as follows:

- **Project Area:** the area within which the Project and all components/activities are located (i.e., the Project footprint; the area of maximum physical disturbance).
- **Local Study Area (LSA):** the area that surrounds the Project Area where both direct and indirect effects resulting from Project activities can be reasonably measured. The LSA is established to assess the potential, largely direct effects of the Project and represents the extent to which there is a reasonable potential for the Project or Project-related activities to interact with and potentially adversely effect the valued components (VCs).
    - The LSA for the ERA represents the area where direct Project-related changes in air quality, sediment and water quality, and soil quality would likely occur. The LSA includes parts of the Icelander River drainage to its confluence with Russell Lake in the Wheeler River.
- **Regional Study Area (RSA):** the area that surrounds and includes the LSA, established to assess the potential, largely indirect effects of the Project in a regional context. The RSA is large enough to capture the extent of potential effects (i.e., zone of influence) on a VC and defines the area within which cumulative effects may occur (i.e., cumulative effects assessment boundary).
    - The RSA for the ERA includes parts of Russell Lake and the Wheeler River downstream of the Project.

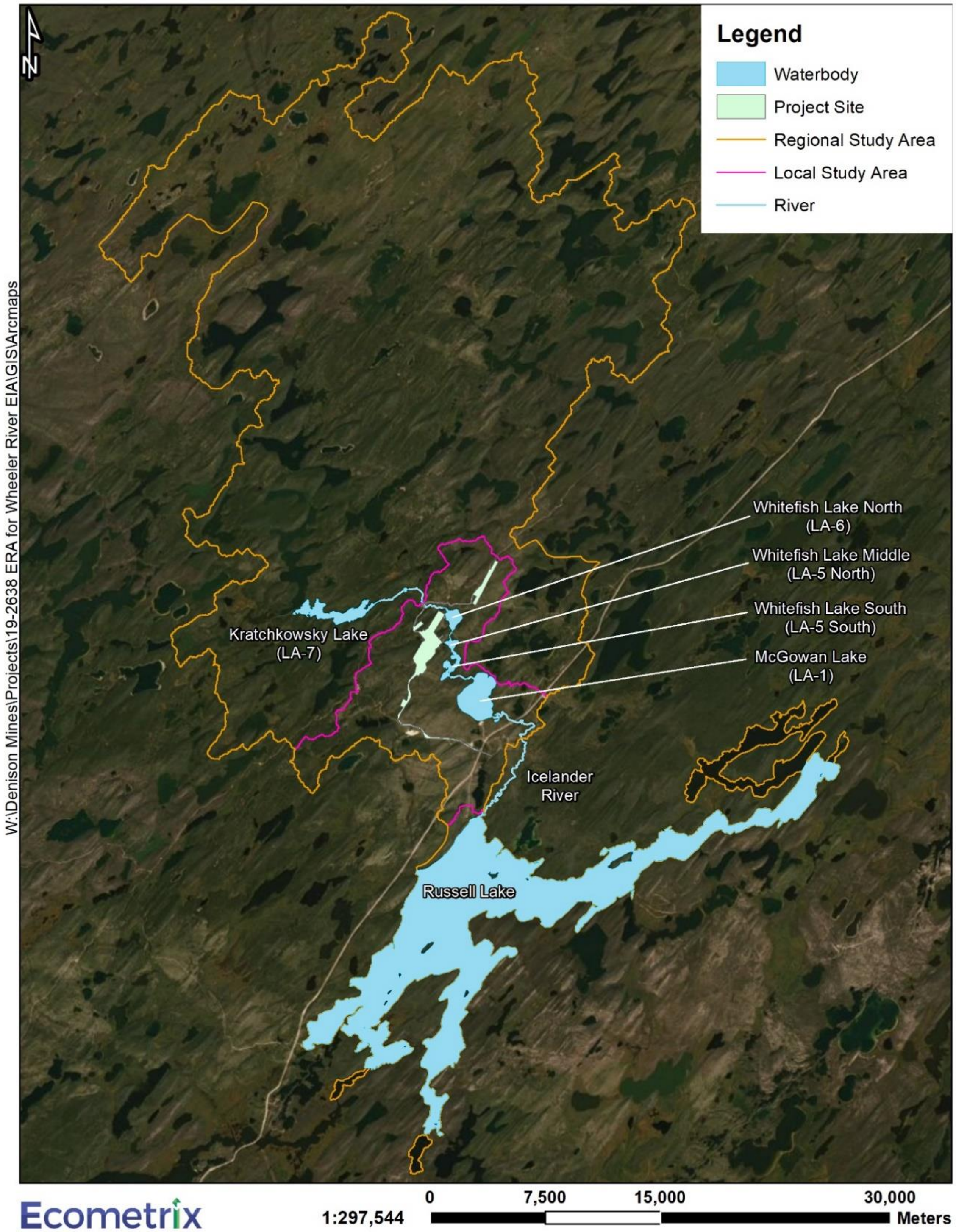


Figure 1-1: Spatial Boundaries of the ERA

1.3.2 Temporal Boundaries

Consistent with the Wheeler River Project EIS, the temporal boundaries of the assessment include the following Project phases: construction (which includes site preparation), operation, decommissioning, and post-decommissioning (Table 1-1). After post-decommissioning, the objective is to transfer the property to the province through the institutional control program or to direct the release of the land back to the Crown.

The temporal boundaries also include the "future centuries" period to assess the potential effects post-restoration (i.e. beyond the Project timeline of 0-38 years) and to reflect the time period over which the highest constituent concentrations in groundwater are predicted to migrate towards and interact with surface water.

This period represents the time where the highest constituent concentrations in groundwater are predicted to interact with surface water based on groundwater modelling. In this context, the future centuries scenario is considered with respect to the interaction of groundwater migration from the Project site and its potential influence on surface water in local water bodies. The future centuries projection encompasses the long-term period during which slow migration of groundwater from the Phoenix Ore Zone area to the surface water environment is anticipated, and it constitutes a bounding scenario of maximum concentrations of constituents of potential concern.

Table 1-1: Project Phases of the Wheeler River Environmental Risk Assessment

Phase and Year	Description of Activities	
Construction Year 1 to 3	• Development of access roads and air strip • Site preparation and earthworks; clearing, leveling and grading of the project area • Power generation – generators • Installation of main substation and distribution of power around site • Wellfield and freeze hole drilling; ground freezing • Batch plant operation (concrete); crusher at borrow area • Development of surface infrastructure (camp, operations centre, plants, ponds, pads and support facilities)	• Waste management (composting, domestic and industrial landfill operation, recycling) • Water management (including treatment and site run-off) • Groundwater supply • Surface water supply and release • Fuel management (e.g., propane for comfort heating; vehicle and aircraft fuel) • On-site and off-site operation of vehicles and transport of materials • Air transportation for workers • Regulatory site inspections • Engagement - site visit from Interested Parties
Operation Year 3 to 18	• Operation of the ISR wellfield • Wellfield and freeze wall drilling • Operation and expansion of freeze wall	• Storage and disposal of drill waste rock, process precipitates and industrial wastewater treatment plant precipitates

Phase and Year	Description of Activities	
	• Batch plant operation (grout and cement); crusher at borrow area • Expansion of pond and pads • Operation of the processing plant and production of uranium concentrate • Water withdrawal from groundwater or surface water body • Management of surface water (including seepage and site run-off) • Water treatment, both domestic and industrial • Water release to surface water body • Waste management (composting, domestic and industrial landfill operation, recycling) • Hazardous waste management (temporary storage, handling, and off-site transportation)	• On-site and off-site operation of vehicles and transport of materials • Power supply – primarily power from the grid, also generators and back-up generators • Package and transport of nuclear substances • Fuel management (e.g., propane for comfort heating; vehicle and aircraft fuel) • Air transportation for workers • Progressive decommissioning and reclamation • Regulatory site inspections • Engagement - site visit from Interested Parties
Decommissioning Year 18 to 23	• Site water management, treatment and release • Mining horizon remediation and thawing of freeze wall • Process water treatment and release • Closure of ISR and freeze wells and related infrastructure • Decontamination of surface facilities and injection, recovery and monitoring wells • Asset removal (including site power transmission lines and electrical infrastructure) • Demolition and disposal of non-salvageable surface infrastructure and materials • Remediation of contaminated areas (wellfield, pads, ponds, domestic wastewater treatment location, and process plant area)	• Power generation – generators • Waste management (composting and landfill operation) • Decommissioning of landfills; hazardous materials management (temporary storage and off-site disposal) • On-site and off-site operation of vehicles and transport of materials • Reclamation of disturbed areas • Regulatory site inspections • Engagement - site visit from Interested Parties
Post-Decommissioning Year 23 to 38	• Environmental monitoring • Regulatory site inspections	• Engagement - site visit from Interested Parties

2.0 Site Description

2.1 Project Description

The mining method proposed for the Project is in-situ recovery, and the process is shown on Figure 2-1.

A mining solution will be used to leach the uranium ore, similar to that used at other Athabasca Basin uranium mills: an acidic or low pH solution. The mining solution will be pumped underground to the uranium deposit via an injection well and recovered as uranium rich mining solution (i.e., mining solution now containing uranium) through a series of recovery wells. Once uranium rich mining solution is recovered to surface, it will be pumped from the pumphouses into the processing plant where uranium will be removed from the uranium rich solution. The mining solution will be refortified with reagents as required and pumped back into the mining horizon via an injection well. In this way, it is expected that the mining solution will be reused over and over again throughout the mining process. A small volume of make-up water will be added to the mining solution to replace moisture removed during the yellowcake precipitation and drying processes. This make-up water will be preferentially sourced from site runoff where possible; however, to be conservative, the assessment has included options for obtaining make-up water from either a shallow groundwater well or a nearby lake.

At the Project, the very low permeability basement rock below the uranium deposit serves as a natural aquitard; however, the sandstone hosting the uranium deposit is permeable and groundwater can flow horizontally through the deposit. To achieve containment at the Project, the uranium deposit will be surrounded by an engineered freeze wall that extends from the basement rock to surface, isolating the mining area from regional groundwater movement.

Processing or milling of the uranium rich solution and final processing to yellowcake will take place in the processing plant. Additionally, in the processing plant, the mining solution will be refortified for continued use in the ISR wellfield. An overview of the processing plant is shown in Figure 2-2. The anticipated production capacity of the Project is up to 12 Mlbs U_3O_8/year with a mine life of up to 15 years.

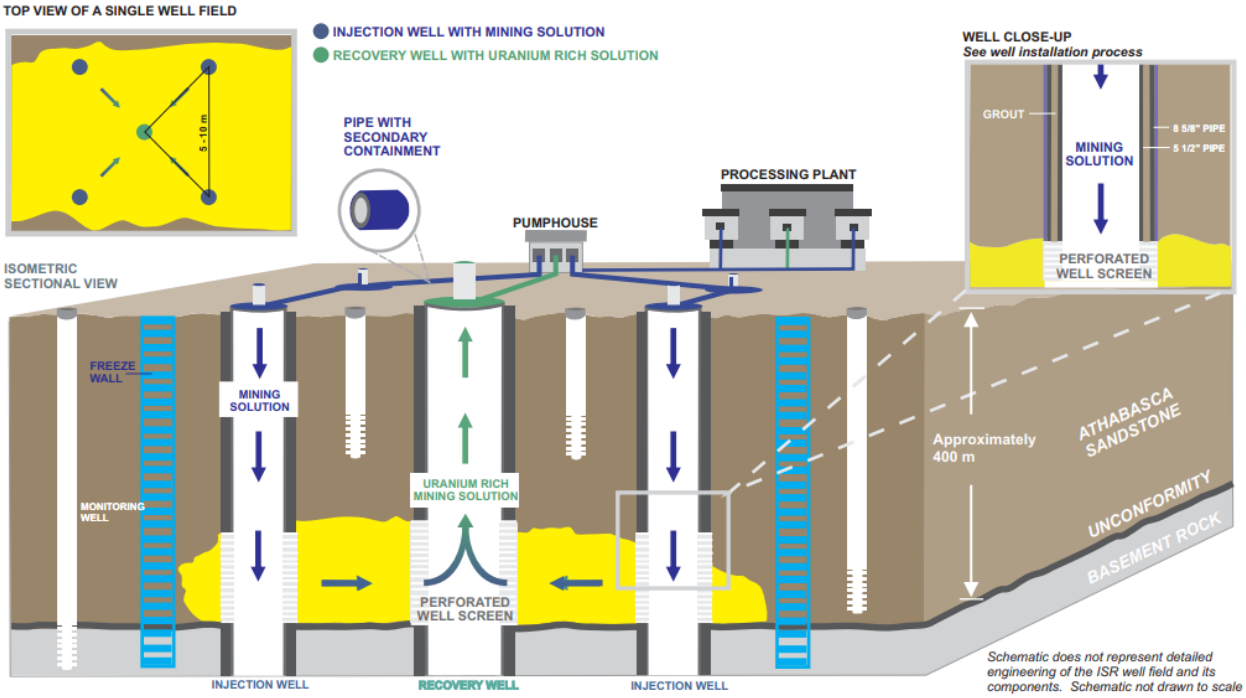


Figure 2-1: Overview of the ISR Process

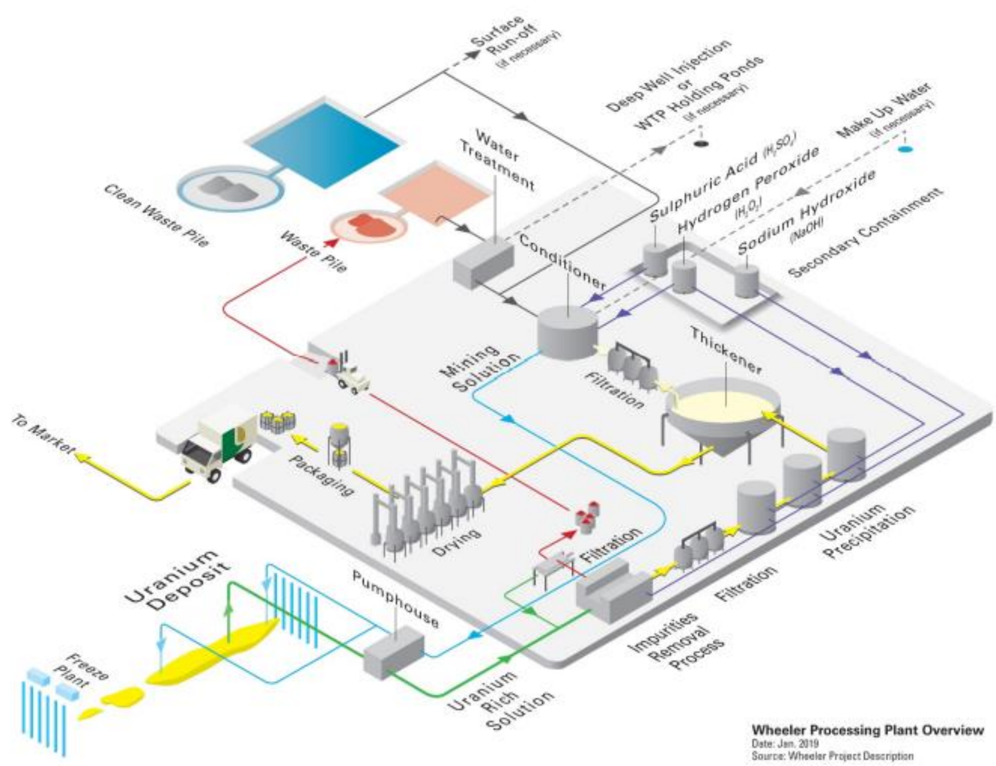


Figure 2-2: Overview of the Processing Plant Process

2.2 Description of the Natural and Physical Environment

The natural and physical environment is presented in the EIS and not reproduced in the ERA. Overall, the site is well characterized with regards to biophysical data and no residual uncertainties in the site characterization have been identified.

3.0 Source Term Characterization

3.1 Aqueous Sources

During construction, no effluent is expected to be released to the aquatic environment. Water management of runoff during construction will follow industry best management practices.

The following describes Denison's water management plan during operation.

Denison's approach to sustainable mining for the Project includes recycling as much process water as possible to reduce the need for fresh water supply.

When freshwater is needed, it would be obtained from a shallow groundwater well and/or from surface water, for a total maximum freshwater withdrawal of 81 m^3/h. Freshwater would be sent to the potable water treatment plant for treatment and distribution.

Domestic wastewater (which includes greywater and sewage) will be generated at the camp, processing plant, airstrip terminal, and the operations centre. Domestic wastewater from the central facilities will be piped directly to the on-site domestic wastewater treatment plant (DWWTP). Other sewage will be collected in septic tanks and transported via a vacuum truck to the DWWTP for treatment. Treated effluent from the DWWTP will be stored in a 5,000 m^3 pond prior to routing to the effluent monitoring and release ponds. Any reject solids from the DWWTP will be collected, dewatered, and disposed of at the site composting system, domestic landfill, or an approved off-site facility.

Contaminated water from the ISR process (e.g., backwash of sand filters, bleed solution) and various sources (e.g., wash bay sump water, leachate from the industrial landfill, wellfield runoff pond) will be treated in a three-stage industrial wastewater treatment plant (IWWTP). Water will be routed to the IWWTP via the process water pond. Treated water in the IWWTP will be routed back into the mining process, any excess treated water will be pumped to the effluent monitoring and release ponds. Any precipitates generated through the treatment process will be primarily comprised of gypsum and will be routed to the IWWTP precipitate pond.

There will be two effluent monitoring and release ponds, each with a composite liner and a capacity for 5,000 m^3 of water. The effluent monitoring and release ponds will primarily receive treated water from the DWWTP and IWWTP, but may also receive water from the process water pond, IWWTP precipitate pond, and wellfield runoff pond.

Effluent will be released to Whitefish Lake Middle (LA-5) via a discharge line with a diffuser at the end to promote effluent mixing within the lake. Effluent will be released at a discharge rate of 36.5 m^3/h as the EA case. The maximum upper bound discharge rate is 81 m^3/hr.

Surface runoff will generally be managed through collection in ponds. The wellfield runoff pond will capture runoff from the wellfield and the special waste pad. Any runoff from the process precipitate pond will be directed to the process water pond. A pond may be constructed beside the clean waste rock pad to collect runoff if required. Any runoff from the clean waste rock pad will be directed to the process water pond or to effluent monitoring and release ponds.

During decommissioning, mining area remediation will be initiated which will involve injecting water into the mining horizon via the injection wells and then recovering the water via the recovery wells. Water would be processed in the processing plant. This process would continue until the recovered water meets acceptable groundwater quality decommissioning objectives. After mining area remediation is complete, the freeze wall would be turned off, which would allow for gradual re-establishment of the pre-operational groundwater flow regime.

As such, during decommissioning effluent may be released to Whitefish Lake, but effluent is not expected to be released during post-decommissioning.

In summary, the main source of aquatic release to Whitefish Lake will be from the effluent monitoring and release ponds during operation and decommissioning. Effluent will undergo monitoring prior to discharge to ensure it meets federal and provincial regulatory discharge limits.

After all Project phases, in the future centuries, there is potential for leaching of post mining and residual mass into groundwater as part of natural groundwater evolution which can result in potential migration of constituents in groundwater into Whitefish Lake (LA-5) (see Section 3.1.2.2 for further details).

3.1.1 Screening for Constituents of Potential Concern

The list of constituents in liquid effluent started with a longer list, and this became more focused as more information became available. The larger list of constituents was based on constituents that:

- are known to be present in the treated effluent; and
- have existing water quality guidelines; or
- are identified in the Metal and Diamond Mining Effluent Regulations, SOR/2002-222, with the exception of cyanide which is considered not applicable.

The longer list of constituents was then reduced to those constituents expected to potentially be operational issues or result in changes to water quality in Whitefish Lake (LA-5) and the downstream environment.

3.1.1.1 Screening Value Selection

Screening values were selected based on the process shown in Figure 3-1. The most restrictive federal or provincial guideline for surface water quality, based on the Canadian Council of Ministers of the Environment (CCME) Canadian water quality guidelines for the protection of fresh water aquatic life, the federal environmental quality guidelines (FEQG), and the

Saskatchewan environmental quality guidelines (SEQG), was selected as the screening value for most surface water COPCs. Guidelines were adjusted for pre-operational hardness and pH, where applicable.

For molybdenum, the Saskatchewan Water Security Agency published an updated water quality objective for the protection of aquatic life based on current understanding of aquatic toxicity of molybdenum to fresh water aquatic organisms (WSA, 2017). This water quality objective of 31 mg/L is based on the 5th percentile of the species sensitivity distribution, and follows the CCME protocol (CCME, 2007). The British Columbia MOE has also published a water quality guideline for molybdenum of 7.6 mg/L (BC MOE, 2021). It was adopted for the Project for protection of aquatic life in preference over the CCME water quality objective of 0.073 mg/L. For protection of human health through the drinking water pathway, a value of 0.07 mg/L was used from the World Heath Organization (WHO, 2017).

Canadian drinking water quality guidelines were included for protection of human health (Health Canada, 2020). These guidelines are based on current, published scientific research related to human health effects, aesthetic effects, and operational considerations. Health-based guidelines are established on the basis of a comprehensive review of the known health effects associated with each constituent, on exposure levels, and on the availability of treatment and analytical technologies. Aesthetic effects (e.g., taste or odour) were taken into account when these play a role in determining whether consumers will consider the water drinkable, as is the case with copper. Where no Canadian drinking water quality guidelines were available, guidelines were obtained from the World Health Organization (WHO, 2017) or British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS, 2020).

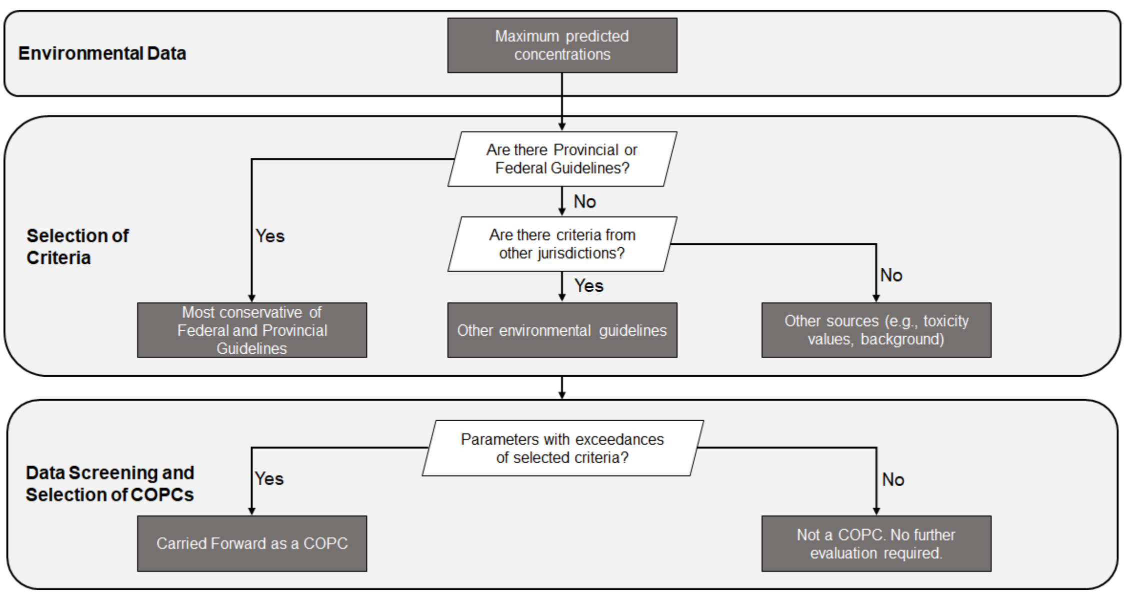


Figure 3-1: Selection of Surface Water Screening Values for the ERA

3.1.1.2 Constituents of Potential Concern in Surface Water

The screening involved a conservative process of comparing the reasonable upper bound treated effluent quality against the selected water quality guidelines protective of human and ecological health (Table 3-1). The reasonable upper bound treated effluent was derived using a combination of information available from lab tests conducted by Denison as well as derived effluent quality based on not exceeding water and sediment quality guidelines in the middle part of Whitefish Lake. Effluent treatment feed solution was prepared by leaching drill core material from the Phoenix deposit, and further processing that solution through two steps (process precipitate removal and yellowcake precipitation) prior to effluent treatment testing. Effluent treatment tests incorporated three stages: low pH, high pH, and neutralization. A combination of reagents (iron sulphate, barium chloride, lime, and sulphuric acid) was used to facilitate precipitation of constituents. After each stage, solid-liquid separation was conducted by mixing flocculant with solution to settle solids to the bottom of the test vessel. The supernatant liquid was used for the following stage. The solids were washed, filtered, and dried to determine solids mass generation for mass balance purposes. For each stage, the liquids and solids were assayed for various COPCs. The reasonable upper bound effluent was usually an expected effluent quality from Denison multiplied by a safety factor of three. The derived effluent quality was used for a handful of constituents including cadmium, chromium, and selenium.

Phosphorus was not considered a COPC for the ERA. Phosphorus is present in the aquatic environment as phosphate, where it acts as a nutrient rather than a toxicant. The water quality guideline selected for screening is the interim Ontario Provincial Water Quality Objective, which was set to avoid nuisance concentrations of algae in lakes and is not relevant to ecological health. Therefore, phosphorus was not considered a COPC for further quantitative assessment.

While the ERA focuses on chronic effects, it is acknowledged that Denison will not be allowed to release effluent above acute guidelines.

No formal screening was conducted for radionuclides. However, since radiation dose to human and ecological receptors is of great public and regulatory interest, the radionuclides in the U-238 decay series (U-238, U-234, thorium-230 [Th-230], radium-226 [Ra-226], Pb-210, polonium-210 [Po-210]) were considered COPCs for further modelling.

Radon-222 was not considered a COPC in surface water. Radon is expected to volatilize rapidly to air. Health Canada considers that the health risk from ingesting radon-contaminated drinking water is negligible (Health Canada, 2020). Radon is expected to escape at the faucet or water outlet, leaving only minimal amounts in the water itself. This assumption is consistent with Clause 5.1.8 of CSA N288.1-20, *Guidelines for calculating derived release limits for radioactive material in airborne or liquid effluents for normal operation of nuclear facilities*, which indicates that noble gases, including radon-222, are not considered relevant for release to water because they do not enter environmental compartments other than air (CSA, 2020).

Based on the screening (see Table 3-1), the following COPCs were included in the surface water modelling for the ERA.

- General Chemistry: chloride, sulphate, and total dissolved solids
- Metals and metalloids: arsenic, cadmium, chromium, cobalt, copper, molybdenum, selenium, uranium, zinc
- Radionuclides: uranium-238, uranium-234, thorium-230, radium-226, lead-210, polonium-210.

Table 3-1: Screening of Effluent Quality against Surface Water Quality Guidelines for the Wheeler River ERA

Constituent	Unit	Reasonable Upper Bound Effluent Quality	CCME Protection of Aquatic Life		Federal Environmental Quality Guideline		Saskatchewan Environmental Quality Guidelines (SEQG Online) (1)		Other		Drinking Water Guidelines			Selected Screening Value	Source	Is Effluent Quality Greater than Screening Value?
			Long Term	Note	Long Term	Note	Long Term	Note	Long Term	Note	Health Canada (15)	Other Source	Note			
Total suspended solids	mg/L	6.00E+00	background + 5 mg/L													N/A
Aluminum	mg/L	5.10E-02	1.00E-01	(6)			1.00E-01				1.00E-01			1.00E-01	SEQG/CCME	No
Arsenic	**mg/L**	**6.00E-03**	**5.00E-03**				**5.00E-03**				**1.00E-02**			**5.00E-03**	**SEQG/CCME**	**Yes**
Cadmium	**mg/L**	**1.80E-03**	**4.00E-05**				**4.00E-05**				**7.00E-03**			**4.00E-05**	**SEQG/CCME**	**Yes**
Chromium	**mg/L**	**2.50E-02**	**1.00E-03**				**1.00E-03**				**5.00E-02**			**1.00E-03**	**SEQG/CCME**	**Yes**
Cobalt	**mg/L**	**2.70E-03**			**7.80E-04**	**(11)**						**1.00E-03**	**(16)**	**7.80E-04**	**FEQG**	**Yes**
Copper	**mg/L**	**2.22E-02**	**2.00E-03**	**(8)**	**2.00E-04**	**(12)**					**2.00E+00**			**2.00E-04**	**FEQG**	**Yes**
Iron	mg/L	3.90E-03	3.00E-01								3.00E-01			3.00E-01	CCME	No
Lead	mg/L	3.00E-04	1.00E-03	(9)			1.00E-03	(2)			5.00E-03			1.00E-03	SEQG/CCME	No
Manganese	mg/L	3.00E-02	2.10E-01	(3)							1.20E-01			1.20E-01	Health Canada	No
Mercury	mg/L	1.00E-05	2.60E-05				2.60E-05				1.00E-03			2.60E-05	SEQG/CCME	No
Molybdenum	**mg/L**	**2.50E+00**	**7.30E-02**	-	-	-	**3.10E+01**	-	**7.60E+00**	**-**	-	**7.00E-02**	**(17)**	**7.00E-02** **7.60E+00**	**WHO (drinking water)** **BC MOE (eco)**	**Yes (human health)** **No (eco health)**
Nickel	mg/L	1.38E-02	2.50E-02	(9)	-	-	2.50E-02	(2)	-	-	-	7.00E-02	(17)	2.50E-02	SEQG/CCME	No
Phosphorous	mg/L	1.00E-02	-	-	-	-	-	-	0.004-0.01	(18)	-	1.00E-02	(16)	0.004-0.01	Ontario PWQO	No
Selenium	**mg/L**	**4.19E-02**	**1.00E-03**				**1.00E-03**				**5.00E-02**			**1.00E-03**	**SEQG/CCME**	**Yes**
Thallium	mg/L	6.00E-04	0.0008	-	-	-	-	-	-	-	-	-	-	0.0008	CCME	No
Uranium	**mg/L**	**5.70E-02**	**1.50E-02**	**-**	**-**	**-**	**1.50E-02**	**-**	**-**	**-**	**2.00E-02**	**-**	**-**	**1.50E-02**	**SEQG/CCME**	**Yes**
Vanadium	mg/L	5.90E-02	-	-	1.20E-01	(14)	-	-	-	-	-	-	-	1.20E-01	FEQG	No
Zinc	**mg/L**	**4.20E-02**	**1.30E-02**	**(10)**	**-**	**-**	**3.00E-02**	**-**	**-**	**-**	**5.00E+00**	**-**	**-**	**1.30E-02**	**CCME**	**Yes**
Total Ammonia as nitrogen	mg/L	3.90E+00	5.74E+00	(4)	-	-	5.74E+00	(4)	-	-	none required	-	-	5.74E+00	SEQG/CCME	No
Un-ionized ammonia as nitrogen (5)	mg/L	1.06E-02	1.56E-02	-	-	-	1.56E-02	-	-	-	none required	-	-	1.56E-02	SEQG/CCME	No
Chloride	**mg/L**	**6.00E+02**	**1.20E+02**	**(7)**	-	-	**1.20E+02**	-	-	-	**none required**	-	-	**1.20E+02**	**SEQG/CCME**	**Yes**
Total dissolved solids	**mg/L**	**6.42E+03**	-	-	-	-	**5.00E+02**	-	-	-	**5.00E+02**	-	-	**5.00E+02**	**SEQG**	**Yes (addressed in Section 10.2 of EIS)**

Constituent	Unit	Reasonable Upper Bound Effluent Quality	CCME Protection of Aquatic Life		Federal Environmental Quality Guideline		Saskatchewan Environmental Quality Guidelines (SEQG Online) (1)		Other		Drinking Water Guidelines			Selected Screening Value	Source	Is Effluent Quality Greater than Screening Value?
			Long Term	Note	Long Term	Note	Long Term	Note	Long Term	Note	Health Canada (15)	Other Source	Note			
Sulphate	**mg/L**	**3.92E+03**	-	-	-	-	-	-	**1.28E+02**	**(13)**	**5.00E+02**	-	-	**1.28E+02**	**BC MOE**	**Yes**
Radium-226	**Bq/L**	**1.50E-01**	-	-	-	-	**0.11**	-	-	-	-	-	-	**0.11**	**SEQG**	**Yes**
Thorium-230	Bq/L	9.00E-01	-	-	-	-	-	-	-	-	-	-	-	N/A	-	N/A
Lead-210	Bq/L	4.19E-01	-	-	-	-	-	-	-	-	-	-	-	N/A	-	N/A
Polonium-210	Bq/L	1.50E-01	-	-	-	-	-	-	-	-	-	-	-	N/A	-	N/A
Uranium-238	Bq/L	7.04E-01	-	-	-	-	-	-	-	-	-	-	-	N/A	-	N/A
Uranium-234	Bq/L	7.04E-01	-	-	-	-	-	-	-	-	-	-	-	N/A	-	N/A

Notes:

(1) Saskatchewan Water Quality Objectives, SEQG on-line (https://envrbrportal.crmp.saskatchewan.ca/seqg-search/), SEQG for the protection of aquatic life were selected, based on total concentrations, a temperature of 15°C and a pH of 7.0.

(2) Hardness dependent WQOs are for very soft water (hardness <25 mg $CaCO_3$/L). Site-specific hardness is 5.26 mg/L (95th percentile of LA-5 and LA-6).

(3) Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life - Manganese, Appendix B - Canadian Water Quality Guidelines Calculator (pH = 6.6, hardness = 5.6 mg/L). Guideline is based on dissolved manganese.

(4) Total ammonia-N calculated from the total ammonia guideline for a temperature of 15°C and a pH of 7.0.

(5) A pH of 7 and a temperature of 15°C were assumed to convert total ammonia to un-ionized ammonia in accordance with CCME (2002)

(6) Based on a pH of >6.5.

(7) Based on water hardness >0 to <17 mg/L.

(8) Based on water hardness >0 to <82 mg/L.

(9) Based on water hardness >0 to ≤60 mg/L.

(10) Guideline is based on dissolved zinc. Long term guideline is based on CWQG = exp(0.947[ln(hardness mg·L-1)] - 0.815[pH] + 0.398[ln(DOC mg·L-1)] + 4.625). (Site-specific background hardness is 5.26 mg/L, DOC is 2.24 mg/L, pH is 6.61 (95th percentile of LA-5 and LA-6). Note – extrapolated for value outside the hardness range.

(11) Environment Canada 2017. Federal Environmental Quality Guidelines, Cobalt, May. Based on equation and lowest hardness for equation of 52 mg/L.

(12) The Biotic Ligand Model was used. The calculated HC_5 is below 0.2 µg/L, however, 0.2 µg/L is considered to be the lowest concentration routinely measured and therefore replaces the calculated HC_5 value for this water chemistry.

(13) BC MECCS 2021. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

(14) Environment Canada 2016. Federal Environmental Quality Guidelines, Vanadium. May.

(15) Health Canada 2020. Guidelines for Canadian Drinking Water Quality Summary Table. September. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/pdf/pubs/water-eau/sum_guide-res_recom/summary-table-EN-2020-02-11.pdf

(16) BC MECCS 2020. Source Drinking Water Quality Guidelines, Guideline Summary Ministry of Environment & Climate Change Strategy Water Protection & Sustainability Branch.

(17) WHO 2017. Guidelines for Drinking Water Quality. Fourth Edition Incorporating The First Addendum.

(18) Ontario Ministry of Environment and Energy: Water management: policies, guidelines, provincial water quality objectives (1994).

(19) BC MOE (B.C. Ministry of Environment and Climate Change Strategy). 2021. Molybdenum Water Quality Guidelines for the Protection of Freshwater Aquatic Life, Livestock, Wildlife and Irrigation. Water Quality Guideline Series, WQG-07. Prov. B.C., Victoria B.C.

3.1.2 Surface Water Quality Modelling

3.1.2.1 Project Phases

Surface water quality modeling was completed using IMPACT version 5.6.0. IMPACT is consistent with the COPC transport equations outlined in CSA N288.1-20. The modeling is discussed in detail in the IMPACT Model Report for the Project (Appendix A). Waterbodies from Whitefish Lake to the Russell Lake inlet were modelled in IMPACT to assess the effects of the Project on the downstream environment – this included the following distinct water polygons: Whitefish Lake Middle, Whitefish Lake South, McGowan Lake, and Russell Lake. Kratchkowsky Lake and Whitefish Lake North were modelled as reference locations.

Treated effluent will be released to Whitefish Lake Middle at an expected discharge rate of 36.5 m^3/h during the operation and decommissioning phases of the Project. The reasonable upper bound effluent quality during the phases where effluent will be released is summarized in Table 3-2 – effluent quality is assumed to be constant over that time period. Receiving water flow varies seasonally, resulting in seasonal fluctuations in receiving water quality. No effluent is expected to be released during construction or post-decommissioning.

Surface water quality modelling included predicting water and sediment concentrations in Whitefish Lake, the lake to which treated effluent will be released, as well as locations farther downstream. The geometric mean of measured water concentrations from baseline studies performed between 2011 and 2019 (Ecometrix, 2020) was selected as the water baseline concentration for constituents that had measured data over the detection limit. Sediment baseline concentrations were predicted from surface water concentrations using the partitioning coefficients (Kd) which consist of regional published values that have been calibrated on similar sites in northern Saskatchewan and have been checked against Wheeler River measurement data. In the case of constituents for which most or all measured concentrations in water were under the detection limit, but sediment concentration measurements were over the detection limit, the baseline water concentration was calculated from the geometric mean of the sediment measurements using the Kds (Section 3.3.2 in Appendix A).

When the treated effluent is released to Whitefish Lake (LA-5), water and sediment concentrations were predicted using IMPACT according to the equations outlined in the IMPACT model (Section 2.2.2 in Appendix A). The predicted maximum concentrations of COPCs in water and sediment are shown in Table 3-3. There are no predicted exceedances of water quality guidelines for any of the COPCs, except for copper where baseline concentrations exceed the federal environmental quality guideline (FEQG). A detailed comparison of sediment concentrations against sediment quality guidelines is discussed in Section 3.1.2.3.

Figure 3-2 and Figure 3-3 show the predicted concentrations of selected COPCs in water and sediment over time at the exposed locations (Whitefish Lake Middle, Whitefish Lake South, McGowan Lake, and Russell Lake) and reference locations (Kratchkowsky Lake and Whitefish Lake North) during project phases. The modelled maximum COPC concentrations in water during decommissioning phase were the same as those during operations (Table 3-3). The peak concentrations of arsenic and polonium-210 appear annually in June, and the peak concentrations of all other COPCs appear annually in March due to the variation of the monthly local inflow during the effluent discharge period (Figure 3-2). It is noted that the maximum predicted concentrations of COPCs in water occurred over short periods of effluent discharge and subsequently decrease relatively quickly during periods when there is no effluent discharge. This is related to the short retention time of the modelled lakes. As shown in Table 3-1 in Appendix A, the modelled lakes (excluding the reference lake) are small, with lake area ranging from 0.10 to 1.49 km^2 and with average depths ranging from 1.0 to 5.5 m. Based on the area, depth and outflow, the calculated retention times ranged from 0.88 to 51.61 days. As noted, the short retention times result in rapid increases and decreases of concentrations of COPCs in response to effluent discharge and then its cessation. Since COPCs accumulate in sediment, the peak concentrations of all COPCs in sediment appear at the end of each individual Project phase, which are year 20 for the operations and year 25 for the decommissioning phase, as shown in Figure 3-3.

Based on the screening methodology in Table 3-1, the effluent quality for TDS is expected to exceed its water quality guideline of 500 mg/L. The water quality guideline for TDS is an aesthetic drinking water objective from Health Canada (1991). No health effects associated with ingestion of TDS have been identified (Health Canada, 1991). Modelling of TDS was not included in the IMPACT model; however, TDS concentrations were predicted in the near-field water quality model in Section 10.2 (see Table 10.2-10) of the EIS, Surface Water Quality. Predicted TDS concentrations are expected to range from approximately 74 mg/L to 131 mg/L under various flow conditions and are well below the drinking water quality objective. Since TDS is not considered a health risk, and concentrations in LA-5 are predicted to be below the aesthetic objective, TDS is not considered further in the ERA.

Table 3-2: Summary of Effluent Quality for the Wheeler River Project

Constituent of Potential Concern	Unit	Effluent Quality
General Chemistry		
Chloride	mg/L	600
Sulphate	mg/L	3915
Total Dissolved Solids	mg/L	6420
Metals and Metalloids		
Arsenic	mg/L	0.006
Cadmium	mg/L	0.0018
Chromium	mg/L	0.025
Cobalt	mg/L	0.003
Copper	mg/L	0.022
Molybdenum	mg/L	2.5
Selenium	mg/L	0.042
Uranium	mg/L	0.057
Vanadium	mg/L	0.059
Zinc	mg/L	0.042
Radionuclides		

Constituent of Potential Concern	Unit	Effluent Quality
Uranium-238	Bq/L	0.7[(a)]
Uranium-234	Bq/L	0.7[(a)]
Thorium-230	Bq/L	0.9
Radium-226	Bq/L	0.15
Lead-210	Bq/L	0.419
Polonium-210	Bq/L	0.15

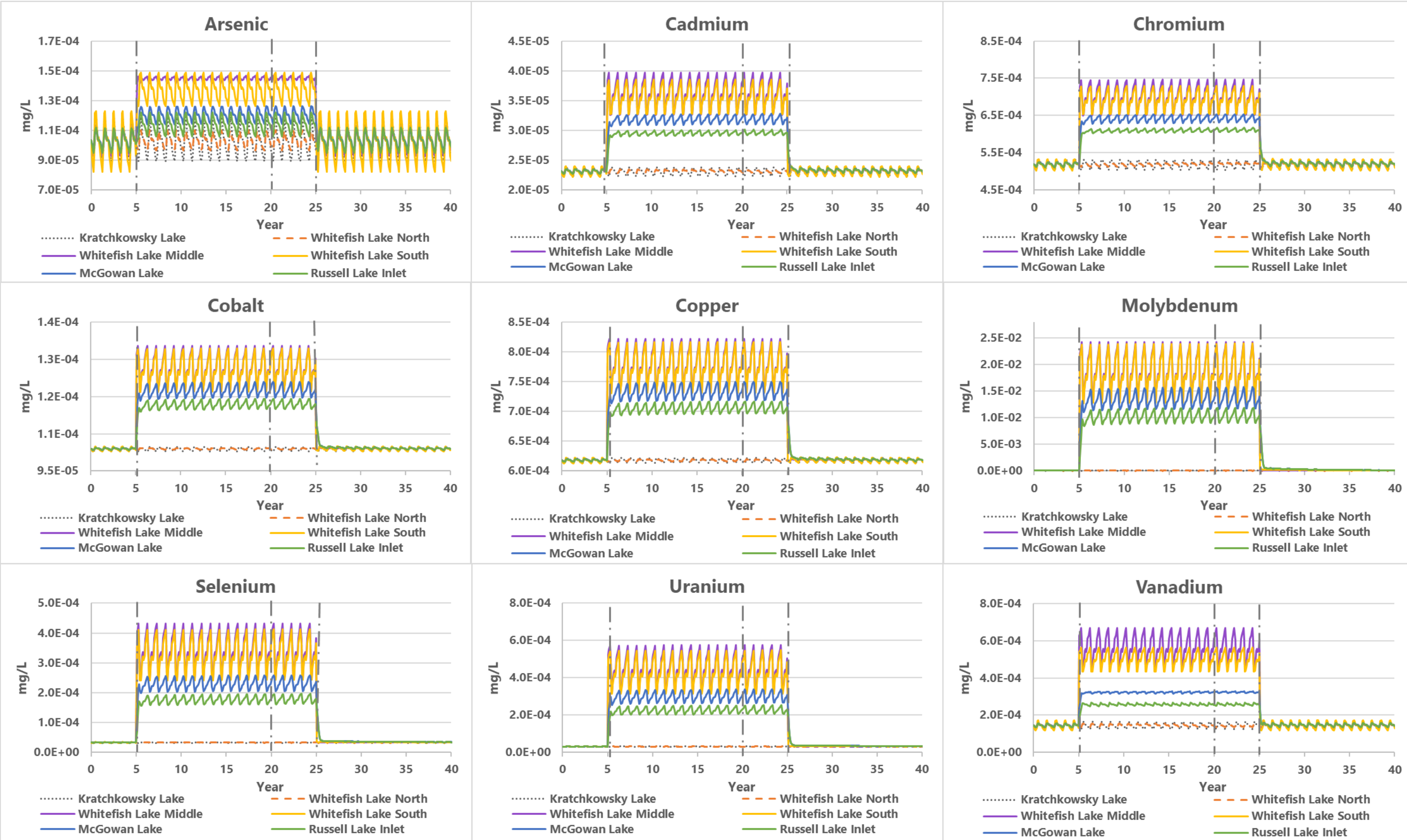
Note:
(a) Estimated from uranium using the specific activity of 12,356 Bq/g and assuming secular equilibrium between uranium-238 and uranium-234 (**https://www.wise-uranium.org/rup.html**)

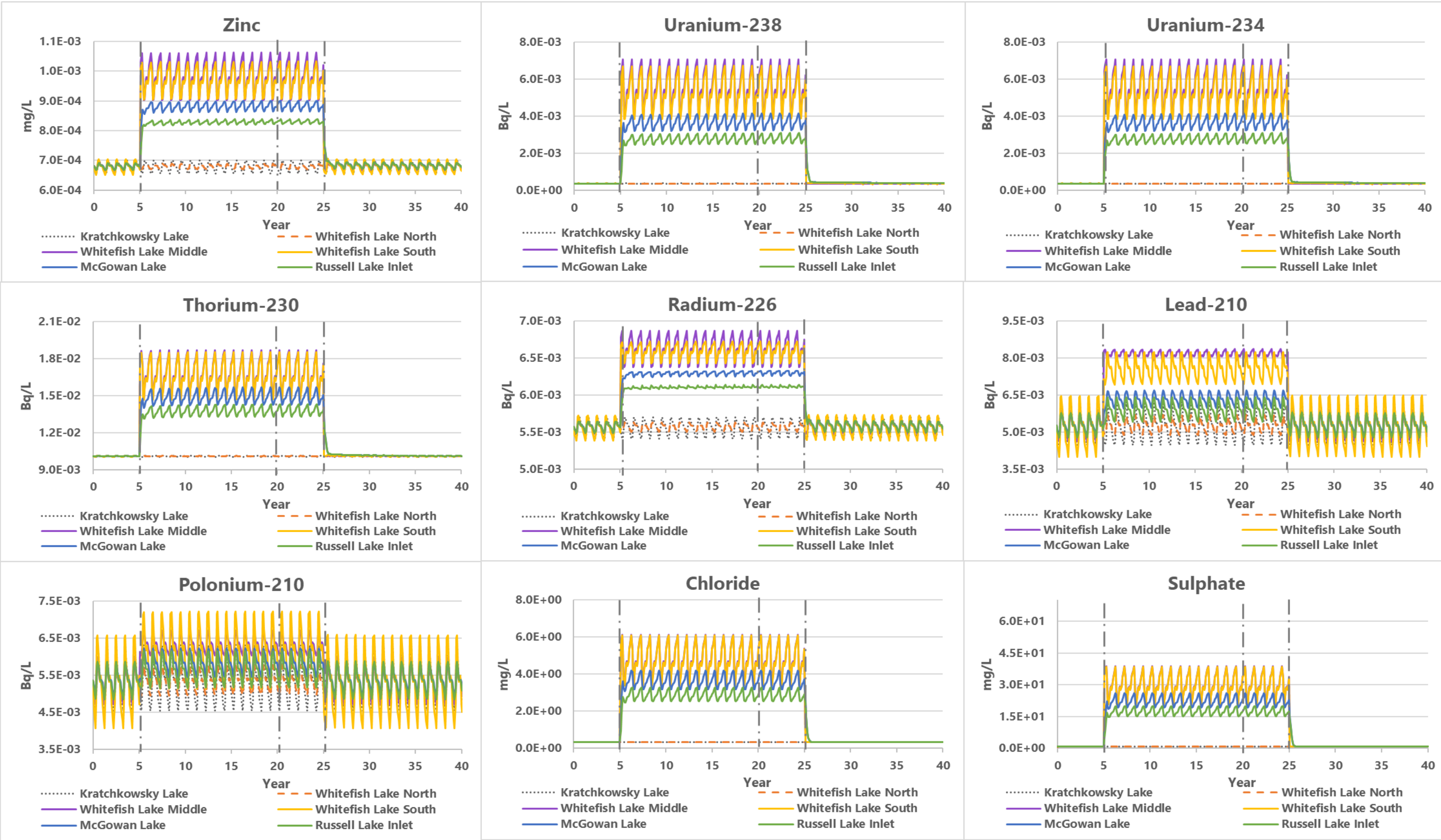
Table 3-3: Maximum Concentration of COPCs in Water and Sediment during Project Phases

Environmental Media	Location	Maximum Concentration of Non-radionuclides during Project Phases											
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Water (mg/L)	Quality Guideline	5.00E-03	4.00E-05	1.20E+02	2.95E-04	1.00E-03	2.00E-04	7.6E+00	1.28E+02	1.00E-03	1.50E-02	1.20E-01	1.30E-02
	Kratchkowsky Lake	1.19E-04	2.38E-05	3.22E-01	1.01E-04	5.30E-04	6.22E-04	1.07E-04	6.87E-01	3.35E-05	3.12E-05	1.67E-04	7.00E-04
	Whitefish Lake North	1.10E-04	2.34E-05	3.22E-01	1.01E-04	5.24E-04	6.20E-04	1.07E-04	6.87E-01	3.28E-05	3.05E-05	1.55E-04	6.89E-04
	Whitefish Lake Middle	1.46E-04	3.97E-05	6.14E+00	1.29E-04	7.46E-04	8.22E-04	2.43E-02	3.87E+01	4.33E-04	5.74E-04	6.70E-04	1.06E-03
	Whitefish Lake South	1.49E-04	3.86E-05	6.11E+00	1.28E-04	7.30E-04	8.17E-04	2.40E-02	3.85E+01	4.12E-04	5.47E-04	5.64E-04	1.03E-03
	McGowan Lake	1.26E-04	3.28E-05	4.20E+00	1.19E-04	6.54E-04	7.50E-04	1.58E-02	2.60E+01	2.59E-04	3.38E-04	3.28E-04	9.01E-04
	Icelander River	1.26E-04	3.26E-05	4.16E+00	1.19E-04	6.52E-04	7.49E-04	1.56E-02	2.57E+01	2.56E-04	3.34E-04	3.26E-04	8.99E-04
	Russell Lake Inlet	1.22E-04	3.01E-05	3.26E+00	1.14E-04	6.17E-04	7.17E-04	1.18E-02	1.99E+01	1.95E-04	2.52E-04	2.69E-04	8.40E-04
Sediment (mg/kg dw)	Quality Guideline	2.10E+01	6.00E-01	n/a	n/a	3.15E+01	9.10E+01	2.30E+01	n/a	3.60E+00	9.70E+01	3.51E+01	1.23E+02
	Kratchkowsky Lake	8.35E+00	3.38E-01	n/a	2.52E-01	5.86E+00	1.85E+00	3.37E-01	n/a	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake North	8.35E+00	3.38E-01	n/a	2.52E-01	5.86E+00	1.85E+00	3.37E-01	n/a	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake Middle	1.10E+01	4.97E-01	n/a	3.05E-01	7.59E+00	2.31E+00	5.72E+01	n/a	5.48E+00	7.18E+00	3.72E+01	1.36E+01
	Whitefish Lake South	1.05E+01	4.90E-01	n/a	3.04E-01	7.53E+00	2.30E+00	5.62E+01	n/a	5.26E+00	6.87E+00	3.33E+01	1.35E+01
	McGowan Lake	9.47E+00	4.43E-01	n/a	2.90E-01	7.03E+00	2.18E+00	4.11E+01	n/a	3.71E+00	4.78E+00	2.22E+01	1.24E+01
	Russell Lake Inlet	9.04E+00	4.15E-01	n/a	2.81E-01	6.73E+00	2.10E+00	3.13E+01	n/a	2.88E+00	3.64E+00	1.82E+01	1.17E+01

Environmental Media	Location	Maximum Concentration of Radionuclides during Project Phases					
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Water (Bq/L)	Quality Guideline	n/a	n/a	n/a	1.10E-01	n/a	n/a
	Kratchkowsky Lake	3.85E-04	3.85E-04	1.01E-02	5.70E-03	6.22E-03	6.33E-03
	Whitefish Lake North	3.77E-04	3.77E-04	1.01E-02	5.63E-03	5.68E-03	5.78E-03
	Whitefish Lake Middle	7.05E-03	7.05E-03	1.87E-02	6.87E-03	8.36E-03	6.71E-03
	Whitefish Lake South	6.72E-03	6.72E-03	1.85E-02	6.73E-03	8.25E-03	7.22E-03
	McGowan Lake	4.15E-03	4.15E-03	1.57E-02	6.33E-03	6.68E-03	6.23E-03
	Icelander River	4.11E-03	4.11E-03	1.56E-02	6.32E-03	6.66E-03	6.20E-03
	Russell Lake Inlet	3.09E-03	3.09E-03	1.43E-02	6.14E-03	6.41E-03	6.16E-03
Sediment (Bq/kg dw)	Quality Guideline	n/a	n/a	n/a	6.00E+02	9.00E+02	8.00E+02
	Kratchkowsky Lake	7.14E+00	7.14E+00	2.32E+01	6.51E+01	3.74E+02	3.80E+02
	Whitefish Lake North	7.14E+00	7.14E+00	2.32E+01	6.51E+01	3.74E+02	3.80E+02
	Whitefish Lake Middle	8.82E+01	8.82E+01	3.83E+01	7.57E+01	5.57E+02	5.58E+02
	Whitefish Lake South	8.44E+01	8.44E+01	3.80E+01	7.52E+01	5.19E+02	5.22E+02
	McGowan Lake	5.87E+01	5.87E+01	3.41E+01	7.23E+01	4.42E+02	4.47E+02
	Russell Lake Inlet	4.48E+01	4.48E+01	3.15E+01	7.04E+01	4.14E+02	4.20E+02

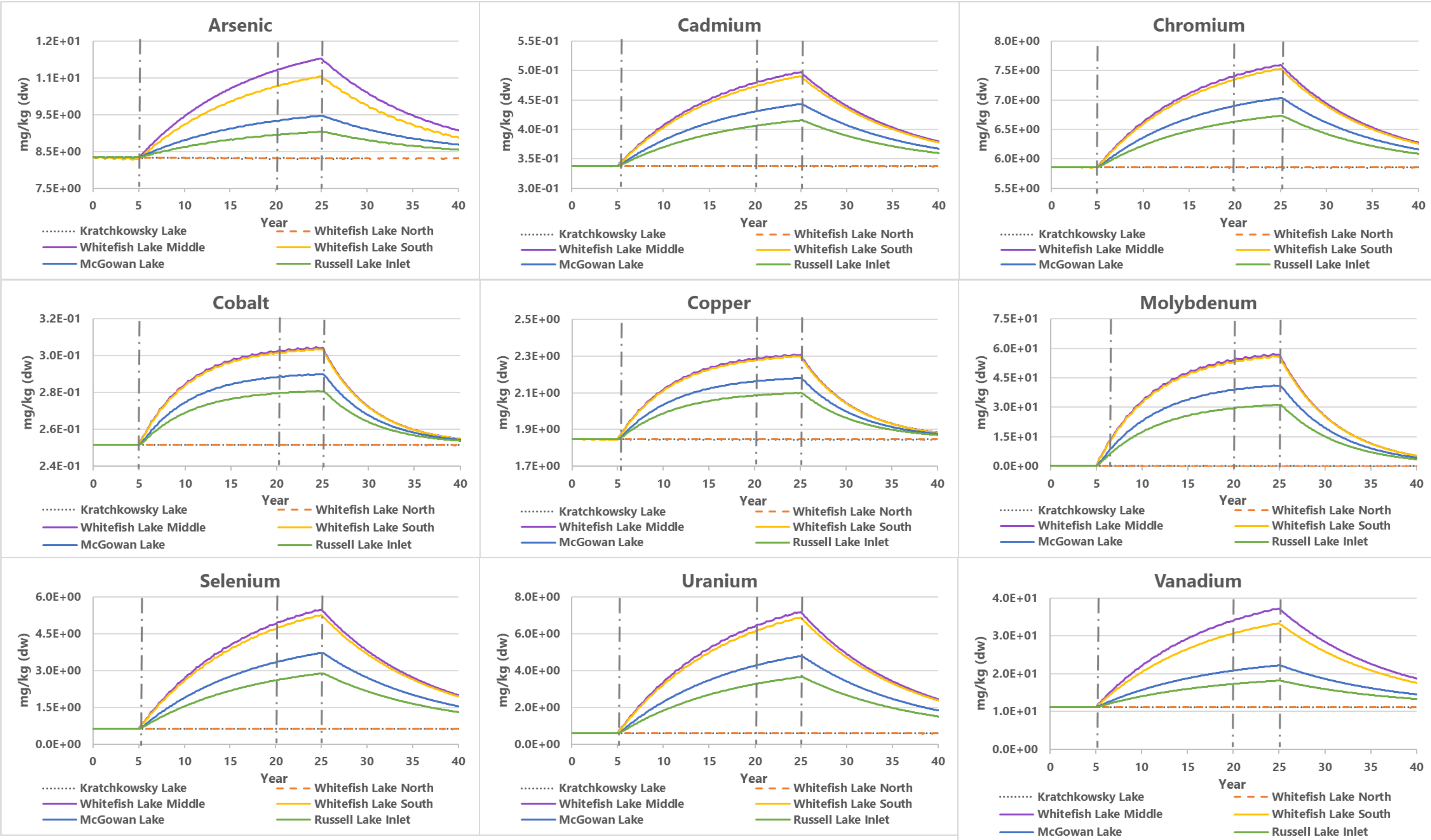
n/a = not applicable
Water quality guidelines are as shown in Table 3-1 and sediment quality guidelines are as shown in Table 3-6.

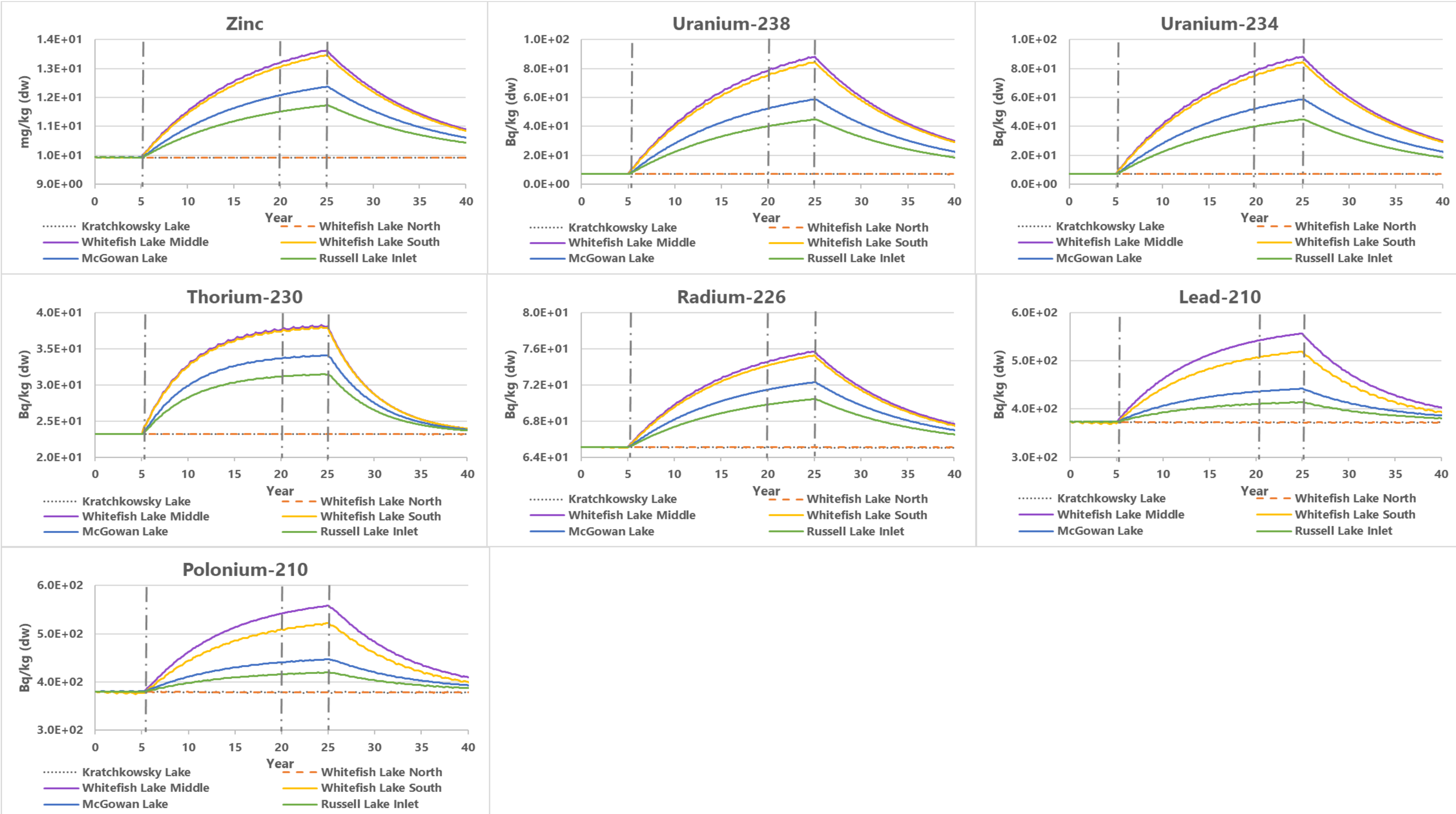

Arsenic
1.7E-04
1.5E-04
1.3E-04
1.1E-04
9.0E-05
7.0E-05
mg/L
Year
Cadmium
4.5E-05
4.0E-05
3.5E-05
3.0E-05
2.5E-05
2.0E-05
Chromium
8.5E-04
7.5E-04
6.5E-04
5.5E-04
4.5E-04
Cobalt
1.4E-04
1.3E-04
1.2E-04
1.1E-04
9.5E-05
Copper
8.5E-04
8.0E-04
7.5E-04
7.0E-04
6.5E-04
6.0E-04
Molybdenum
2.5E-02
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
Selenium
5.0E-04
4.0E-04
3.0E-04
2.0E-04
1.0E-04
0.0E+00
Uranium
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
Vanadium
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
0 5 10 15 20 25 30 35 40
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet



Long dash dot lines separate the time periods of project phases: 3 years baseline; 2 years construction; 15 years operation; 5 years decommissioning; first 15 years post-decommissioning

Figure 3-2: Modelled Concentrations of COPCs in Water during Project Phases


Arsenic
1.2E+01
1.1E+01
9.5E+00
8.5E+00
7.5E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Cadmium
5.5E-01
5.0E-01
4.5E-01
4.0E-01
3.5E-01
3.0E-01
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Chromium
8.0E+00
7.5E+00
7.0E+00
6.5E+00
6.0E+00
5.5E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Cobalt
3.2E-01
3.0E-01
2.8E-01
2.6E-01
2.4E-01
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Copper
2.5E+00
2.3E+00
2.1E+00
1.9E+00
1.7E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Molybdenum
7.5E+01
6.0E+01
4.5E+01
3.0E+01
1.5E+01
0.0E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Selenium
6.0E+00
4.5E+00
3.0E+00
1.5E+00
0.0E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Uranium
8.0E+00
6.0E+00
4.0E+00
2.0E+00
0.0E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Vanadium
4.0E+01
3.0E+01
2.0E+01
1.0E+01
0.0E+00
mg/kg (dw)
0 5 10 15 20 25 30 35 40
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet



Long dash dot lines separate the time periods of project phases: 3 years baseline; 2 years construction; 15 years operation; 5 years decommissioning; first 15 years post-decommissioning

Figure 3-3: Modelled Concentrations of COPCs in Sediment during Project Phases

3.1.2.2 Future Centuries

The potential migration of constituents from groundwater into Whitefish Lake (LA-5) which could influence the surface water quality is modelled in a "future centuries" scenario.

During decommissioning, groundwater quality within the ISR mining zone will be remediated to meet decommissioning objectives. In post-decommissioning, the freeze wall will be allowed to thaw and natural groundwater flow conditions will be re-established, as discussed in Section 9 of the EIS, Geology and Hydrogeology. During the "future centuries", groundwater plumes may develop from residual mass (i.e., remediated groundwater) remaining post mining (this is based on bench-scale lab tests of core flushing, and subsequent numerical modelling of reactive fate and transport).

Groundwater flow and reactive transport of dissolved constituents were modelled using three-dimensional modelling whereby the reactions were computed using PHREEQC and the transport was computed using FEFLOW (Ecometrix, 2022). Groundwater flow observed, and simulated in the calibrated groundwater model, travels eastward from the mining zone within the Lower Sandstone Aquifer before moving upward through the Desilicified Zone in the Athabasca Sandstone and overlying overburden deposits toward Whitefish Lake. Modelled transport of dissolved constituents along the groundwater flow path allowed for interactions of the dissolved constituents with the geologic media through which they are flowing. Due to the relatively low groundwater velocities between the mining zone and Whitefish Lake and chemical reactions along the groundwater flow pathway, the "future centuries" scenario spans 100s to 1000s of years.

The results of the numerical model (as provided in Section 7 of the EIS) indicate that dissolved constituent concentrations emanating over hundreds to thousands of years in the future from the deep Ore Zone to Whitefish Lake remain below fresh water environmental quality criteria in Whitefish Lake.

For the COPCs identified in the effluent, the predicted mass flux from groundwater into Whitefish Lake Middle starting 200 years after the Project phases, during the future centuries, was input to the IMPACT model to predict the water and sediment concentrations over time at the exposed locations. The COPCs in groundwater will be released to Whitefish Lake Middle at a predicted mass flux as shown in Table 3-4 (Ecometrix, 2022). The same modelling approach as described in Section 3.1.2 was applied in the "future centuries" scenario except that the annual average flow of the receiving water and a 2-year monitoring time step were used due to the long modelling time period of 1000 years.

The predicted maximum concentrations of COPCs in water and sediment during future centuries are shown in Table 3-5. There are no predicted exceedances of water and sediment quality guidelines for any of the COPCs, except for copper in water where baseline concentrations exceed the FEQG. Figure 3-4 and Figure 3-5 show the predicted concentrations of COPCs in water and sediment over time at the exposed locations (Whitefish Lake Middle, Whitefish Lake South, McGowan Lake, and Russell Lake) and reference locations (Kratchkowsky Lake and Whitefish Lake North) during future centuries.

Table 3-4: Summary of Predicted Mass Flux of COPCs in Groundwater for Future Centuries

Mass Flux (mg/s or Bq/s)									
Year after Project Phases	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
General Chemistry									
Chloride	1.26E+02	1.28E+02	1.29E+02	1.29E+02	1.29E+02	1.29E+02	1.29E+02	1.28E+02	1.28E+02
Sulphate	4.08E+01	4.47E+01	4.69E+01	4.62E+01	4.44E+01	4.28E+01	4.16E+01	4.07E+01	3.99E+01
Metals and Metalloids									
Arsenic	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.73E-03	5.74E-03
Cadmium	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.88E-04	1.88E-04
Chromium	9.45E-03	9.45E-03	9.44E-03	9.43E-03	9.42E-03	9.42E-03	9.41E-03	9.40E-03	9.40E-03
Cobalt	7.51E-03	7.50E-03	7.49E-03	7.47E-03	7.46E-03	7.44E-03	7.43E-03	7.41E-03	7.40E-03
Copper	1.15E-02	1.15E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02
Molybdenum	1.34E-02	1.34E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02
Selenium	1.52E-02	1.52E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02
Uranium	9.47E-03	9.47E-03	9.47E-03	9.46E-03	9.46E-03	9.45E-03	9.45E-03	9.45E-03	9.45E-03
Vanadium	1.89E-03	1.89E-03	1.90E-03	1.90E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.92E-03
Zinc	8.30E-02	8.30E-02	8.30E-02	8.29E-02	8.29E-02	8.28E-02	8.28E-02	8.28E-02	8.28E-02
Radionuclides									
Uranium-238	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01
Uranium-234	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01
Thorium-230	3.69E-01	3.70E-01	3.71E-01	3.71E-01	3.72E-01	3.72E-01	3.72E-01	3.73E-01	3.73E-01
Radium-226	1.14E+00	1.14E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00
Lead-210	1.14E+00	1.14E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00	1.15E+00
Polonium-210	1.16E+00	1.16E+00	1.17E+00	1.17E+00	1.17E+00	1.17E+00	1.17E+00	1.17E+00	1.17E+00

Note:

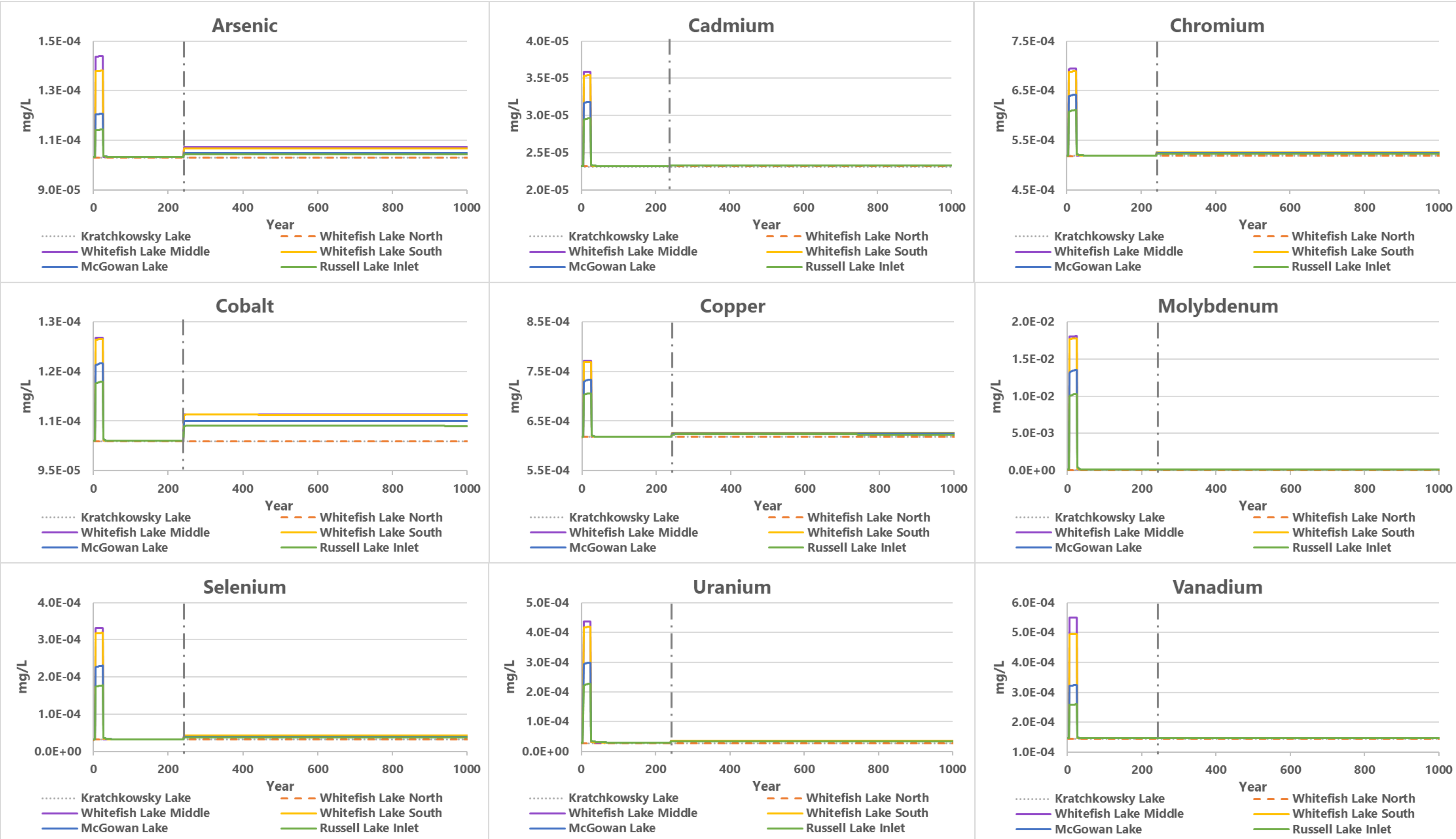
a) Estimated from uranium using the specific activity of 12356 Bq/g and assuming secular equilibrium between uranium-238 and uranium-234.
b) Unit conversion from mg/s to Bq/s using the specific activity of 7.47E+08 Bq/g which was calculated from its half-life of 77000 y.
c) Unit conversion from mg/s to Bq/s using the specific activity of 3.66E+10 Bq/g which was calculated from its half-life of 1600 y.
d) Assuming equilibrium between radium-226 and lead-210 due to the long half-life of radium-226.
e) Calculated from lead-210 assuming transient equilibrium between lead-210 and polonium-210.

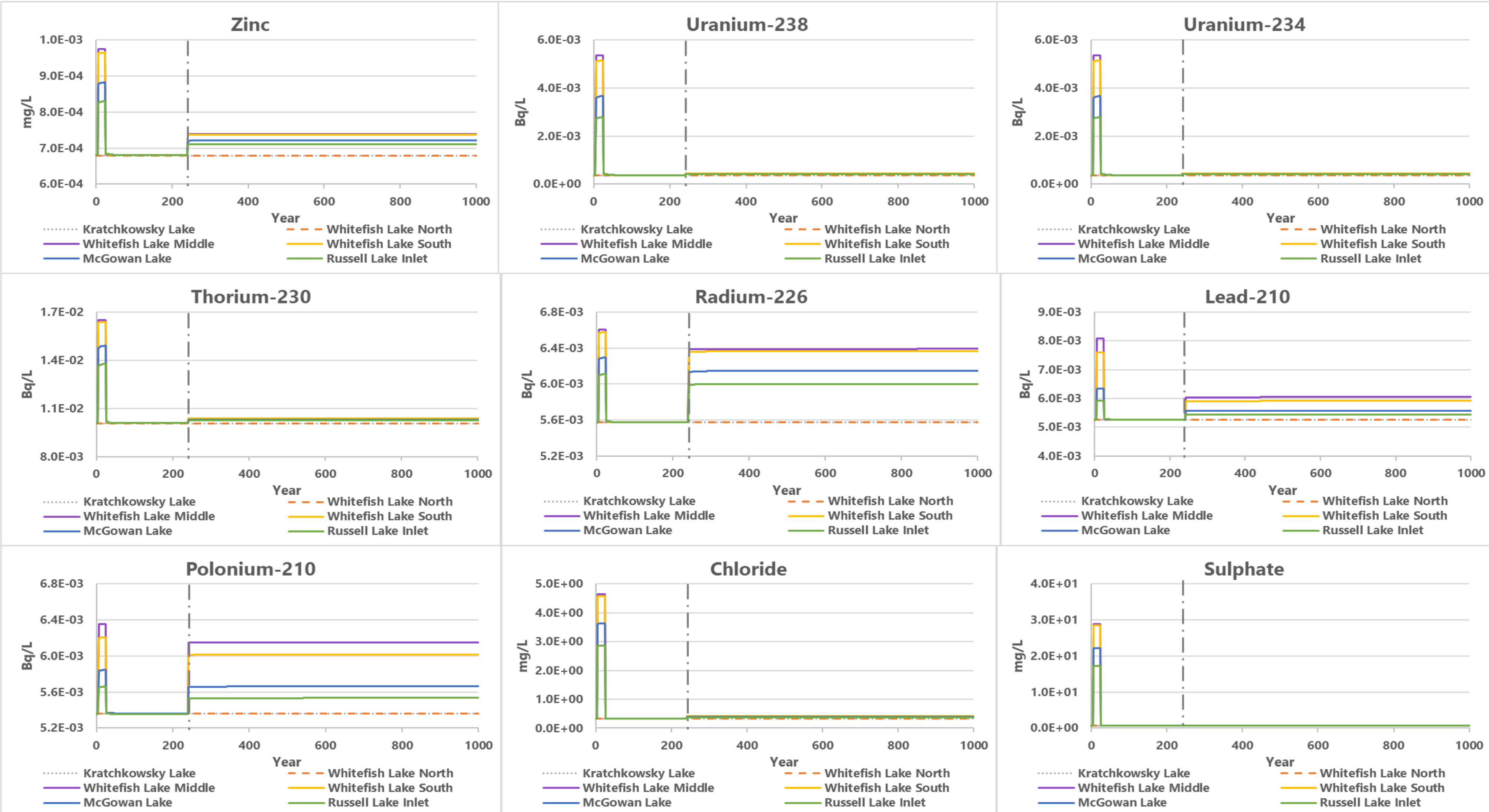
Table 3-5: Maximum Concentration of COPCs in Water and Sediment during Future Centuries

Environmental Media	Location	Maximum Concentration of Non-radionuclides during Project Phases											
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Water (mg/L)	Quality Guideline	5.00E-03	4.00E-05	1.20E+02	2.95E-04	1.00E-03	2.00E-04	7.60E+00	1.28E+02	1.00E-03	1.50E-02	1.20E-01	1.30E-02
	Kratchkowsky Lake	1.03E-04	2.32E-05	3.22E-01	1.01E-04	5.19E-04	6.18E-04	1.07E-04	6.87E-01	3.23E-05	3.01E-05	1.46E-04	6.81E-04
	Whitefish Lake North	1.03E-04	2.32E-05	3.22E-01	1.01E-04	5.19E-04	6.18E-04	1.07E-04	6.87E-01	3.23E-05	3.01E-05	1.46E-04	6.81E-04
	Whitefish Lake Middle	1.07E-04	2.33E-05	4.15E-01	1.06E-04	5.26E-04	6.26E-04	1.16E-04	7.21E-01	4.30E-05	3.68E-05	1.47E-04	7.40E-04
	Whitefish Lake South	1.07E-04	2.33E-05	4.14E-01	1.06E-04	5.26E-04	6.26E-04	1.16E-04	7.20E-01	4.26E-05	3.65E-05	1.47E-04	7.37E-04
	McGowan Lake	1.05E-04	2.33E-05	3.93E-01	1.05E-04	5.24E-04	6.24E-04	1.14E-04	7.13E-01	3.94E-05	3.45E-05	1.46E-04	7.21E-04
	Icelander River	1.05E-04	2.33E-05	3.92E-01	1.05E-04	5.24E-04	6.24E-04	1.14E-04	7.13E-01	3.94E-05	3.45E-05	1.46E-04	7.21E-04
	Russell Lake Inlet	1.04E-04	2.32E-05	3.76E-01	1.04E-04	5.23E-04	6.23E-04	1.12E-04	7.07E-01	3.76E-05	3.33E-05	1.46E-04	7.11E-04
Sediment (mg/kg dw)	Quality Guideline	2.10E+01	6.00E-01	n/a	n/a	3.15E+01	2.20E+01	2.30E+01	n/a	3.60E+00	9.70E+01	3.51E+01	1.23E+02
	Kratchkowsky Lake	8.35E+00	3.38E-01	n/a	2.52E-01	5.86E+00	1.85E+00	3.37E-01	n/a	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake North	8.35E+00	3.38E-01	n/a	2.52E-01	5.86E+00	1.85E+00	3.37E-01	n/a	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake Middle	8.66E+00	3.40E-01	n/a	2.65E-01	5.94E+00	1.87E+00	3.68E-01	n/a	8.28E-01	7.07E-01	1.13E+01	1.08E+01
	Whitefish Lake South	8.62E+00	3.40E-01	n/a	2.65E-01	5.93E+00	1.87E+00	3.67E-01	n/a	8.19E-01	7.02E-01	1.13E+01	1.08E+01
	McGowan Lake	8.48E+00	3.39E-01	n/a	2.62E-01	5.91E+00	1.87E+00	3.60E-01	n/a	7.59E-01	6.64E-01	1.13E+01	1.05E+01
	Russell Lake Inlet	8.43E+00	3.39E-01	n/a	2.59E-01	5.90E+00	1.86E+00	3.55E-01	n/a	7.22E-01	6.41E-01	1.12E+01	1.04E+01

Environmental Media	Location	Maximum Concentration of Radionuclides during Project Phases					
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Water (Bq/L)	Quality Guideline	n/a	n/a	n/a	1.10E-01	n/a	n/a
	Kratchkowsky Lake	3.71E-04	3.71E-04	1.01E-02	5.57E-03	5.27E-03	5.36E-03
	Whitefish Lake North	3.71E-04	3.71E-04	1.01E-02	5.57E-03	5.27E-03	5.36E-03
	Whitefish Lake Middle	4.54E-04	4.54E-04	1.04E-02	6.39E-03	6.05E-03	6.15E-03
	Whitefish Lake South	4.51E-04	4.51E-04	1.04E-02	6.37E-03	5.92E-03	6.02E-03
	McGowan Lake	4.26E-04	4.26E-04	1.03E-02	6.15E-03	5.57E-03	5.66E-03
	Icelander River	4.26E-04	4.26E-04	1.03E-02	6.14E-03	5.56E-03	5.64E-03
	Russell Lake Inlet	4.12E-04	4.12E-04	1.03E-02	6.00E-03	5.45E-03	5.53E-03
Sediment (Bq/kg dw)	Quality Guideline	n/a	n/a	n/a	6.00E+02	9.00E+02	8.00E+02
	Kratchkowsky Lake	7.14E+00	7.14E+00	2.32E+01	6.51E+01	3.74E+02	3.80E+02
	Whitefish Lake North	7.14E+00	7.14E+00	2.32E+01	6.51E+01	3.74E+02	3.80E+02
	Whitefish Lake Middle	8.74E+00	8.74E+00	2.38E+01	7.47E+01	4.29E+02	4.36E+02
	Whitefish Lake South	8.67E+00	8.67E+00	2.38E+01	7.44E+01	4.19E+02	4.27E+02
	McGowan Lake	8.20E+00	8.20E+00	2.36E+01	7.18E+01	3.95E+02	4.01E+02
	Russell Lake Inlet	7.92E+00	7.92E+00	2.35E+01	7.01E+01	3.86E+02	3.93E+02

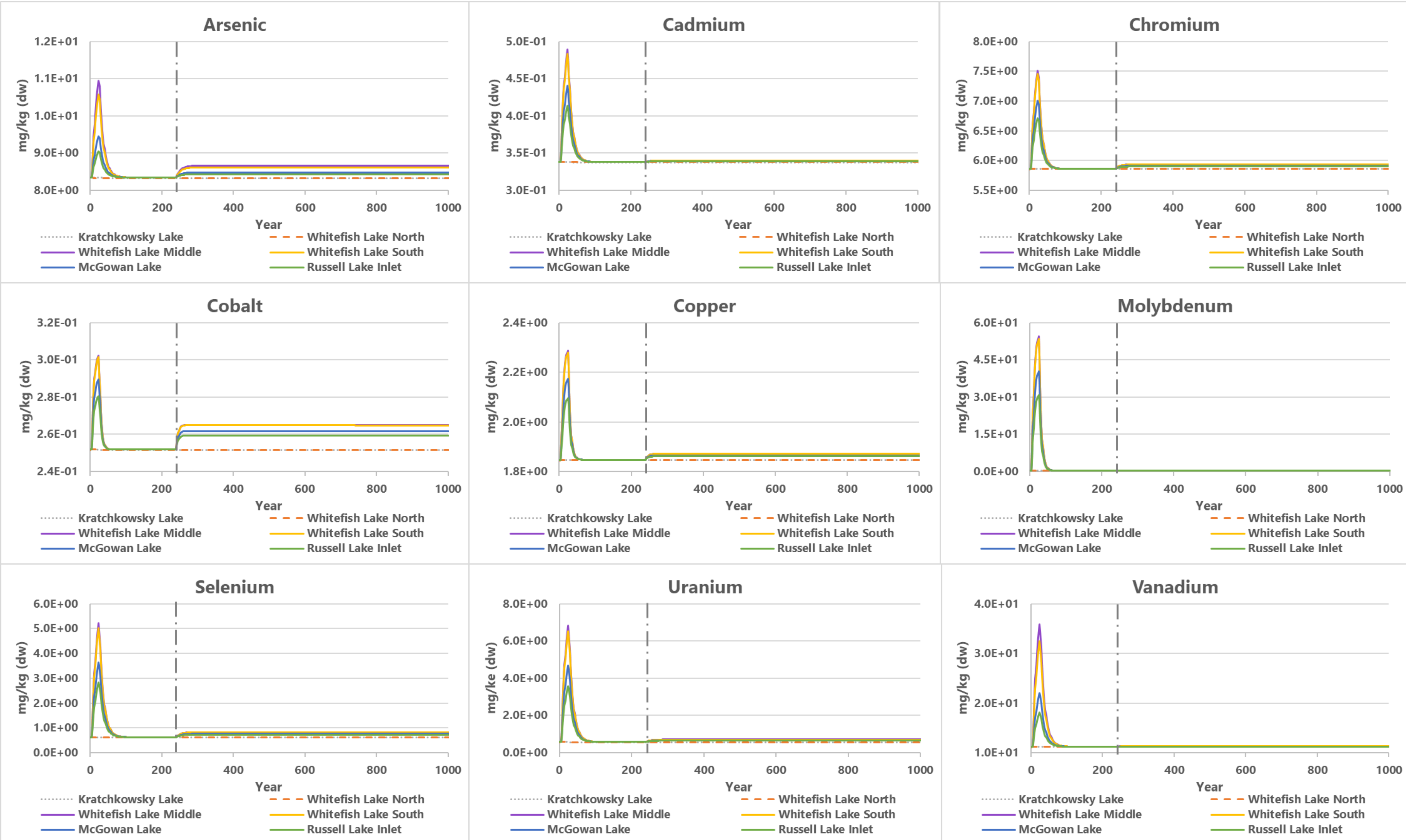
n/a = not applicable
Water quality guidelines are as shown in Table 3-1 and sediment quality guidelines are as shown in Table 3-6.

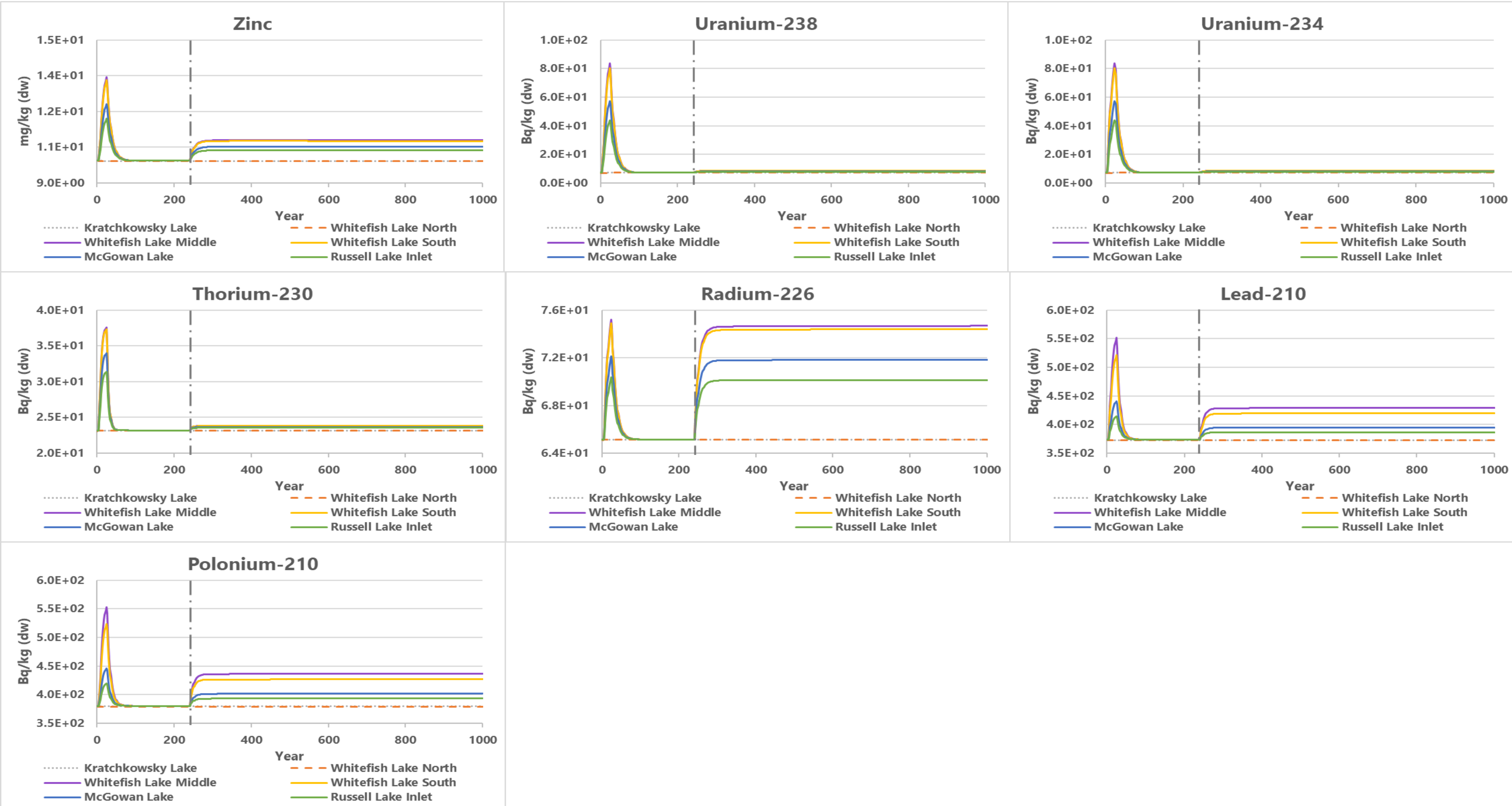

Arsenic
1.5E-04
1.3E-04
1.1E-04
9.0E-05
mg/L
0
200
400
600
800
1000
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Cadmium
4.0E-05
3.5E-05
3.0E-05
2.5E-05
2.0E-05
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Chromium
7.5E-04
6.5E-04
5.5E-04
4.5E-04
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Cobalt
1.3E-04
1.2E-04
1.1E-04
9.5E-05
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Copper
8.5E-04
7.5E-04
6.5E-04
5.5E-04
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Molybdenum
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Selenium
4.0E-04
3.0E-04
2.0E-04
1.0E-04
0.0E+00
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Uranium
5.0E-04
4.0E-04
3.0E-04
2.0E-04
1.0E-04
0.0E+00
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Vanadium
6.0E-04
5.0E-04
4.0E-04
3.0E-04
2.0E-04
1.0E-04
mg/L
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet



Long dash dot lines represent the beginning of the future centuries period when the groundwater solutes reach Whitefish Lake.

Figure 3-4: Modelled Concentrations of COPCs in Water during Future Centuries


Arsenic
1.2E+01
1.1E+01
1.0E+01
9.0E+00
8.0E+00
mg/kg (dw)
0
200
400
600
800
1000
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Cadmium
5.0E-01
4.5E-01
4.0E-01
3.5E-01
3.0E-01
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Chromium
8.0E+00
7.5E+00
7.0E+00
6.5E+00
6.0E+00
5.5E+00
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Cobalt
3.2E-01
3.0E-01
2.8E-01
2.6E-01
2.4E-01
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Copper
2.4E+00
2.2E+00
2.0E+00
1.8E+00
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Molybdenum
6.0E+01
4.5E+01
3.0E+01
1.5E+01
0.0E+00
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Selenium
6.0E+00
5.0E+00
4.0E+00
3.0E+00
2.0E+00
1.0E+00
0.0E+00
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Uranium
8.0E+00
6.0E+00
4.0E+00
2.0E+00
0.0E+00
mg/ke (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Vanadium
4.0E+01
3.0E+01
2.0E+01
1.0E+01
mg/kg (dw)
Year
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet



Long dash dot lines represent the beginning of the future centuries period when the groundwater solutes reach Whitefish Lake.

Figure 3-5: Modelled Concentrations of COPCs in Sediment during Future Centuries

3.1.2.3 Constituents of Potential Concern in Sediment

A sediment screening was performed as a secondary check to determine if there are any constituents not identified as COPCs in the surface water screening that would be identified as COPCs based on exceedances of sediment quality guidelines. Predicted maximum concentrations of constituents of interest in sediment were compared against sediment quality guidelines for the protection of aquatic life and other relevant screening values. Sediment concentrations were predicted from surface water concentrations using IMPACT according to the equations outlined in the IMPACT model (Appendix A).

Sediment quality screening values were selected based on the following of sources:

- reference (REF) and no-effect (NE2) sediment quality values from Burnett-Seidel and Liber (Burnett-Seidel and Liber, 2013);
- lowest effect levels (LELs) and severe effect levels (SELs) from Thompson et al. (Thompson et al., 2005); and
- Canadian interim sediment quality guidelines (ISQGs) and probable effect levels (PELs) from the CCME (CCME, 1999a).

Burnett-Seidel and Liber (2013) was selected as the preferred source, as the reported NE2 and REF values are specifically applicable to Saskatchewan waterbodies. The REF values refer to locations upstream of mining or milling activities or located within separate but nearby drainages. Exceedances of REF values indicate that sediments downstream of predicted discharges contain elevated metal concentrations compared to natural background conditions. The NE2 values refer to exposed (lightly contaminated) areas with elevated concentrations but no significant effect on benthic invertebrate abundance, richness, and evenness. Concentrations below the NE2 values indicate that benthic invertebrate community metrics (abundance, richness, and evenness) downstream of discharges are not expected to differ significantly (less than 20% difference) from those observed at natural background conditions.

Two tiers of sediment quality guidelines are defined by Thompson et al. (2005): LELs and SELs. The CCME also provides two tiers of guidelines in sediments: ISQGs and PELs. If a predicted COPC concentration in sediment is less than the LEL or ISQG, adverse effects on benthic invertebrate communities are not anticipated for that constituent. Predicted concentrations in sediments that exceed the LEL or ISQG would not necessarily indicate that adverse effects are occurring but suggest that further investigation is warranted. These levels were, therefore, used for screening levels where there were no available REF levels.

An exceedance of a PEL or SEL is more likely to be associated with ecological effects. The SEL has been interpreted by some practitioners to be the specific COPC concentration in sediment that the majority of benthic organisms are not expected to tolerate (Persaud et al., 1993). The PEL is defined as the concentration of a COPC above which adverse effects are expected to occur frequently (more than approximately 50% of adverse effects occur above the PEL; (CCME, 1995)).

The sediment screening (Table 3-6) focused on COPCs identified in the surface water screening as exceeding screening values, and on other constituents of interest from other uranium mining and milling operations. Based on comparison of maximum predicted sediment quality in Whitefish Lake (LA-5) against the REF values from Burnett-Seidel and Liber (2013), molybdenum and selenium would exceed the REF values; however, they are not predicted to exceed the NE2 values. Molybdenum and selenium were already identified as COPCs based on the surface water screening, and are assessed further in the quantitative ERA, considering both water and sediment concentrations. The maximum vanadium concentration in sediment is 37.2 mg/kg dw in Whitefish Lake (LA-5), which exceeds its sediment quality guideline of 35.1 mg/kg dw (REF value from Burnett-Seidel and Liber, 2013). Therefore, vanadium was identified as a COPC in sediment. Note that, as indicated above, exceedances of REF values do not necessarily indicate effects, but indicate that sediments downstream of predicted discharges contain elevated metal concentrations compared to natural background conditions.

There is no sediment screening value for cobalt; however, cobalt has already been identified as a COPC in surface water. As such, it will be subject to further quantitative assessment in the ERA, considering both water and sediment concentrations.

Predicted concentrations of all other COPCs do not exceed sediment quality guidelines. The COPCs that were already considered COPCs based on the results of the surface water screening, as well as vanadium based on the results of the sediment screening, were evaluated further in the ERA, considering both water and sediment concentrations.

Table 3-6: Sediment Quality Screening for the Wheeler River Project

Constituent	Units	Maximum – Whitefish Lake (LA-5)	Sediment Quality Guidelines						Selected Sediment Screening Value	Is Concentration Greater than Selected Screening Value? (Y/N)
			Burnett-Seidel and Liber[b]		Thompson et al.[c]		CCME[d]			
			REF	NE2	LEL	SEL	ISQG	PEL		
Metals and Metalloids										
Arsenic	mg/kg dw	11.03	21	522	9.8	346	5.9	17	21	No
Cadmium	mg/kg dw	0.50	n/d	n/d	n/d	n/d	0.6	3.5	0.6	No
Chromium	mg/kg dw	7.59	31.5	26.2	47.6	115.4	37.3	90	31.5	No
Cobalt	mg/kg dw	0.30	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/a
Copper	mg/kg dw	2.31	9.1	11.3	22	268.8	35.7	197	9.1	No
Lead	mg/kg dw	10.24	16.3	19.7	37	412	35	91.3	16.3	No
Molybdenum	**mg/kg dw**	**57.20**	**23**	**245**	**14**	**1,239**	**n/d**	**n/d**	**23**	**Yes**
Nickel	mg/kg dw	4.08	21	326	23	484	n/d	n/d	21	No
Selenium	**mg/kg dw**	**5.48**	**3.6**	**30**	**1.9**	**16**	**n/d**	**n/d**	**3.6**	**Yes**
Uranium	mg/kg dw	7.18	97	2,296	104	5,874	n/d	n/d	97	No
Vanadium	**mg/kg dw**	**37.20**	**35.1**	**31.8**	**35.2**	**160**	**n/d**	**n/d**	**35.1**	**Yes**
Zinc	mg/kg dw	13.63	n/d	n/d	n/d	n/d	123	315	123	No
Radionuclides										
Uranium-234	Bq/kg dw	88.20	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/a
Uranium-238	Bq/kg dw	88.20	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/a
Thorium-230	Bq/kg dw	38.27	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/a
Radium-226	Bq/kg dw	75.71	n/d	n/d	600	14,400	n/d	n/d	600	No
Lead-210	Bq/kg dw	556.58	n/d	n/d	900	20,800	n/d	n/d	900	No
Polonium-210	Bq/kg dw	558.00	n/d	n/d	800	12,100	n/d	n/d	800	No

Bold and Grey shading indicates sediment concentration exceeds the REF or LEL value.
a) Sediment concentrations predicted based on release of aqueous source-terms to LA-5 and interaction with sediment. Modelling performed in IMPACT according to the equations outlined in Appendix A.

b) Burnett-Seidel and Liber (2013) – Sediment quality values derived for application at Saskatchewan uranium operations; reference (REF) values based on reference sites unaffected by mining and milling (representing background), and no-effect level (NE2) values based on sites with no significant difference in benthic invertebrate community effects criteria of abundance, richness and evenness between reference and exposure locations.
c) Thompson et al. (2005) – Sediment quality guidelines derived for application to uranium ore bearing regions of northern Saskatchewan and Ontario; lowest effect levels (LELs) and severe effect levels (SELs) from the "weighted method".
d) CCME – Canadian Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life (CCME, 1999a); updated September 2007; accessed July 2021: **http://ceqg-rcqe.ccme.ca/**).

3.2 Atmospheric Sources

The Project has the potential to change air quality through the emission of gases and particulates as well as deposition of particulates generated by Project activities. For emission to the atmosphere, the ERA focused on the Construction, Operation and Decommissioning phases when effects on air quality are expected to be the greatest due to the intensity and number of Project-related activities.

The Project-related atmospheric releases considered in the ERA were consistent with the air emissions inventory detailed in the Air Quality Impact Assessment (EIS Section 6). The emissions will vary over time based on the schedule of Project activities. The major air emission sources considered for the ERA include the following:

- fossil fuel combustion emissions from mobile equipment and stationary equipment (e.g., generators, heaters, vehicle and equipment movements);
- fugitive dust emissions from drilling and blasting, material handling, crushing, vehicle-generated road dust, and wind erosion from waste piles;
- air emissions released from processing (e.g., the ISR calciner, dryer and hygiene scrubber stacks); and
- removal of site infrastructure and reclamation of waste piles and other storage areas/ponds during the decommissioning phase.

Project-related atmospheric releases would include criteria air contaminants (CACs; nitrogen oxides [assessed as nitrogen dioxide], sulphur dioxide, hydrogen sulphide, ozone, carbon monoxide, total suspended particulates [TSP], and fine particulate matter [PM_{10} and $PM_{2.5}$]), metals including uranium in dust, and radon.

Criteria air contaminants have either federal or provincial ambient air quality criteria or both. Nitrogen oxides, sulphur dioxide, carbon monoxide, and particulates (TSP, PM_{10}, and $PM_{2.5}$) would be CACs directly emitted by the Project from stationary and mobile sources. Sources of hydrogen sulphide and ozone are expected to be negligible and therefore were not retained for further assessment of impacts to air quality.

Particulates would be associated with such activities as road dust from unpaved roads; wind erosion; materials handling; dozing at the wellfield and waste pads; the ISR calciner, dryer and hygiene scrubber stacks (dusts emitted in the form of yellowcake); and construction activities. Particulates would be measured in terms of TSP, PM_{10}, and $PM_{2.5}$.

Metals would be emitted as a portion of dust. Dust emissions were assumed to contain metals from emissions from wellfield drilling in mineralized waste, wind erosion from the mineralized waste pad, material handling at the wellfield and mineralized waste pad, and stack emissions from the ISR Plant (the dryer, calciner, and hygiene scrubber stacks).

Long-lived radioactive dust is of primary concern at the back end of the ISR process, since the process is wet until the yellowcake product (uranium oxides) is precipitated out of solution and dried. The long-lived species of concern at that point are uraniuim-238 and uranium-234. The uranium mass is almost entirely uraniuim-238; on an activity basis, uranium-238 and uranium-234 contribute equal activity. It was assumed that other radionuclides in the uranium-238 decay chain would not be present at the point of release but decay and ingrowth is accounted for over time at the point of exposure.

Radon emissions from a number of sources were included in the air quality assessment: wellfield drilling, groundwater exposure to the atmosphere, mining solution venting from wellheads and leaking transport piping, radon surge tank venting, recovered solution pond, ISR plant ventilation, and the mineralized waste and Fe-Ra precipitates storage pads.

3.2.1 Screening for Constituents of Potential Concern

Constituents of potential concern for air, as defined by Health Canada (Health Canada, 2016a), are chemicals whose concentration(s) may become elevated in ambient air as a result of project-related activities, and which have the potential for adverse human or ecological health effects based on documented scientific evidence or suspected causal relationships. The purpose of this section is to identify those Project-related constituents in air that may be of concern for human and/or ecological health and require further assessment.

The screening of air quality constituents was based on maximum predicted concentrations of CACs, metals including uranium, radon, and maximum dust deposition, at air quality model locations that correspond with receptor locations (Table 3-7 below, see Figure 2 in Air Quality Impact Assessment, Section 6 of the EIS), as described in Section 4.2.1, Exposure Locations, Duration, and Frequency, for the human health risk assessment, and Section 5.2.1, Exposure Locations, for the ecological risk assessment.

Maximum predicted concentrations are total concentrations, including background, except for radon which is an incremental concentration.

Table 3-7: Concordance between Air Quality Model and Receptor Locations

Air Quality Model Location	Human and Ecological Receptor Location	Air Quality Model Coordinates	
		X (m)	Y (m)
Risk1	Ecological Location – On-site	477708	6374351
Risk2	Human Location – Recreational Fisher/Trapper (Seasonal resident at McGowan Lake [LA-1])	478245	6372039
Risk3	Human Location – Camp Worker	476896	6373487
Risk4	Human location – Seasonal Resident (Russell Lake)	478415	6368289
Risk5	Human location – Reference Receptor (LA-7)	473146	6375099

Human and ecological receptors at receptor locations were assumed to be in contact with air emissions for prolonged periods of time, at intervals that may be long-term (i.e., annual average) or repeated and short-term (i.e., 24 hours or less) over a lifetime. For this reason, long-term and short-term screening values at the receptor locations were used for the screening of constituents in air at receptor locations.

In addition to the specific receptor locations shown in Table 3-7 above, the screening also considered a fenceline receptor (a receptor at the Project boundary) for short-term exposures (i.e., 24 hours or less). Although the Wheeler River site is remote and access to the site fenceline by a receptor, other than at the locations of trails or roads is unlikely, receptors were assessed along the fenceline boundary. For each air constituent, concentrations were predicted all along the project fenceline boundary and the highest predicted concentration was retained as the maximum for screening purposes. This means that the “fenceline” receptor could occur in different discrete locations for different constituents.

Screening of constituents in air for the receptor locations was based on maximum predicted concentrations for all receptor locations for the relevant time period, as follows:

1. If the model results from the Air Quality Impact Assessment (EIS Section 6) for a constituent were below its relevant air quality screening values for all averaging times at all receptor locations, the constituent was assumed to be below levels associated with potential human health and ecological risks and was not considered further in the ERA for direct atmospheric exposures.

2. If the model result for an air quality constituent was greater than any one of its relevant air quality screening values at any receptor location, the constituent was evaluated further in secondary screening to determine if it should be carried forward as a COPC for quantitative risk assessment.

3.2.1.1 Screening Value Selection

Ambient air quality criteria are available for different exposure averaging periods (e.g., 1-hour, 24-hour, annual). Ambient air quality criteria for the relevant averaging periods were selected based on the following hierarchy:

- Saskatchewan Ambient Air Quality Standards (SAAQS) are maximum concentrations in ambient air from all sources as stipulated in *The Clean Air Regulations* (Government of Saskatchewan, 2015).

- Alberta Ambient Air Quality Objectives (AAAQO) are based on an evaluation of scientific, social, technical, and economic factors (Alberta, 2021).

- Ontario Ambient Air Quality Criteria (OAAQC) are concentrations of a constituent in air that are protective against adverse effects on health and/or the environment (MECP, 2020).

- Texas effects screening levels (ESLs) are air concentrations at or below which adverse health effect in the general public, including sensitive subgroups such as children, the elderly, pregnant women, and people with pre-existing health conditions, are not likely to occur (TCEQ, 2016).

Canadian Ambient Air Quality Standards (CAAQS) established under the national Air Quality Management System were considered as screening criteria, as appropriate.

Screening values for radionuclide concentrations in ambient air were not available. All relevant radionuclides were assessed in the ERA in terms of their contribution to the total radiological dose to human and ecological receptors.

As noted in the Air Quality assessment, the Ontario criteria for uranium in PM_{10} were conservatively selected given that the literature suggests that the particle size distribution for yellowcake is 80% less than PM_{10} (US EPA, 1980). The predictions for all other metals were compared to criteria based on TSP.

The selected ambient air quality screening values for different averaging periods, their source, and their rationale in terms of potential effects are summarized in Table 3-8. Where multiple sources recommended the same criterion value, each of the relevant sources is identified. The rationale provided in Table 3-8 for each of the selected screening values describes the sensitive effect that is the basis for the value cited by the relevant source.

Table 3-8: Screening Values for the Selection of Air Quality Constituents of Potential Concern for the Environmental Risk Assessment

Constituent	Averaging Period	Selected Screening Value	Source	Rationale
CACs				
Nitrogen dioxide (NO_2)	1 hour	300 (79)	SAAQS/AAAQO (CAAQS 2025)	Respiratory effects
	24-hour	200	SAAQS/OAAQC	Human health
	Annual	45 (23)	SAAQS/AAAQO (CAAQS 2025)	Vegetation
Sulphur dioxide (SO_2)	1 hour	450 (170)	SAAQS/AAAQO (CAAQS 2025)	Pulmonary function
	24-hour	125	SAAQS/AAAQO	Human health
	Annual	20 (11)	SAAQS/AAAQO (CAAQS 2025)	Ecosystem health
Carbon monoxide (CO)	1 hour	15000	SAAQS/AAAQO	Oxygen carrying capacity of blood
	8-hour	6000	SAAQS/AAAQO	Oxygen carrying capacity of blood
Total suspended particulates (TSP)	24-hour	100	SAAQS/AAAQO	Human health. Pulmonary effects
	Annual	60	SAAQS/OAAQC	Visibility
Particulate matter (PM_{10})	24-hour	50	SAAQS/OAAQC	Human health
Particulate matter ($PM_{2.5}$)	24-hour	27	OAAQC/CAAQS	Human health
	Annual	8.8	OAAQC/CAAQS	Human health
Dustfall				
TSP deposition	Annual	4.6	OAAQC	Dustfall criterion. Aesthetics ($g/m^2/yr$)
	30-day	2	SAAQS	Aesthetics ($mg/cm^2/30$ days)
Radionuclides				
	24-hour	n/v	n/a	Addressed in terms of radiation dose in the ERA

Constituent	Averaging Period	Selected Screening Value	Source	Rationale
Thorium-230, Radium-226, Lead-210, Polonium-210	Annual	n/v	n/a	Addressed in terms of radiation dose in the ERA
Radon				
Radon	Annual	n/v	n/a	Addressed in terms of radiation dose in the ERA
Metals				
Arsenic (As)	24-hour	0.3	OAAQC	Human health. Applies to arsenic and arsenic compounds.
	Annual	0.01	AAAQO	Human health. Carcinogenic effects.
Cadmium (Cd)	24-hour	0.025	OAAQC	Human health. Applies to cadmium and cadmium compounds. Converted from the annual AAQC to allow assessment of 24-hour air quality data.
	Annual	0.005	OAAQC	Human health. Applies to cadmium and cadmium compounds.
Cobalt (Co)	24-hour	0.1	OAAQC	Human health
	Annual	n/v	n/a	n/a
Chromium (Cr)	24-hour	0.5	OAAQC	Human health. Applies to either chromium metallic, divalent, and trivalent, or to the percentage of chromium metallic, divalent, and trivalent relative to total chromium.
	Annual	n/v	n/a	n/a
Copper (Cu)	24-hour	50	OAAQC	Human health
	Annual	n/v	n/a	n/a
Molybdenum (Mo)	24-hour	120	OAAQC	Particulate – visibility; molybdenum is more likely emitted as TSP, and therefore the AAQC for TSP is applied.
	Annual	n/v	n/a	n/a

Constituent	Averaging Period	Selected Screening Value	Source	Rationale
Nickel (Ni)	24-hour	0.2	OAAQC	In TSP. Human health. Applies to nickel and nickel compounds. Converted from the annual criterion to allow assessment of the 24-hour data (TSP). Intended to protect from development of chronic effects.
	Annual	0.04	OAAQC	In TSP. Human health. Applies to nickel and nickel compounds.
	24-hour	0.1	OAAQC	In PM_{10}. Human health. Applies to nickel and nickel compounds. Converted from the annual criterion to allow assessment of the 24-hour data (PM_{10}). Intended to protect from development of chronic effects
	Annual	0.02	OAAQC	In PM_{10}. Human health. Applies to nickel and nickel compounds.
Lead (Pb)	24-hour	0.5	OAAQC	Human health. Applies to lead and lead compounds. Converted from the 30-day AAQC to allow assessment of 24-hour air quality data
	Monthly	0.2	OAAQC	Human health. Applies to lead and lead compounds. As arithmetic mean of a 30-day period.
	Annual	n/v	n/a	n/a
Selenium (Se)	24-hour	10	OAAQC	Human health
	Annual	n/v	n/a	n/a
Uranium (U)	24-hour	0.3	OAAQC	In TSP. Human health. Applies to uranium and uranium compounds. Converted from the annual AAQC to allow assessment of 24-hour air quality data.
	Annual	0.06	OAAQC	In TSP. Human health. Applies to uranium and uranium compounds.
	24-hour	0.15	OAAQC	In PM_{10}. Human health. Applies to uranium and uranium compounds. Converted from the annual AAQC to allow assessment of 24-hour air quality data.
	Annual	0.03	OAAQC	In PM_{10}. Human health. Applies to uranium and uranium compounds.
Vanadium (V)	24-hour	2	OAAQC	Human health
	Annual	n/v	n/a	n/a

Constituent	Averaging Period	Selected Screening Value	Source	Rationale
Zinc (Zn)	24-hour	120	OAAQC	Particulates
	Annual	n/v	n/a	n/a
Other				
Acrolein	1-hour	4.5	OAAQC	Human health
	24-hour	0.4	OAAQC	Human health
	Annual	0.02	US EPA IRIS	Human Health. Chronic Reference Concentration

Notes:

Units are µg/m³ unless otherwise specified.

3.2.1.2 Screening of Air Quality Constituents

The screening of air quality constituents involved the following two types of screenings:

- Primary Screening - Comparing the predicted maximum (short or long-term) air concentrations from the air quality model at all human and ecological receptor locations against the corresponding (short or long-term) air quality criteria (Table 3-9). For the fenceline receptor, comparison of the predicted maximum (short-term) air concentrations from the air quality model against the corresponding short-term air quality criteria (Table 3-10).

- Secondary Screening - For constituents exceeding air quality criteria, screening based on consideration of the locations, receptors present, the type of criterion exceeded (short or long-term) and the frequency of exceedance.

The primary screening of air quality constituents at the human and ecological receptor locations for short- and long-term averaging periods at receptor locations is provided in Table 3-9. Both human and ecological receptors were assumed to be present for extended periods of time at these locations and therefore susceptible to both short- and long-term exposures to airborne constituents. Constituents were not considered further if the maximum predicted concentrations for both short and long-term averaging periods was less than the applicable screening value, as shown in Table 3-9.

Air quality constituents with maximum concentrations that exceeded either their short- or long-term screening value at receptor locations were nitrogen dioxide, particulate matter (TSP, PM_{10}), and uranium. Air quality constituents with maximum concentrations that exceeded their short-term screening value at the fenceline were nitrogen dioxide and particulate matter (TSP, PM_{10}). These constituents were subjected to secondary screening in Section 3.2.1.3, to identify COPCs that require further evaluation in terms of human health and/or ecological risk.

Baseline concentrations were compared to the Project air quality criteria in EIS Appendix 6-A, Table 5.

Table 3-9: Air Quality Screening for Short-term and Long-term Exposures to Constituents in Air at Human and Ecological Receptor Locations

Constituent	Maximum Concentration at Receptor Locations			Screening Value	Averaging Period	Source	Is Concentration Greater than Selected Screening Value? (Yes/No)	Considered Further in Secondary Screening? (Yes/No)
	Construction	Operation	Decommissioning					
CACs								
Nitrogen dioxide (NO_2)	17.1	11.3	16.4	23	Annual	CAAQS	**Yes (1-hour)**	**Yes. No exceedances of annual or 24-hour screening values, but there is a 1-hour exceedance at the camp worker location during all phases of the project.**
	70.6	100	120	200	24-hour	SAAQS/OAAQC		
	181	**275**	**355**	79	1-hour	CAAQS		
Sulphur dioxide (SO_2)	0.0165	0.0111	0.0174	11	Annual	CAAQS	No	No
	0.0814	0.123	0.154	125	24-hour	SAAQS/AAAQO		
	0.216	0.371	0.471	450	1-hour	SAAQS/AAAQO		
Carbon monoxide (CO)	614	639	661	6000	8-hour	SAAQS/AAAQO	No	No. Toxicity of CO is only relevant for short-term (i.e., 8 hours or less) timeframes.
	646	691	741	15000	1-hour	SAAQS/AAAQO		
TSP	48.0	20.6	22.1	60	Annual	SAAQS/OAAQC	**Yes (24-hour)**	**Yes. No exceedances of its annual screening value, but there are exceedances of the 24-hour screening value during all phases of the project.**
	286	**124**	**135**	100	24-hour	SAAQS/AAAQO		
PM_{10}	**136**	**57.0**	**61.1**	50	24-hour	SAAQS/OAAQC	**Yes (24-hour)**	**Yes. No annual screening value but considered further because it exceeds its 24-hour screening value during all phases of the project.**
$PM_{2.5}$	5.4	3.66	3.99	8.8	Annual	OAAQC/CAAQS	No	No
	21	11.0	14.5	27	24-hour	OAAQC/CAAQS		

Constituent	Maximum Concentration at Receptor Locations			Screening Value	Averaging Period	Source	Is Concentration Greater than Selected Screening Value? (Yes/No)	Considered Further in Secondary Screening? (Yes/No)
	Construction	Operation	Decommissioning					
Dustfall								
TSP deposition	0.701	0.0802	0.811	7	Annual	OAAQC Dustfall Criteria ($g/m^2/yr$)	No	No
	1.05	0.181	0.197	2	Monthly	SAAQS ($mg/cm^2/30$ days)		
Radon (Bq/m^3)								
Radon (incremental)	2.15	33.3	15.7	<7.4 to 25	Annual	EIS *Appendix 6-A*	Yes	**Yes. Assessed in terms of radiation dose in the ERA**
Metals								
Arsenic (As)	7.05E-04	7.12E-04	7.01E-04	0.01	Annual	AAAQO	No	No
	3.03E-03	3.13E-03	3.01E-03	0.3	24-hour	OAAQC		
Cadmium (Cd)	7.50E-05	7.75E-05	7.45E-05	0.005	Annual	OAAQC	No	No
	2.81E-04	3.01E-04	2.79E-04	0.025	24-hour	OAAQC		
Cobalt (Co)	2.65E-03	2.75E-03	2.64E-03	0.1	24-hour	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its 24-hour screening value
Chromium (Cr)	5.82E-04	8.96E-04	5.74E-04	0.5	24-hour	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its 24-hour screening value
Copper (Cu)	3.30E-01	3.35E-01	3.29E-01	50	24-hour	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its 24-hour screening value

Constituent	Maximum Concentration at Receptor Locations			Screening Value	Averaging Period	Source	Is Concentration Greater than Selected Screening Value? (Yes/No)	Considered Further in Secondary Screening? (Yes/No)
	Construction	Operation	Decommissioning					
Molybdenum (Mo)	2.71E-03	2.83E-03	2.70E-03	120	24-hour	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its 24-hour screening value
Nickel (Ni) in TSP	4.08E-04	4.41E-04	4.02E-04	0.04	Annual	OAAQC	No	No
	2.05E-03	2.32E-03	2.02E-03	0.2	24-hour	OAAQC	No	No
Nickel (Ni) in PM_{10}	4.08E-04	4.41E-04	4.02E-04	0.02	Annual	OAAQC	No	No
	2.05E-03	2.32E-03	2.02E-03	0.1	24-hour	OAAQC	No	No
Lead (Pb)	6.43E-03	7.48E-03	6.31E-03	0.2	Monthly	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its monthly or 24-hour screening values
	1.71E-02	2.32E-02	1.66E-02	0.5	24-hour	OAAQC		
Selenium (Se)	8.11E-04	8.58E-04	8.07E-04	10	24-hour	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its 24-hour screening value
Uranium (U) in PM_{10}	4.12E-03	**3.45E-02**	1.47E-03	0.03	Annual	OAAQC	**Yes (24-hour and annual)**	**Yes. Exceedances of the 24-hour screening value during the Operation phase at the on-site ecological receptor location and the camp worker location, and of the annual screening value at the on-site ecological location only.**
	2.49E-02	**2.60E-01**	1.25E-02	0.15	24-hour	OAAQC		
Vanadium (V)	5.40E-03	5.93E-03	5.35E-03	2	24-hour	OAAQC	No	No. No annual screening value but not considered further because it

Constituent	Maximum Concentration at Receptor Locations			Screening Value	Averaging Period	Source	Is Concentration Greater than Selected Screening Value? (Yes/No)	Considered Further in Secondary Screening? (Yes/No)
	Construction	Operation	Decommissioning					
								does not exceed its 24-hour screening value
Zinc (Zn)	1.13E+00	1.13E+00	1.13E+00	120	24-hour	OAAQC	No	No. No annual screening value but not considered further because it does not exceed its 24-hour screening value
Other								
Acrolein	4.84E-02	3.91E-02	8.29E-02	4.5	1-hour	OAAQC	No	No
	1.75E-02	1.35E-02	2.66E-02	0.4	24-hour	OAAQC	No	No
	3.19E-03	6.02E-03	2.44E-03	0.02	Annual	US EPA IRIS	No	No

Notes:
Air Concentrations are maximum predicted values (including background) from the Air Quality model for human health and ecological receptor locations Risk1 to Risk5, inclusively, for the period indicated.
Maximum Concentration values are rounded to 3 significant figures.
Units are µg/m^3 unless otherwise specified.
Bold represents air quality parameters predicted to exceed screening values at receptor locations, or parameters that did not exceed the screening level but are discussed further in the ERA.
n/c = not calculated; n/v = no value; n/a = not applicable; ERA = environmental risk assessment; SAAQS = Saskatchewan Ambient Air Quality Standards (Government of Saskatchewan 2015); AAAQO = Alberta Ambient Air Quality Objectives (Alberta 2021); OAAQC = Ontario Ambient Air Quality Criteria (MECP 2020); CAAQS = Canadian Ambient Air Quality Standards (CCME 2021b); < = less than; Bq/m^3 = becquerels per cubic metre; TSP = total suspended particulates; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; CAC = criteria air contaminant.

Table 3-10: Air Quality Screening for Short-term Exposures to Constituents in Air at the Fenceline

Constituent	Maximum Concentration at Fenceline			Screening Value	Averaging Period	Source	Is Concentration Greater than Selected Screening Value? (Yes/No)	Considered Further in Secondary Screening? (Yes/No)
	Construction	Operation	Decommissioning					
CACs								
Nitrogen dioxide (NO_2)	42.9	46.8	42.7	200	24-hour	SAAQS/OAAQC	**Yes (1-hour)**	**Yes. There are exceedances of the 1-hour screening value during all phases of the project.**
	176	**178**	**178**	79	1-hour	SAAQS/AAAQO		
Sulphur dioxide (SO_2)	0.0329	0.0403	0.0342	125	24-hour	SAAQS/AAAQO	No	No
	0.171	0.172	0.166	170	1-hour	CAAQS		
Carbon monoxide (CO)	596	596	596	6000	8-hour	SAAQS/AAAQO	No	No. Toxicity of CO is only relevant for short-term (i.e., 8 hours or less) timeframes.
	615	614	615	15000	1-hour	SAAQS/AAAQO		
TSP	**313**	**281**	**115**	100	24-hour	SAAQS/AAAQO	**Yes (24-hour)**	**Yes. There are exceedances of the 24-hour screening value during all phases of the project.**
PM_{10}	**116**	**104**	47.4	50	24-hour	SAAQS/OAAQC	**Yes (24-hour)**	**Yes. There are exceedances of the 24-hour screening value during Construction and Operation.**
$PM_{2.5}$	16.3	15.0	10.0	27	24-hour	OAAQC/CAAQS	No	No
Radon (Bq/m^3)								
Radon (incremental)	1.12	12.5	7.04	<7.4 to 25	Annual	EIS *Appendix 6-A*	No	**Yes. Assessed in terms of radiation dose in the ERA**
Metals								
Arsenic (As)	3.01E-03	3.07E-03	3.01E-03	0.3	24-hour	OAAQC	No	No

Constituent	Maximum Concentration at Fenceline			Screening Value	Averaging Period	Source	Is Concentration Greater than Selected Screening Value? (Yes/No)	Considered Further in Secondary Screening? (Yes/No)
	Construction	Operation	Decommissioning					
Cadmium (Cd)	2.78E-04	2.94E-04	2.78E-04	0.025	24-hour	OAAQC	No	No
Cobalt (Co)	2.64E-03	2.72E-03	2.64E-03	0.1	24-hour	OAAQC	No	No
Chromium (Cr)	5.62E-04	7.98E-04	5.63E-04	0.5	24-hour	OAAQC	No	No
Copper (Cu)	3.29E-01	3.33E-01	3.29E-01	50	24-hour	OAAQC	No	No
Molybdenum (Mo)	2.69E-03	2.76E-03	2.69E-03	120	24-hour	OAAQC	No	No
Nickel (Ni) in TSP	2.01E-03	2.22E-03	2.01E-03	0.2	24-hour	OAAQC	No	No
Nickel (Ni) in PM_{10}	2.01E-03	2.22E-03	2.01E-03	0.1	24-hour	OAAQC	No	No
Lead (Pb)	1.64E-02	2.05E-02	1.64E-02	0.5	24-hour	OAAQC	No	No
Selenium (Se)	8.05E-04	8.42E-04	8.05E-04	10	24-hour	OAAQC	No	No
Uranium (U) in PM_{10}	8.75E-03	**2.23E-01**	7.41E-03	0.15	24-hour	OAAQC	**Yes**	**Yes. Exceedances of the 24-hour screening value during the Operation phase at the fenceline.**
Vanadium (V)	5.34E-03	5.75E-03	5.33E-03	2	24-hour	OAAQC	No	No
Zinc (Zn)	1.13E+00	1.13E+00	1.13E+00	120	24-hour	OAAQC	No	No
Other								
Acrolein	4.71E-02	2.47E-02	4.01E-02	4.5	1-hour	OAAQC	No	No
	9.56E-03	5.55E-03	8.02E-03	0.4	24-hour	OAAQC	No	No

Notes:
Air Concentrations are maximum predicted values (including background) from the Air Quality model for locations along the project fenceline, for the period indicated.
Maximum Concentration values are rounded to 3 significant figures.
Units are µg/m³ unless otherwise specified.
Bold represents air quality parameters predicted to exceed screening values at receptor locations, or parameters that did not exceed the screening level but are discussed further in the ERA.

n/c = not calculated; n/v = no value; n/a = not applicable; ERA = environmental risk assessment; SAAQS = Saskatchewan Ambient Air Quality Standards (Government of Saskatchewan 2015); AAAQO = Alberta Ambient Air Quality Objectives (Alberta 2021); OAAQC = Ontario Ambient Air Quality Criteria (MECP 2020); CAAQS = Canadian Ambient Air Quality Standards (CCME 2021b); < = less than; Bq/m^3 = becquerels per cubic metre; TSP = total suspended particulates; PM_{10} = particulate matter with a diameter of 10 microns or less; $PM_{2.5}$ = particulate matter with a diameter of 2.5 microns or less; CAC = criteria air contaminant.

3.2.1.3 Secondary Screening of Air Quality Constituents

Air quality constituents that exceeded a screening value were nitrogen dioxide, particulate matter (TSP, PM_{10}), and uranium (Table 3-11). These constituents were further evaluated to determine if they require additional quantitative assessment in the ERA.

Table 3-11: Summary of Air Quality Constituents that Exceed a Screening Value

Constituent	Screening Criteria Exceeded		Predicted Exceedances at Human/Ecological Locations	Hours/Days Exceeding at Human/Ecological Locations	Frequency of Exceedance at Human/Ecological Locations
	Short-Term	Long-Term			
Nitrogen dioxide	1-hour	none exceeded	Construction: exceedance of 1-hour screening value at the camp worker location and fenceline; no 24-hour or annual exceedances Operation: exceedance of 1-hour screening value at the camp worker location and fenceline; no 24-hour or annual exceedances Decommissioning: exceedance of 1-hour screening value at the camp worker location and fenceline; no 24-hour or annual exceedances	Construction: 1-hr: 296 hours (Camp) 28 hours (fenceline) Operation: 1-hr: 402 hours (Camp) 28 hours (fenceline) Decommissioning: 1-hr: 494 hours (Camp) 25 hours (fenceline)	Construction: 1-hr: 3.4% (Camp) 0.3% (fenceline) Operation: 1-hr: 4.6% (Camp) 0.3% (fenceline) Decommissioning: 1-hr: 5.6% (Camp) 0.2% (fenceline)
Particulate Matter: TSP	24-hour	none exceeded	Construction: exceedance of 24-hour screening value at camp worker location and fenceline; no annual exceedances Operation: exceedance of 24-hour screening value at camp worker location and fenceline; no annual exceedances Decommissioning: exceedance of 24-hour screening value at camp worker location and fenceline; no annual exceedances	Construction: 24-hr: 108 days (Camp), 104 days (fenceline) Operation: 24-hr: 8 days (Camp), 80 days (fenceline) Decommissioning: 24-hr: 6 days (Camp), 2 days (fenceline)	Construction: 24-hr: 30% (Camp), 29% (fenceline) Operation: 24-hr: 2.2% (Camp), 22% (fenceline) Decommissioning: 24-hr: 1.6% (Camp), 0.5% (fenceline)
Particulate Matter: PM_{10}	24-hour	n/a	Construction: exceedance of 24-hour screening value at camp worker location and fenceline	Construction: 24-hr: 78 days (Camp), 61 days (fenceline) Operation: 24-hr: 4 days (Camp), 42 days (fenceline)	Construction: 24-hr: 21% (Camp), 17% (fenceline) Operation: 24-hr: 1.1% (Camp), 12% (fenceline)

Constituent	Screening Criteria Exceeded		Predicted Exceedances at Human/Ecological Locations	Hours/Days Exceeding at Human/Ecological Locations	Frequency of Exceedance at Human/Ecological Locations
	Short-Term	Long-Term			
			Operation: exceedance of 24-hour screening value at camp worker location and fenceline Decommissioning: exceedance of 24-hour screening value at camp worker location	Decommissioning: 24-hr: 6 days	Decommissioning: 24-hr: 1.6%
Uranium	24-hour	Annual	Construction: no exceedances Operation: exceedance of 24-hour screening value at the on-site ecological receptor location and camp worker location, also fenceline; annual exceedance at the on-site ecological location Decommissioning: no exceedances	Construction: n/a Operation: 24-hr: 8 days (Camp), 3 days (fenceline) Decommissioning: 24-hr: 5%	Construction: n/a Operation: 24-hr: 5% (Camp), 0.8% (fenceline) Decommissioning: n/a

3.2.1.3.1 Nitrogen Dioxide

Screening values were available for 1-hour, 24-hour, and annual averaging periods for nitrogen dioxide. The exceedances are summarized below, followed by a discussion of the critical effects upon which the screening values were based and an overall conclusion related to whether nitrogen dioxide was ultimately retained for further evaluation in the ERA.

Summary of Exceedances at Human/Ecological Locations

- 1-hour: Exceedances during all project phases; however, the maximum 1-hour NO_2 concentration is during the decommissioning phase. The camp worker location (Risk3) had a predicted max 1-hour NO_2 concentration during decommissioning of 355 µg/m^3, which exceeds its screening value from the CAAQS of 79 µg/m^3. Exceedances at the camp worker location were noted for a maximum of 5.6% of the year (decommissioning), which corresponds to 494 hours out of 8760 hours in a year. Exceedances were also noted for 1-hour NO_2 at the fenceline for 0.3% of the year (for approximately 28 hours per year during construction and operation), although concentrations at the fenceline were lower than at the camp worker location.

- There were no exceedances of the 24-hour or annual screening values at any human or ecological locations for any Project phase.

Health/Environmental Effect(s) for Short-term and Long-term Exposures

- Long-term (annual): As noted, there are no predicted exceedances of annual screening values at any receptor location during all Project phases; therefore, no long-term effects are expected.

- Short-term (1-hour, 24-hour): There are no predicted exceedances of 24-hr screening values at any receptor location during all Project phases; however, there are infrequent predicted exceedances of 1-hr NO_2 at the camp worker location and the fenceline. There are no exceedances at other receptor locations.

To put the exceedances of NO_2 into context, hazard quotients (HQ) for all receptors have been calculated using the 1-hr and annual CAAQSs as the toxicity reference values (see Table 3-12). HQs above 1 require further discussion. As shown in Table 3-12, HQs are below 1 for long-term NO_2 exposure at all receptor locations, and HQs exceed 1 for short-term 1-hr NO_2 exposure only for the on-site receptors (camp worker, on-site ecological location), and the fenceline receptor.

Potential adverse health effects that are attributed to short-term exposures to ambient nitrogen dioxide include asthma exacerbations and possibly increased risk of cardiopulmonary effects, and to a lesser extent cardiovascular and respiratory mortality (Health Canada, 2016b). Individuals with certain pre-existing diseases such as asthma appear to be sensitive to exposure to ambient NO_2. Although it has been suggested that there may not be a threshold for the health effects of NO_2 even considering short-term (1-hour) exposures (CCME, 2020), at least some reviews (e.g. (Hesterberg TW et al., 2009) do not support this assertion and rather support a 1-hour threshold. Hesterberg et al. (2009) completed a critical review of over 50 human clinical studies in which human volunteers (including sensitive sub-populations: the elderly, children, and asthmatics) were exposed to NO_2 at concentrations ranging from 0.1 to 3.5 ppm (equivalent to 188 to 6,580 µg/m^3 [1 ppm = 1880 µg/m^3) for periods of 30 minutes to 6 hours, often combined with exercise and co-pollutants. Their findings indicated that there is evidence of no-effect at low concentrations, and that a threshold of approximately 0.2 ppm (or 376 µg/m^3) is supported. The maximum predicted concentration of 1-hour NO_2 was 355 µg/m^3, which is less than the concentration protective for short-term exposures in asthmatics per Hesterberg et al. (2009). If sensitive individuals are present at the camp worker location or the fenceline during periods when ambient NO_2 concentrations exceed the screening value, it is possible that they could experience minor irritation of the respiratory system. These effects would be reversible and would subside after exposure.

Additionally, as reported in Health Canada (2016b), both the WHO and US EPA concluded that healthy individuals do not experience any adverse effects at concentrations up to 1 ppm (or 1880 µg/m^3), and as such would not be affected by short-term exposures to NO_2 at the concentrations predicted for the Project.

Conclusion

Overall, the predicted exceedance of the 1-hour short-term screening value for nitrogen dioxide at the camp worker location (Risk3) and the fenceline would be limited to a small percentage of the time, and any health effects would be reversible and would subside after exposure. The elevated predicted NO_2 concentrations are based on the conservative assumption that backup diesel generators will be used continuously to supply power to support site activities; however, it is anticipated that power will be obtained from the provincial grid during the Project phases. The backup diesel generators make up more than 85% of the NO_2 emission sources, with the remaining coming from vehicle/equipment combustion, propane heaters, and the ISR Plant stacks.

Other strategies to reduce NO_2 emissions will include planning vehicle and equipment routes, to minimize travel distances and limit idling, and employing standard operating procedures for equipment and machinery use, completing regular inspections of equipment machinery to make sure it is in good working order.

Denison has committed to NO_2 monitoring during all Project phases. Monitoring will include monthly collection using passive samplers, and will follow an adaptive management process to identify if (and when) more frequent monitoring would be needed.

Considering the above discussion, NO_2 was not considered for further assessment in the ERA.

Table 3-12: Predicated 1-hr and Annual NO_2 Concentrations at Receptor Locations during all Project Phases and Associated Hazard Quotients

		NO_2 1 hr Air Concentration (µg/m³)			NO_2 annual Air Concentration (µg/m³)		
Location	**Name**	**Construction**	**Operation**	**Decommissioning**	**Construction**	**Operation**	**Decommissioning**
On-Site Ecological Location	Risk1	**124.3**	**116.3**	**120.9**	8.3	4.4	7.1
Recreational Fisher/Trapper (LA1) - McGowan Lake	Risk2	43.0	40.2	41.6	4.7	4.0	4.6
Camp Worker	Risk3	**181.0**	**274.8**	**355.1**	17.1	11.3	16.4
Seasonal Resident (Russell Lake)	Risk4	22.9	24.0	22.7	4.0	3.8	4.0
Reference Receptor (LA-7)	Risk5	40.2	43.2	39.0	4.2	3.9	4.2
Fenceline	-	**176.5**	**177.7**	**177.7**	6.8	4.4	6.6
	CAAQS	**79.0**	**79.0**	**79.0**	**23.0**	**23.0**	**23.0**
		NO_2 1 hr Hazard Quotient			**NO_2 annual Hazard Quotient**		
Location	**Name**	**Construction**	**Operation**	**Decommissioning**	**Construction**	**Operation**	**Decommissioning**
On-Site Ecological Location	Risk1	**1.6**	**1.5**	**1.5**	0.4	0.2	0.3
Recreational Fisher/Trapper (LA1) - McGowan Lake	Risk2	0.5	0.5	0.5	0.2	0.2	0.2
Camp Worker	Risk3	**2.3**	**3.5**	**4.5**	0.7	0.5	0.7
Seasonal Resident (Russell Lake)	Risk4	0.3	0.3	0.3	0.2	0.2	0.2
Reference Receptor (LA-7)	Risk5	0.5	0.5	0.5	0.2	0.2	0.2
Fenceline	-	**2.2**	**2.2**	**2.2**	0.3	0.2	0.3

Notes:
Bold and shaded values indicate exceedance of the CAAQS. Hazard quotients greater than 1 are bold and shaded.
Air concentrations are obtained from EIS Section 6, Appendix 6-A.

3.2.1.3.2 Particulate Matter

Particulate matter is defined as liquid or solid particles, or a mixture of both, less than 100 µm in diameter. Particulate matter includes TSP, particulate matter less that 10 µm (PM_{10}), and particulate matter less than 2.5 µm ($PM_{2.5}$). Particulate matter in the form of TSP, PM_{10}, $PM_{2.5}$, and TSP deposition were screened. Screening values were based on 24-hour and annual averaging periods for TSP, and a 24-hour averaging period for PM_{10}. No exceedances of $PM_{2.5}$ are predicted.

3.2.1.3.2.1 Total Suspended Particulates

Screening values were available for 24-hour and annual averaging periods for TSP. The exceedances are summarized below, followed by a discussion of the critical effects upon which the screening values were based and an overall conclusion related to whether TSP was ultimately retained for further evaluation in the ERA.

<u>Summary of Exceedances at Human/Ecological Locations</u>

- 24-hour: During the Construction, Operation and Decommissioning phases of the project, the camp worker location (Risk3) had predicted 24-hour TSP concentrations that exceeded the screening value. Compared to the 24-hour TSP screening value of 100 µg/m^3, concentrations ranged up to 286 µg/m^3 during Construction, 124 µg/m^3 during Operation, and 135 µg/m^3 during Decommissioning. The frequency of exceedance ranged from 30% during Construction, to 2.2% and 1.6% for Operation and Decommissioning, respectively.

- There were no exceedances of the annual screening value at any human or ecological locations for any phase of the project.

<u>Summary of Exceedances at the Fenceline</u>

- 24-hour: During the Construction, Operation and Decommissioning phases of the project, 24-hour TSP concentrations were predicted to exceed the screening value at the fenceline. Compared to the 24-hour TSP screening value of 100 µg/m^3, concentrations ranged up to 313 µg/m^3 during Construction, 281 µg/m^3 during Operation, and 115 µg/m^3 during Decommissioning. The frequency of exceedance ranged from 29% during Construction and 22% during Operation, to 0.5% for Decommissioning.

<u>Health/Environmental Effect(s) for Short-term and Long-term Exposures</u>

- The 24-hour screening value of 100 µg/m^3 for TSP is an ambient air quality standard cited by both Saskatchewan and Alberta. The 24-hour ambient air quality objective is based on potential adverse pulmonary effects (Alberta, 2021). A higher 24-hour effects-based screening value of 120 µg/m^3 for TSP in ambient air is available from Ontario. The Ontario 24-hour and annual ambient air quality criteria (OAAQC) are meant to be protective of chronic effects. Ontario identifies visibility as the sensitive endpoint for the TSP OAAQC rather than human or ecological health. Elevated TSP concentrations are generally not considered to pose significant health risks because these particles are too large to be inhaled deep into the lungs; therefore, TSP was not considered for further assessment in the ERA.

<u>Discussion and Conclusion</u>

As described above, TSP particles are too large to be inhaled deep into the lungs and the air quality objectives for TSP are generally based on an aesthetic endpoint (visibility) rather than a health endpoint. As such, TSP was not considered further in the ERA.

3.2.1.3.2.2 Fine Particulate Matter (PM_{10})

Screening values were available for the 24-hour averaging period for PM_{10}.

<u>Summary of Exceedances at Human/Ecological Locations</u>

- 24-hour: During the Construction, Operation and Decommissioning phases of the project, the camp worker location (Risk3) had predicted 24-hour PM_{10} concentrations that exceeded the screening value. Compared to the 24-hour PM_{10} screening value of 50 µg/m^3, concentrations ranged up to 136 µg/m^3 during Construction, 57.0 µg/m^3 during Operation, and 61.1 µg/m^3 during Decommissioning. The frequency of exceedance ranged from 21% during Construction, to 1.1% and 1.6% for Operation and Decommissioning, respectively.

<u>Summary of Exceedances at the Fenceline</u>

- 24-hour: During the Construction and Operation phases of the project, 24-hour PM_{10} concentrations had predicted concentrations exceeding the screening value at the fenceline. Compared to the 24-hour TSP screening value of 50 µg/m^3, concentrations ranged up to 116 µg/m^3 during Construction and 104 µg/m^3 during Operation. The frequency of exceedance ranged from 17% during Construction to 12% for Operation.

<u>Health/Environmental Effect(s) for Short-term and Long-term Exposures</u>

- Human health has been shown to be the most sensitive receptor for exposure to PM_{10} in ambient air (Health Canada, 1998). Exposure to elevated concentrations of PM_{10} are associated with various respiratory and cardiovascular effects in humans. The finer particles that can be inhaled deeply into the lungs (i.e., $PM_{2.5}$) are associated with greater risk because they are more chemically active and have more complex characteristics than larger particles (Health Canada, 2016c). For example, WHO has derived its particulate matter guidelines on $PM_{2.5}$, and its guidelines for PM_{10}, assuming that 50% of PM_{10} is present as $PM_{2.5}$ (i.e., the criteria for $PM_{2.5}$ are multiplied by 2)(WHO, 2006). If individuals are present during short-term periods of elevated PM_{10} and/or $PM_{2.5}$, they may experience respiratory symptoms such as coughing or difficulty breathing, or asthma symptoms and chronic bronchitis. For most individuals, effects would be reversible and would subside after exposure.

<u>Discussion and Conclusion</u>

Overall, exceedances of the 24-hour short-term screening values for PM_{10} were identified at the camp worker location during Construction, Operation and Decommissioning, with infrequent exceedances occurring during Operation and Decommissioning. Exceedances of the 24-hour short-term screening values were also identified at the fenceline during Construction and Operation. There were no exceedances of $PM_{2.5}$ which is generally considered to be a more reliable indicator of potential health effects. However, health effects would be infrequent and reversible, subsiding after exposure; therefore, PM_{10} was not considered for further quantitative assessment in the ERA.

3.2.1.3.3 Uranium

<u>Summary of Exceedances at Human/Ecological Locations</u>

- 24-hour: During the Operation phase, the on-site ecological location (Risk1) and the camp worker location (risk3) both had predicted 24-hour uranium concentrations that exceeded the screening value. Compared to the 24-hour screening value of 0.15 µg/m^3, concentrations ranged up to 0.26 µg/m^3 at the on-site ecological location and 0.208 µg/m^3 at the camp worker location, with the frequency of exceedance at 4.7% and 2.2%, respectively. The published 24-hour criterion for uranium is converted from the annual criterion to allow for assessment of the 24-hour data.

- Annual: During the Operation phase, the on-site ecological location (Risk 1) had a predicted annual uranium concentration of 0.0345 µg/m^3 which slightly exceeds its screening value of 0.03 µg/m^3.

Summary of Exceedances at the Fenceline

- 24-hour: During the Operation phase, the fenceline had predicted 24-hour uranium concentrations that exceeded the screening value. Compared to the 24-hour screening value of 0.15 µg/m^3, concentrations ranged up to 0.223 µg/m^3 with a frequency of exceedance of 0.8%.

Health/Environmental Effect(s) for Short-term and Long-term Exposures

- Uranium can be toxic to humans due to its chemical and radiological properties. The ambient air quality criteria for uranium (Ontario MOE, 2011) are based on non-radiological effects; kidney toxicity was the most sensitive endpoint associated with chronic exposure to uranium in air.

Discussion and Conclusion

The health effects associated with uranium (kidney toxicity) are linked to chronic exposures. However, there were no exceedances of the annual screening value at any potential human receptor location. Exceedances of the short-term, 24-hour screening value were identified at the camp worker location (Risk3) and the fenceline. However, these exceedances were infrequent, and as such uranium was not retained for further consideration in the ERA.

Uranium concentrations exceeded both the 24-hour and annual screening values at the on-site ecological location (Risk1). Given its exceedance of an annual screening value and that uranium is a metal and persistent in the environment, there is the potential that long-term generation of uranium in dust may contribute to deposition onto soil and subsequent uptake into the food chain. This pathway was assessed in Section 3.2.1.5 related to the screening of COPCs in soil.

3.2.1.4 Constituents of Potential Concern in Air

There were no non-radiological COPCs identified for further quantitative assessment in the air pathway. The secondary screening of NO_2, PM_{10} and uranium indicated that although there are exceedances of air quality screening values, these constituents are unlikely to be associated with a human health or environmental risk and as such were not carried forward as COPCs in air.

The only COPCs identified for air include radionuclides and radon due to public interest and not due to exceeding a screening value.

3.2.1.5 Constituents of Potential Concern in Soil

No specific COPCs were retained from the screening of atmospheric constituents; however, as a secondary check, mine-related metals which could potentially partition from air to soil were further assessed in terms of concentration in soil (Table 3-13).

The soil type selected for modeling of deposition to soil is sandy soil, consistent with baseline studies that describe sandy and gravelly Podzols, Brunisols, and Luvisols occurring on till materials, while sand and sandy loam Brunisols have developed on glaciofluvial deposits (Omnia, 2020).

Predicted soil concentrations were estimated from atmospheric deposition, using the maximum air concentrations at the on-site ecological receptor location (Table 3-14), along with constituent-specific deposition rates, according to the equations defined in the IMPACT Model Report (Appendix A, Section 2.3.4, Terrestrial Pathways). The on-site ecological receptor location has the highest concentration of metals in air compared to other locations assessed, and represents a worst-case location for deposition modelling.

Predicted maximum concentrations of constituents in soil from atmospheric deposition were compared against soil quality guidelines. The selected soil quality guidelines were the federal CCME (CCME, 1999b) soil quality guidelines for protection of human health and environmental health. Agricultural soil quality values were used, because these guidelines account for soil to plant uptake and ingestion of plants by birds and mammals. As shown in Table 3-13, all predicted soil concentrations were below the CCME soil quality guidelines. As such, no additional COPCs were identified for further quantitative assessment in the ERA based on the soil pathway. However, considering the multi-media pathways analysis, all terrestrial pathways (other than air inhalation) were considered further for the COPCs identified in the aquatic environment.

A summary of the maximum modelled concentrations at human and ecological receptor locations of interest is shown in Table 3-14.

Table 3-13: Soil Quality Screening for the Wheeler River ERA

Parameter	Maximum Predicted Air Concentrations [(a)]	Maximum Predicted Soil Concentration from Atmospheric Deposition[(b)]	Soil Screening Guideline[(c)]				Is Concentration Greater than Selected Screening Value? (Y/N)
			Agricultural	Residential/ Parkland	Commercial	Industrial	
Non-radionuclides	**µg/m³**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	
Arsenic	7.12E-04	0.62	**12**	12	12	12	N
Cadmium	7.75E-05	0.36	**1.4**	10	22	22	N
Chromium	1.93E-04	3.31	**64**	64	87	87	N
Cobalt	7.22E-04	0.27	**40**	50	300	300	N
Copper	6.38E-02	1.51	**63**	63	91	91	N
Lead	3.89E-03	2.98	**70**	140	260	600	N
Molybdenum	7.34E-04	0.12	**5**	10	40	40	N
Nickel	4.41E-04	1.00	**45**	45	89	89	N
Selenium	1.61E-04	0.11	**1**	1	2.9	2.9	N
Uranium	3.45E-02	2.89	**23**	23	33	300	N
Vanadium	1.51E-03	4.82	**130**	130	130	130	N
Zinc	2.16E-01	5.33	**250**	250	410	410	N

Bold indicates soil guideline value selected for this assessment.
a) Maximum annual average concentrations out of all human/ecological receptor locations from CALPUFF (EIS Section 6).
b) Maximum soil concentrations estimated from maximum annual air concentrations in Table 3-14 of the HHRA and constituent-specific deposition rates in IMPACT.
c) (CCME, 1999b)
N = no; Y = yes; dw = dry weight.

Table 3-14: Maximum Concentration of COPCs in Air and Soil – Project Phases

Environmental Media	Location	Maximum Concentration of Non-radionuclides during Project Phases										
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Zinc
Air (mg/m³)	Reference Location	7.00E-07	7.44E-08	n/a	7.07E-07	1.49E-07	6.30E-05	7.19E-07	n/a	1.54E-07	6.00E-07	2.16E-04
	Camp Location	7.05E-07	7.58E-08	n/a	7.14E-07	1.68E-07	6.33E-05	7.25E-07	n/a	1.57E-07	1.77E-05	2.16E-04
	Ecological On-site	7.12E-07	7.75E-08	n/a	7.22E-07	1.93E-07	6.38E-05	7.34E-07	n/a	1.61E-07	3.45E-05	2.16E-04
	McGowan Lake	7.01E-07	7.49E-08	n/a	7.09E-07	1.56E-07	6.31E-05	7.20E-07	n/a	1.55E-07	6.65E-06	2.16E-04
	Russell Lake Inlet	7.00E-07	7.45E-08	n/a	7.07E-07	1.50E-07	6.30E-05	7.19E-07	n/a	1.54E-07	1.79E-06	2.16E-04
Soil (mg/kg dw)	Reference Location	6.16E-01	3.61E-01	n/a	2.65E-01	3.31E+00	1.46E+00	1.15E-01	n/a	1.07E-01	3.82E-01	5.31E+00
	Camp Location	6.16E-01	3.61E-01	n/a	2.66E-01	3.31E+00	1.48E+00	1.15E-01	n/a	1.07E-01	1.68E+00	5.32E+00
	Ecological On-site	6.16E-01	3.61E-01	n/a	2.67E-01	3.31E+00	1.51E+00	1.15E-01	n/a	1.08E-01	2.89E+00	5.33E+00
	McGowan Lake	6.16E-01	3.61E-01	n/a	2.65E-01	3.31E+00	1.46E+00	1.15E-01	n/a	1.07E-01	8.30E-01	5.31E+00
	Russell Lake Inlet	6.16E-01	3.61E-01	n/a	2.65E-01	3.31E+00	1.46E+00	1.15E-01	n/a	1.07E-01	4.70E-01	5.31E+00

Environmental Media	Location	Maximum Concentration of Radionuclides during Project Phases						
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Radon-222	Lead-210	Polonium-210
Air (Bq/m³)	Reference Location	7.41E-06	7.41E-06	n/a	n/a	0.00E+00	n/a	n/a
	Camp Location	2.19E-04	2.19E-04	n/a	n/a	1.24E+01	n/a	n/a
	Ecological On-site	4.26E-04	4.26E-04	n/a	n/a	3.61E+01	n/a	n/a
	McGowan Lake	8.22E-05	8.22E-05	n/a	n/a	2.50E+00	n/a	n/a
	Russell Lake Inlet	2.21E-05	2.21E-05	n/a	n/a	5.92E-01	n/a	n/a
Soil (Bq/kg dw)	Reference Location	4.72E+00	4.72E+00	2.00E+01	1.52E+01	n/a	7.29E+01	6.55E+01
	Camp Location	2.08E+01	2.08E+01	2.00E+01	1.52E+01	n/a	7.29E+01	6.55E+01
	Ecological On-site	3.57E+01	3.57E+01	2.00E+01	1.52E+01	n/a	7.29E+01	6.55E+01
	McGowan Lake	1.03E+01	1.03E+01	2.00E+01	1.52E+01	n/a	7.29E+01	6.55E+01
	Russell Lake Inlet	5.81E+00	5.81E+00	2.00E+01	1.52E+01	n/a	7.29E+01	6.55E+01

n/a = not applicable

3.3 Final List of Constituents of Potential Concern

Based on evaluation of aqueous and atmospheric sources, including a conservative screening of maximum predicted concentrations in surface water, sediment, air and soil, the final list of COPCs to be evaluated further in the HHRA and EcoRA is presented in Table 3-15.

No specific COPCs were identified in air for further quantitative assessment in the ERA; however, to be sure exposures were not underestimated in the multi-media pathways analysis, evaluation of potential human and ecological health risk via indirect exposures such as air to soil deposition, soil contact and exposure through the food chain was included for all COPCs identified in water.

Table 3-15: Final List of Constituents of Potential Concern for Wheeler River Environmental Risk Assessment

Major Ions	Physical Media where Guideline Exceeded
Chloride	Water
Sulphate	Water
Metals and Metalloids	
Arsenic	Water
Cadmium	Water
Chromium	Water
Cobalt	Water
Copper	Water
Molybdenum	Water, Sediment
Selenium	Water, Sediment
Uranium	Water
Vanadium	Sediment
Zinc	Water
Radionuclides	
Uranium-238	All pathways (based on public concern)
Uranium-234	All pathways (based on public concern)
Thorium-230	All pathways (based on public concern)
Radium-226	All pathways (based on public concern)
Radon-222	Air only
Lead-210	All pathways (based on public concern)
Polonium-210	All pathways (based on public concern)

COPC = constituent of potential concern.

4.0 Human Health Risk Assessment

The components of a human health risk assessment (HHRA) include: Problem Formulation (Section 4.1); Exposure Assessment (Section 4.2); Toxicity Assessment (Section 4.3); and Risk Characterization (Section 4.4).

4.1 Problem Formulation

The intent of the problem formulation for an HHRA is to define the goals of the risk assessment, develop an understanding of site conditions, and develop working hypotheses as to how potential exposure of people to constituents may result in potential risks to human health. The assessment endpoint of interest for the HHRA is the health of individual humans.

The problem formulation for this HHRA:

- Identifies COPCs for human health risks;
- Identifies and characterizes non-nuclear energy workers and other members of the public who may frequent the site, and the human health receptor groups that represent them in the ERA; and
- Identifies the complete exposure pathways by which the COPCs may affect the human health receptors in a conceptual site model.

The conceptual site model for the HHRA summarizes the links between constituent sources, exposure pathways, and receptors of concern.

4.1.1 Indigenous and Local Knowledge

Indigenous and Local Knowledge was used to inform assumptions for human health receptors (i.e., people) who consume Traditional Foods in terms of their locations, residency times, components, and quantities of the Traditional Foods diet.

The following studies and reports were reviewed to inform assumptions:

- Kineepik Métis Local (KML) and Northern Village of Pinehouse Lake (NVP). 2022a. Kineepik Métis Local #9 Kineepik Valued Ecosystem Components. KML Pre-statement for Denison EIS (KML and NVP, 2022a).
- Kineepik Métis Local and Northern Village of Pinehouse Lake. 2022b. Response to the Environment Impact Assessment. For the Proposed Ministry of Highways 914 Extension Project. Submitted February 11, 2022 (KML and NVP, 2022b).
- English River First Nation (ERFN) and Shared Value Solutions (SVS). 2022a. Wheeler River Project – Summary of Health and Socio-Economy Study Results – English River First Nation. Shared Value Solutions. Prepared for English River First Nation. March 2022 (ERFN and SVS, 2022a).

- English River First Nation and Shared Value Solutions. 2022b. Wheeler River Project – Summary of Traditional Knowledge Study Results – English River First Nation. Shared Value Solutions. Prepared for English River First Nation. March 2022 (ERFN and SVS, 2022b).

- CanNorth. 2017. English River First Nation Country Foods Study – Final Report (Project No. 2147). Canada North Environmental Services Limited Partnership (CanNorth, 2017).

- English River First Nation. 2011. English River First Nation, Aboriginal Traditional Knowledge Summary Report. Compiled by Environment Canada, September 2011 (ERFN, 2011).

- Ya'thi Néné Lands and Resources Office (YNLRO). 2022. An Exploration of Recorded Athabasca Denesųłine Traditional Knowledge, Land Use, and Occupancy Study in the Vicinity of Denison Mines Wheeler River Project. March 2022 (YNLRO, 2022).

A number of these studies including YNLRO (2022), ERFN and SVS (2022a, 2022b), and CanNorth (2017) provided guidance for identifying locations where people may reside, areas where traditional foods are hunted, fished, and gathered, and mammal, bird, and plant species that are traditionally used by local Indigenous communities for food, medicine, and other traditional uses. Additionally, available land use maps and information about local cabin locations was used to inform receptor locations as well as receptor types, and specific engagement activities (e.g., formal and informal engagement meetings with one or more community members) were used to better incorporate LK into the assessment of human health. Other sources of engagement included:

- Key Person Interview Program (KPI Program). 2018. ERFN Patuanak Reserve workshop conducted by Denison Mines. May 3, 2018 (KPI Program, 2018).

- Key Person Interview Program (KPI Program). 2019. Interview with the English River First Nation trapper conducted by Denison Mines. October 29, 2019. Notes finalized January 2, 2020 (KPI Program, 2019).

- Key Person Interview Program (KPI Program). 2020. Cabin owner survey conducted by Denison Mines. February 14–24, 2020 (KPI Program, 2020).

Information regarding IK and LK was primarily available for two Indigenous communities:

- English River First Nation; and

- Kineepik Métis Local 9.

4.1.2 Human Receptor Selection and Characterization

The human receptors for the HHRA were selected and characterized to represent potential exposures from both radiological and non-radiological COPCs. Human receptors would potentially be exposed to low levels of airborne or waterborne constituents being released during Project activities.

Nuclear Energy Workers (NEWs) and other workers on-Site (ISR mine and processing plant) are not addressed for the radiological assessment because their radiation exposure is monitored and their doses are controlled through a Radiation Protection Program. They are protected from non-radiological exposures through the Health and Safety Program. However, workers at the Denison Mine Camp (non-NEWs) will be assessed for both radiological and non-radiological exposures. This approach is consistent with CSA N288.6-22 (CSA, 2022) .

Recreational land users (fishers, hunters, firewood gatherers) and seasonal residents (visitors and lodge operators) may be present in the LSA and RSA for part of the year. The presence of industrial leases in the LSA and RSA suggest that workers may be present within the study area. The non-NEW workers at the Denison Mine residing part of the year at Denison's camp would be subject to the highest levels of exposures to COPCs from the operation given their close proximity to the source.

No permanent communities or residences have been identified within the LSA and RSA. Although it is not expected that individuals are present who harvest traditional foods from the area for subsistence on a permanent basis, individuals who hunt and/or fish are known to use the area and depend on a higher proportion of country foods in their diet than the general regional population. Therefore, an adult fisher/trapper receptor has been included in the assessment during all Project phases. The residency and dietary assumptions for the fisher/trapper, and for the recreational fisher/hunter, have been developed through engagement with communities during the EA process.

For the purposes of the assessment, a future permanent resident has been included as a conservative assumption that would cover off other types of receptors for post-decommissioning.

Human receptors are assumed to be in the project area during all phases of the project, with the exception of the Camp Worker which will be replaced by a Permanent Resident during the future centuries after all Project phases.

In summary, human receptors for the Project include:

- camp worker during all Project phases;
- seasonal resident during all Project phases;
- recreational fisher/hunter during all Project phases;
- fisher/trapper during all Project phases; and,
- future permanent resident in the future centuries.

During Post-Decommissioning, the Project area could be accessed intermittently by members of the public for various land use purposes. Any risks to these members of the public would be less than those assessed for the camp worker and therefore additional on-site receptors were not assessed during Post-Decommissioning.

4.1.2.1 Camp Worker

The camp worker is a non-NEW worker such as a camp cook. A camp worker is an adult male or female. This receptor group is assumed to work and reside at the Denison camp for 50% of the year and away from the site for the other 50% of the year, based on a two-weeks in and two-weeks out schedule. The camp worker would be present during construction, operation, decommissioning and post-decommissioning phases.

It is assumed that a camp worker will occasionally consume traditional foods and will hunt, fish or gather berries/plants in the area during operation. Drinking water and water for bathing would be obtained from local groundwater and surface water sources. A camp worker could come in direct contact with surface water through swimming, and with sediments through activities such as wading. Finally, a camp worker would be exposed to project related COPCs through inhalation of air and dermal contact with and/or incidental ingestion of dust deposited to soil.

4.1.2.2 Seasonal Resident

Seasonal residents are adults and one-year-olds (male and female), who would visit and reside in the area for part of the year, every year, during all project phases. Their residence during that time would be at the nearest reasonable location to the site. As indicated in Section 2.3, potential recreational leases occur at Russell Lake, McGowan Lake and Whitefish Lake North, with the majority surrounding Russell Lake (Denison, 2019), and traditional land use within the LSA and RSA also includes camping near Russell Lake. Therefore, the nearest reasonable location to the site for seasonal residents could be Russell Lake. The seasonal residents may be assumed to reside at a lodge on Russell Lake for three months of the year during the tourist season, or approximately 30% of the year.

While at Russell Lake, seasonal residents may ingest local country foods fished, hunted and gathered in the vicinity of Russell Lake as part of their diet while residing in the area. While at the lodge, water for drinking, bathing and swimming would be obtained from Russell Lake. The seasonal resident could come in contact with the surface water of Russell Lake while swimming, and with sediments during the practice of activities such as wading. Finally, a seasonal resident may be exposed to project related COPCs through inhalation of air and dermal contact and/or incidental ingestion of dust deposited to soil.

4.1.2.3 Recreational Fisher/Hunter

Recreational fishers/hunters are adults, male and female, who would visit and reside in the area for part of the year, every year, during all project phases. Traditional land uses that have been identified from available Traditional Land Use studies include hunting (large game and game birds), fishing, and firewood gathering. The traditional land use activities closest to the Project site are reported to occur in the Russell Lake area. Land use activities have also been reported further west, outside the RSA, near the MacIntyre Lake and Holgar Lake areas, which are representative of background environmental conditions. These regions have also been identified as overnight tent sites (ERFN and SVS, 2022b; YNLRO, 2022). Additionally, a potential recreational lease has been identified at McGowan Lake. A survey conducted by Denison determined a number of cabins used by local residents for recreational and outfitting/guiding purposes (KPI Program, 2020).

Traditional land use studies of the region around the Project site identified two camps considered by local Indigenous groups to be important locations for the facilitation of traditional land-based activities and Indigenous Knowledge transfer. These camps include:

- The ERFN culture camp, located approximately 85 km southwest of Russell Lake. This camp is an area where recreational activities occur, in addition to youth education activities, traditional Indigenous games and activities, and contemporary gathering.

- The Kineepik Metis (Pinehouse) camp, located approximately 67 km north of the village of Pinehouse. This camp is situated in an area where hunting, fishing and harvesting of country foods is commonly reportedly.

The two camps are situated well beyond the boundaries of the RSA; therefore, it is expected that the recreational fisher/hunter receptor will represent a highly conservative assessment of potential risk for Indigenous peoples engaging in traditional land-based activities at these culturally-significant camp sites.

Recreational fishers/hunters may ingest local country foods fished, hunted and gathered at and near Russell Lake or McGowan Lake; therefore, two recreational fishers/hunters were identified – one at McGowan Lake and one at Russell Lake.

They may also conserve local country foods collected from the area for consumption with their family throughout the year; therefore, a one-year old is also assessed. While at the lodge, water for drinking, bathing and swimming would be obtained from Russell Lake or McGowan Lake. The recreational fisher/hunter may come in contact with surface waters of Russell Lake or McGowan Lake while swimming, and with sediments during the practice of activities such as wading. In comparison to a seasonal resident, a recreational fisher/hunter would spend approximately the same amount of time annually in the study area, but obtain a higher portion of local country foods in their overall annual diet from the study area. Finally, a recreational fisher/hunter may be exposed to project related COPCs through inhalation of air and dermal contact and/or incidental ingestion of dust deposited to soil. The recreational fishers/hunters are assumed to reside at the exposure locations for approximately 30% of the year, as indicated in Table 4-2 in Section 4.2.1.

The Wheeler River is considered both culturally and economically important to ERFN, and is an area where traditional land activities such as hunting, fishing and trapping occur year-round.

Members of ERFN have expressed the importance of protecting the area and managing impacts to the environment to protect the ability for Indigenous residents to continue to engage in traditional land activities (ERFN and SVS, 2022a). The recreational fisher/hunter receptor is expected to adequately represent the traditional land uses identified in the Traditional Land Use studies, and to capture any potential risk to local Indigenous and non-Indigenous hunters and fishers.

4.1.2.4 Fisher/Trapper

The adult fisher/trapper represents a member of the public who lives in the region year-round and regularly consumes local country foods and water. The fisher/trapper will be assessed for all project phases. Assumptions made about the fisher/trapper receptor were formed following consultation with local Indigenous community members. Denison recognizes that ERFN considers the fisher/trapper's use of the area as representative of current and future land users and expects that their relationship to the Project Area will be continued and strengthened through generations of future use.

The residency characteristics of the fisher/trapper have been developed from resource use information collected from a local trapper. The local fisher/trapper had:

- A primary cabin along the Wheeler River upstream of its confluence with Moon Creek at Bobby's Pond (represented by Reference conditions);
- A secondary cabin at Russell Lake (which is downstream of the Icelander Creek drainage and represents a far-field exposure location); and,
- Two other minor residences away from the Project area (represented by Reference conditions).

For assessment purposes, it is assumed that the fisher/trapper spends 6 months of the year at a primary residence (a reference location) and the other 6 months of the year at a secondary residence on Russell Lake. Subsistence hunting is assumed to occur while at both cabin locations. While at the Russell Lake cabin, the fisher/trapper is assumed to hunt mallard ducks as indicated by the resource use information. In contrast to the resource use information which suggests that subsistence fishing would occur at multiple locations including Russell Lake and reference lakes in the Project area, it was conservatively assumed that 100% of the fish in the fisher/trapper's diet would be from the far-field exposure location at Russell Lake and no fish would be from the Reference location.

In comparison to the other adult human receptor groups, the fisher/trapper consumes a greater proportion of country game and fish in his diet annually. The fisher/trapper is assumed to consume local country foods and store foods in equal proportions on an annual basis. Country game meats and fish sources are assumed to be equally distributed in the diet, each representing approximately 25% of the annual diet based on fresh weight.

Similar to the recreational fisher/hunter, the fisher/trapper receptor is expected to sufficiently represent the traditional land uses recognized in the Traditional Land Use studies, and to capture any potential risk to local Indigenous community members who live in the region year-round, regularly partake in land-based traditional activities, and frequently consume a higher proportion of traditional foods in their diet.

4.1.2.5 Future Permanent Resident

The future permanent resident is a hypothetical adult and one-year-old (male or female) who would reside full time at the Denison camp site after the post-decommissioning phase has been fully implemented, during the future centuries. Currently, there are no permanent residents or communities within 150 km of the Project Area.

Permanent residents would have a diet similar to that of the seasonal resident and the recreational fisher but would ingest a high proportion of local country foods fished, hunted and gathered in the area because of their full-time residency in the Project area. Local country foods would likely be sourced from drainages affected and not affected by the former operation. Drinking water and water for bathing would be obtained from a local surface water source, such as Whitefish Lake Middle and Whitefish Lake South. A permanent resident could come in direct contact with surface water through swimming, and with sediments through the practice of activities such as wading. It is anticipated that a permanent resident would not be exposed to project related COPCs through inhalation of air after decommissioning; however, they could be exposed by dermal contact and/or incidental ingestion of dust deposited to soil for some time after decommissioning. Assumptions for a permanent resident after decommissioning should be refined near the time of decommissioning with community input where possible.

4.1.3 Selection of Chemical, Radiological, and Other Stressors

The selection of COPCs retained for the HHRA is presented in Section 3.0 of this report. The selection of chemical stressors to be evaluated in the HHRA followed a tiered screening approach to reduce the risk of overlooking Project-related COPCs relevant to human health that would be emitted through water and air.

The screening involved a conservative process of comparing the expected treated effluent quality against the selected water quality guidelines protective of human health (refer to Table 3-1 in Section 3.0). While chloride and sulphate were identified as COPCs for further assessment in the ERA, they are not considered further in the HHRA. These COPCs are associated with water ingestion. Chloride does not have a drinking water standard and is not considered to present a risk to human health at concentrations found in drinking water or at concentrations predicted for Whitefish Lake (LA-5). Sulphate in drinking water is associated with adverse physiological effects such as diarrhoea or dehydration at concentrations above 500 mg/L. The predicted maximum concentration of sulphate in LA-5 is 58 mg/L (Table 3-3), which is below 500 mg/L; therefore, concentrations at exposure points farther downstream would be less than those associated with adverse physiological effects. For these reasons, chloride and sulphate were not assessed further in the HHRA.

No formal screening was conducted for radionuclides. However, since radiation dose to human receptors is of public and regulatory interest, the radionuclides in the uranium-238 decay series are carried forward as COPCs for further assessment.

No specific COPCs were identified in air for further quantitative assessment in the ERA; however, to be sure exposures were not underestimated in the multi-media pathways analysis, evaluation of potential human health risk via indirect exposures such as air to soil deposition, soil contact and exposure through the food chain was included for all COPCs identified in water. Exposure to constituents that may deposit from air to surface water was not considered, as that pathway is considered negligible according to CSA N288.1-20.

4.1.4 Selection of Exposure Pathways

The potential exposure pathways are expected to be the same for most human receptors. Exposure pathways for human receptors are summarized in Table 4-1.

Table 4-1: Summary of Human Health Exposure Pathways

Human Receptor Group	Environmental Exposure Pathway				
	Air	Soil	Water	Sediment	Traditional Foods
Camp Worker	Inhalation[(a)]	Direct contact Incidental ingestion	Direct contact Ingestion	Direct contact Incidental ingestion	Ingestion
Seasonal Resident	Inhalation[(a)]	Direct contact Incidental ingestion	Direct contact Ingestion	Direct contact Incidental ingestion	Ingestion
Recreational Fisher/ Hunter	Inhalation[(a)]	Direct contact Incidental ingestion	Direct contact Ingestion	Direct contact Incidental ingestion	Ingestion
Fisher / Trapper	Inhalation[(a)]	Direct contact Incidental ingestion	Direct contact Ingestion	Direct contact Incidental ingestion	Ingestion
Future Permanent Resident	Incomplete Pathway	Direct contact Incidental ingestion	Direct contact Ingestion	Direct contact Incidental ingestion	Ingestion

Note:
(a) Inhalation pathway was only evaluated for radionuclides, as inhalation was not identified as a pathway of concern for non-radionuclides based on the atmospheric screening in Section 3.2.

4.1.4.1 Summary of Complete Exposure Pathways

Radiological and non-radiological exposure pathways were assessed in the HHRA. The primary exposure routes for human health included:

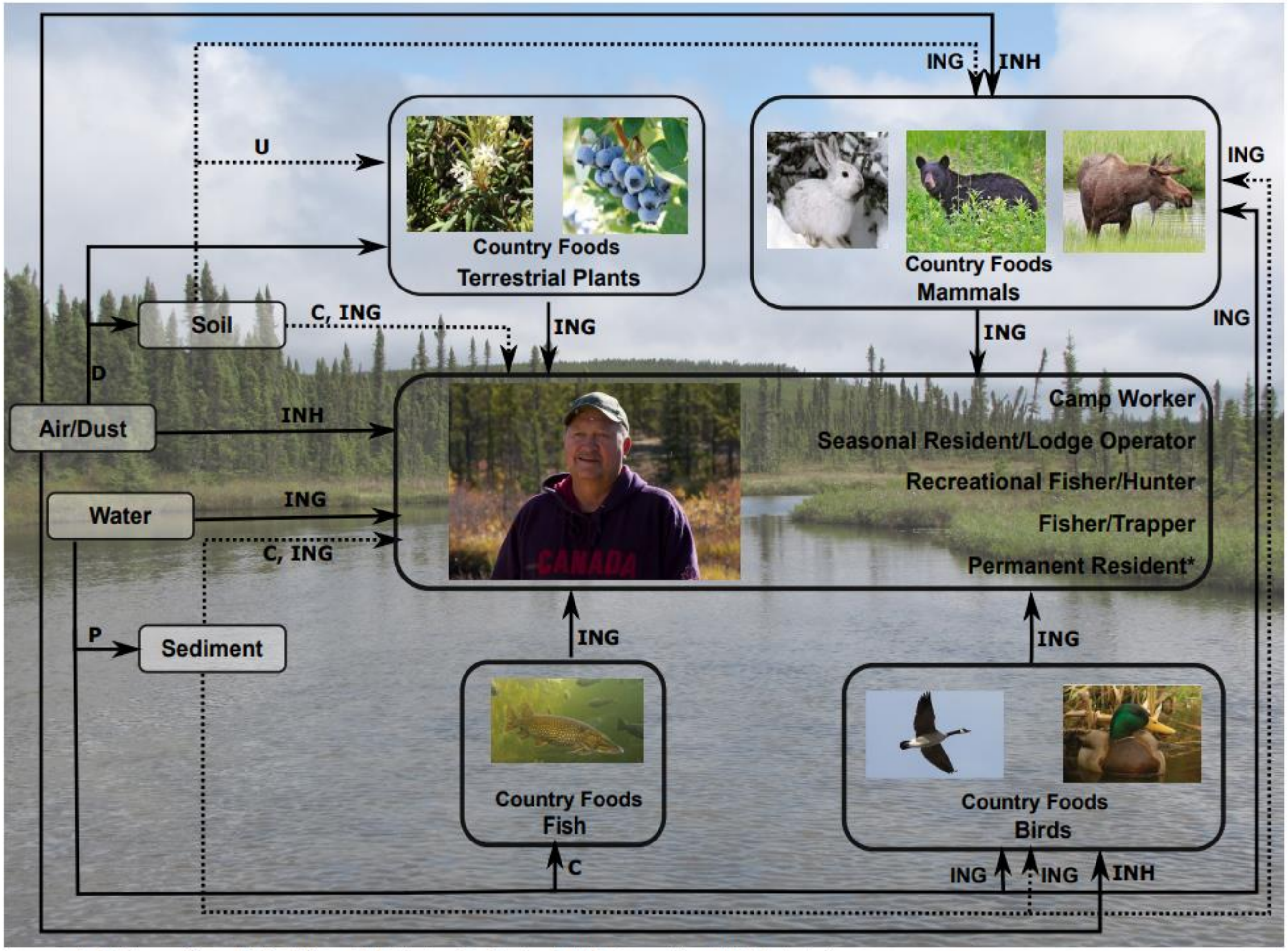
- Inhalation of airborne COPCs (outdoor air) for radionuclides only;

- Dermal contact with soil while gardening or harvesting;
- Ingestion of country foods (e.g., fish, vegetation, game), and ingestion of store-bought foods;
- Ingestion of surface water as drinking water and incidental ingestion during bathing and swimming;
- Incidental ingestion of soil (i.e., while harvesting) or sediment (i.e., while wading);
- Dermal contact with surface water and sediment while swimming or doing other recreational activities; and
- External exposure to radiation from air, water, soil, and sediment.

4.1.5 Human Health Conceptual Site Model

The human health conceptual model illustrates how receptors are exposed to COPCs. It represents the relationship between the source and receptors by identifying the source of constituents, the receptors, and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or for radionuclides, how they may exert effects from outside the body.

The complete exposure pathways for the human receptors that are considered in the HHRA are illustrated in Figure 4-1 below.



Legend: D: Deposition; **P:** Partition; **U:** Uptake; **C:** Contact; **ING:** Ingestion; **INH:** Inhalation;
⟶ Exposure pathway from primary media; ·······► Exposure pathway from secondary media.

* Human Receptors are assumed to be present during all project stages, except the Permanent Resident who is assumed to be present during future centuries.

Figure 4-1: Human Health Conceptual Site Model (CSM) for the Wheeler River Project

Note: Denison would like to gratefully acknowledge the contributions of Bobby John (shown in the centre of this image) to this EIS and extend a thank you to his family for granting permission to use his image herein.

4.1.6 Uncertainty in the Problem Formulation

The assumptions used to characterize human health receptors and develop the conceptual site model followed best industry practices and CSA guidance. Where possible, region-specific information was used to develop initial assumptions for human health receptor groups, locations and frequency, and duration of exposures. Communities and regulators were engaged in the process, which resulted in adjustments to the initial assumptions to better represent affected communities and increase conservatism in areas (such as the Traditional Foods diet) where regional information was scarce.

The selection of Project-related COPCs was based on comparing maximum predicted water, sediment, air, and soil concentrations at the human health receptor locations to relevant environmental guideline concentrations (i.e., screening values). Numerous conservative measures were integrated into the models used to predict COPC concentrations used in the screening process (refer to Appendix A for a discussion of the modelling used to inform the ERA). The predicted concentrations were compared to screening values protective of both human health and ecological biota. There is, therefore, a high level of confidence that the HHRA captures all Project-related COPCs that would be emitted by Project activities to water and air.

4.2 Exposure Assessment

The exposure assessment included identification of exposure locations and exposure factors for each receptor, presentation of exposure concentrations and doses (radiological and non-radiological), and discussion of uncertainties. This section presents at a high-level, the information used in the IMPACT model; however, the details of the model are included in Appendix A.

4.2.1 Exposure Locations, Duration, and Frequency

The selection of exposure locations for human receptors groups was based on current understanding of how people use the LSA and RSA, including Indigenous and Local Knowledge from land use maps, as well as the potential for exposure to Project-related media concentrations during one or more Project phases. Exposure locations are shown in Figure 4-2.

The residency assumptions for human receptors used for the human health risk assessment are summarized in Table 4-2. This includes the fraction of time the receptor spends at a given location as well as the exposure frequency (which refers to the frequency at which the activity causing the exposure occurs). The exposure duration (which refers to the length of time the receptor engages in the activity causing the exposure) was either the duration of the Project phases (30 years) for non-carcinogens, or the lifetime of the receptor (80 years) for carcinogens, except for the camp worker, where only the adult life stage would be relevant for carcinogens.

With the exception of the future permanent resident, all of the human receptors were assumed to spend part of their time away from the LSA and RSA at a location represented in the model by the reference location.

Table 4-2: Summary of Residency Assumptions for Human Health Receptor Groups

Human Health Receptor Group	Age Group(s)	Residence within Study Area	Project Phases	Fraction of Time at Residence/ Reference Location	Exposure Frequency at Residence/Refence Location (months/year)
Camp Worker (such as a cook)	Adult	Whitefish Lake (LA-5)	Construction Operation Decommissioning Post-decommissioning	0.5/0.5	6/6
Recreational Fisher/Hunter	Adult and one-year-old	McGowan Lake (LA-1) Russell Lake	Construction Operation Decommissioning Post-decommissioning Future centuries	0.3/0.7	4/8
Seasonal Resident	Adult and one-year-old	Russell Lake			
Fisher/Trapper	Adult	Russell Lake		0.5/0.5	6/6
Future Permanent Resident	Adult and one-year-old	Whitefish Lake (LA-5)	Future centuries	1	12

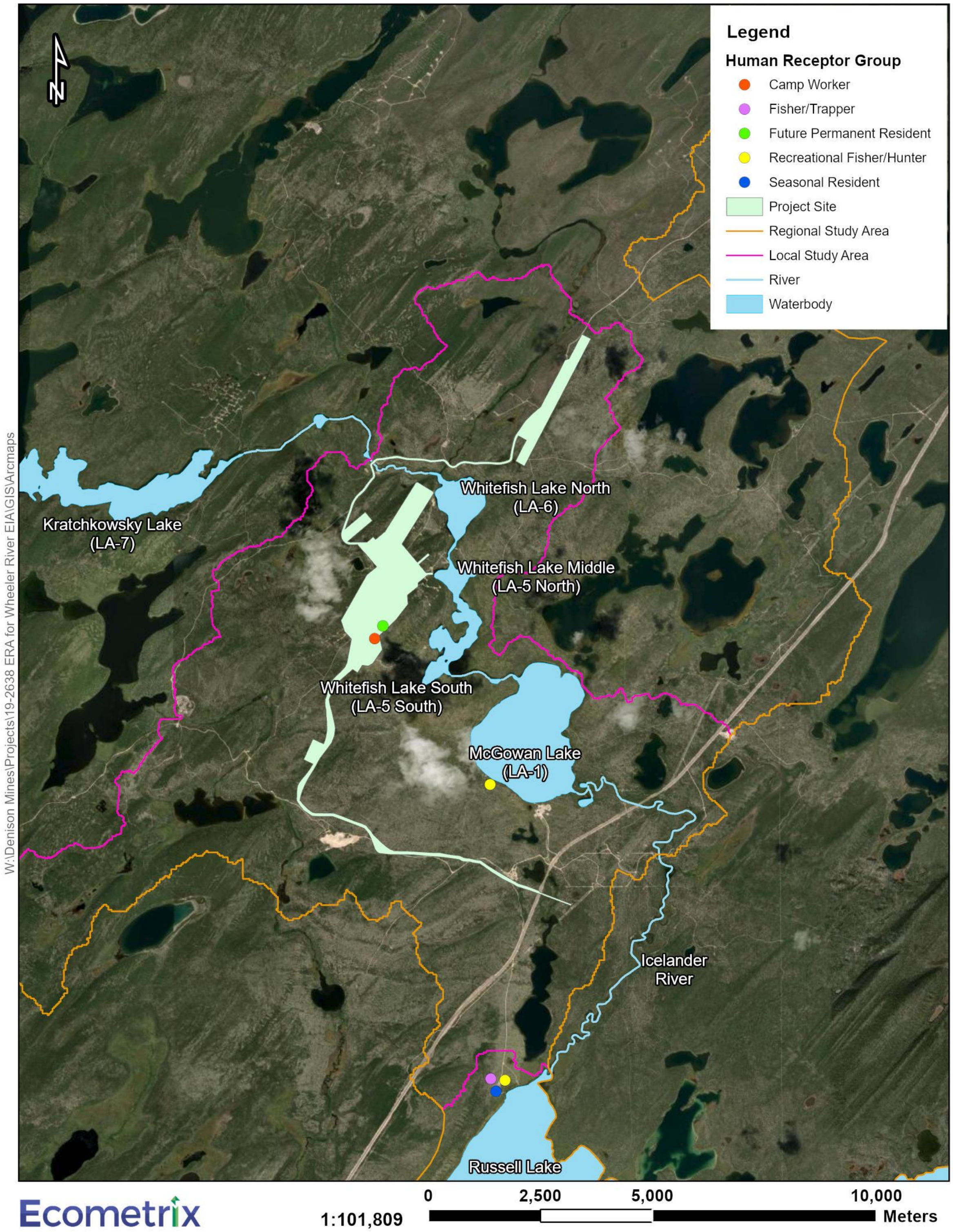


Figure 4-2: Human Receptor Locations for the Wheeler River HHRA

4.2.2 Exposure and Dose Calculations

Exposure and dose calculations for human receptors were completed using IMPACT version 5.6.0. IMPACT is consistent with the COPC transport equations and radiological dose calculations outlined in CSA N288.1-20. Equations used for non-radiological dose calculations are consistent with CSA N288.6-22, which have generally been obtained from Health Canada guidance.

The equations are outlined in the Wheeler River IMPACT Model Report, in Appendix A.

4.2.3 Exposure Factors

Exposure estimates rely on several COPC- and media-specific exposure factors for the dose calculations. These parameters include body characteristics and intake rates as well as exposure duration and frequency (Section 4.2.1, Exposure Locations, Durations, and Frequency) and dose coefficients.

Exposure factors are outlined in detail in the IMPACT Model Report for the Wheeler River Project, Appendix A. Exposure factors including inhalation rates, water, sediment and soil ingestion rates and total food ingestion rates were generally mean values from CSA N288.1-20 (CSA, 2020). Ingestion rates including the Traditional Foods diet are discussed in Section 4.2.4, Human Diet.

Dose coefficients (DCFs) for all internal and external exposure routes for humans are used to estimate radiological exposure. The DCFs for ingestion and inhalation by human receptors were taken from CSA N288.1-20 (CSA, 2020). The external DCFs used in the IMPACT model were derived based on the methods described in N288.1-20. Dose coefficients used in the IMPACT model are provided in Appendix A.

For non-radiological dose calculations relative absorption factors (RAF) were needed. The RAF for soil ingestion was assumed to be 1 for all non-radiological COPCs. The RAFs for soil dermal exposure were COPC specific and generally obtained from Health Canada (Health Canada, 2021b) or Ontario MECP (MECP, 2011).

4.2.3.1 Bioavailability

In general, the IMPACT model was used to calculate exposure doses for arsenic. However, the general assumption in IMPACT is that a COPC is 100% bioavailable from all media types, including food.

Arsenic may be present in the environment in different chemical forms such as arsenopyrite and arsenic trioxide. Some forms of arsenic can be absorbed in the gastrointestinal tract and taken up by plants, while other forms are poorly absorbed.

To account for that uncertainty, and provide a more realistic interpretation of results, the model outputs were amended to incorporate arsenic bioaccessibility into the outputs for moose meat and moose organs, using data collected as part of a study based out of British Columbia (Laird and Chan, 2013). Laird and Chan (2013) collected samples of various types of traditional foods including moose organs (kidney and liver) and moose meat. The mean percent in vitro bioaccessibility (a surrogate for bioavailability) ranged from 7% to 19% for moose organs, and was 59% for moose meat. These bioaccessibilities were incorporated into the exposure assessment by adjusting the model outputs from IMPACT by 0.19 for moose organs and 0.59 for moose meat. The bioaccessibility for moose meat of 0.59 was also applied to caribou meat.

ATSDR indicates that in seafood (i.e., fish), approximately 10% of arsenic is present in the inorganic form, while the remainder is in an organic form (arsenobetaine) that is generally not associated with toxicity (ATSDR, 2007). Therefore, the estimates of exposure generated by IMPACT overestimate arsenic exposure from the fish consumption pathway. As such, the model outputs from IMPACT were adjusted such that the exposure doses from fish were multiplied by a factor of 0.10.

These are reasonable estimates of bioaccessibility and are expected to reduce the uncertainty associated with the risk estimates for those food types. However, 100% bioaccessibility was assumed for the remaining food types (i.e., terrestrial plants, muskrat, mallard, and goose), and as such, exposure and risks for those other food types may be overestimated.

4.2.4 Human Diet

The total human diet is comprised of the portion of the diet obtained from Traditional Foods and the portion of the diet obtained from store bought foods. Traditional Foods are those animals and plants that are fished, hunted, or gathered from the land and consumed as food (Health Canada, 2018).

4.2.4.1 Total Diet

The initial assumptions for ingestion rates and components of the total foods diet for the HHRA were taken from CSA N288.1-20 Adult (Table G.9b – Central) total diet. The CSA N288.1-20 dietary composition was based on the 2004 Canadian nutrition survey results (Health Canada, 2004), processed for International Commission on Radiological Protection (ICRP) age groups and for two sexes in the adult age group. The dietary intakes for ICRP ages were adjusted to align with ICRP reference energy intakes for each age group (ICRP, 2003).

The N288.1-20 human diet was selected over the Health Canada human diet for the HHRA (Health Canada, 2010a). Health Canada references Richardson (Richardson, 1997), which used survey results from the late 1970s. The Richardson diet was also a combined adult male/female diet. The CSA N288.1-20 total adult diet is a smaller overall diet (706 kg/yr) than the Richardson diet (808 kg/yr; by about 100 kg/yr) and is based on more recent data.

Annual food consumption rates for the one-year-old diet were calculated using adult-to-one-year-old ratios from CSA N288.1-20 for each of the selected food categories. Annual ingestion rates for individual food categories were combined into relevant food categories, and the adult-to-one-year-old ratios were determined for each of these food categories.

4.2.4.2 Traditional Foods Diet

Human receptors were assumed to consume lower or higher proportions of Traditional Foods in their overall diets depending on their lifestyles. These are referred to as average Traditional Foods consumers and high Traditional Foods consumers, respectively. In both cases, the proportion of Traditional Foods in the overall diet of human health receptor groups in the HHRA was based on dietary studies from local and Indigenous communities.

The Project is a remote site, with no communities in close proximity. By distance, the closest communities are approximately 150 km away in the northern settlement of Wallaston Lake and Lac La Hache. The closest community by road is Pinehouse which is approximately 260 km away. The communities and associated Indigenous Communities of Interest that Denison has identified for engagement activities includes: the English River First Nation (ERFN), the Kineepik Métis Local 9, the Sipisishik Métis Local 37, the A La Baie Métis Local 21, and the Patuanak Métis Local 82.

Indigenous Knowledge was available from Indigenous Communities of Interest, including a dietary study for the ERFN (CanNorth, 2017). Local Knowledge was available from a local fisher/trapper whose primary residence has been in the LSA, that has extensive experience fishing, hunting, and trapping throughout the LSA and RSA.

The ERFN is comprised of seven reserve lands across Saskatchewan. Patuanak is located on the Churchill River and the north end of Lac-Île-à-la-Crosse, approximately 90 km north of Beauval and over 500 km from Saskatoon. Patuanak has 625 members on reserve and a hamlet with approximately 75 residents. La Plonge is located approximately 90 km south of Patuanak 8 km east of the town of Beauval near the Beaver River, and has approximately 148 people living on reserve. ERFN community members also travel to a seasonal culture camp along Highway 914 approximately 50 km south of the Key Lake Operation to hunt, fish, and gather berries (CanNorth, 2017).

A dietary study was performed for residents of Patuanak and La Plonge to understand which traditional foods were consumed by each community and the approximate amounts consumed. The results of the survey were summarized in CanNorth (2017) by average daily intake in grams (fresh weight) of country foods by species and season, for Patuanak, La Plonge, and an average. A summary of the ERFN traditional food ingestion rates by food type is shown in Table 4-3 and the proportions of food types are shown in Figure 4-3. Overall, fish, large mammals (meat and organs) and plants make up the majority of the traditional food diet, in similar proportions. Small mammals and birds make up a smaller proportion of the traditional food diet. Moose (*Alces americanus)* is the most commonly eaten large mammal. The most commonly eaten fish include walleye (*Sander vitreus*) and lake whitefish (*Coregonus clupeaformis*).

The results of the dietary study indicate that Patuanak has a higher traditional food ingestion rate than La Plonge, and has a similar distribution of country food types as the average diet. As a conservative approach for this assessment, the Patuanak diet was selected to represent the average traditional foods consumer in the HHRA. This includes the seasonal resident and the recreational fisher/hunter.

The traditional foods diet for past assessments for other uranium mining facilities in the area were based on the Hatchet Lake First Nation study (CanNorth, 2000). Overall, the quantities and types of traditional foods documented in the Hatchet Lake First Nation study were similar to the results from the ERFN dietary study, with the exception of the high ingestion rate of barren-ground caribou (*Rangifer tarandus groenlandicus*). Responses from the ERFN dietary study indicated that the Patuanak and La Plonge communities consume small quantities of caribou and preferred to eat moose.

Table 4-3: ERFN Ingestion Rates – Traditional Food

Country Food Type	La Plonge (g/d)	Patuanak (g/d)	All (g/d)
Birds	4.1	13.3	10.2
Edible Plants	62.8	54.3	57.2
Fish	16.4	73.0	53.7
Mammals (meat)	19.4	35.5	30.0
Mammals (organs)	6.2	16.2	12.8
Small mammal	3.3	6.7	5.5
Total	**112.2**	**199.0**	**169.4**

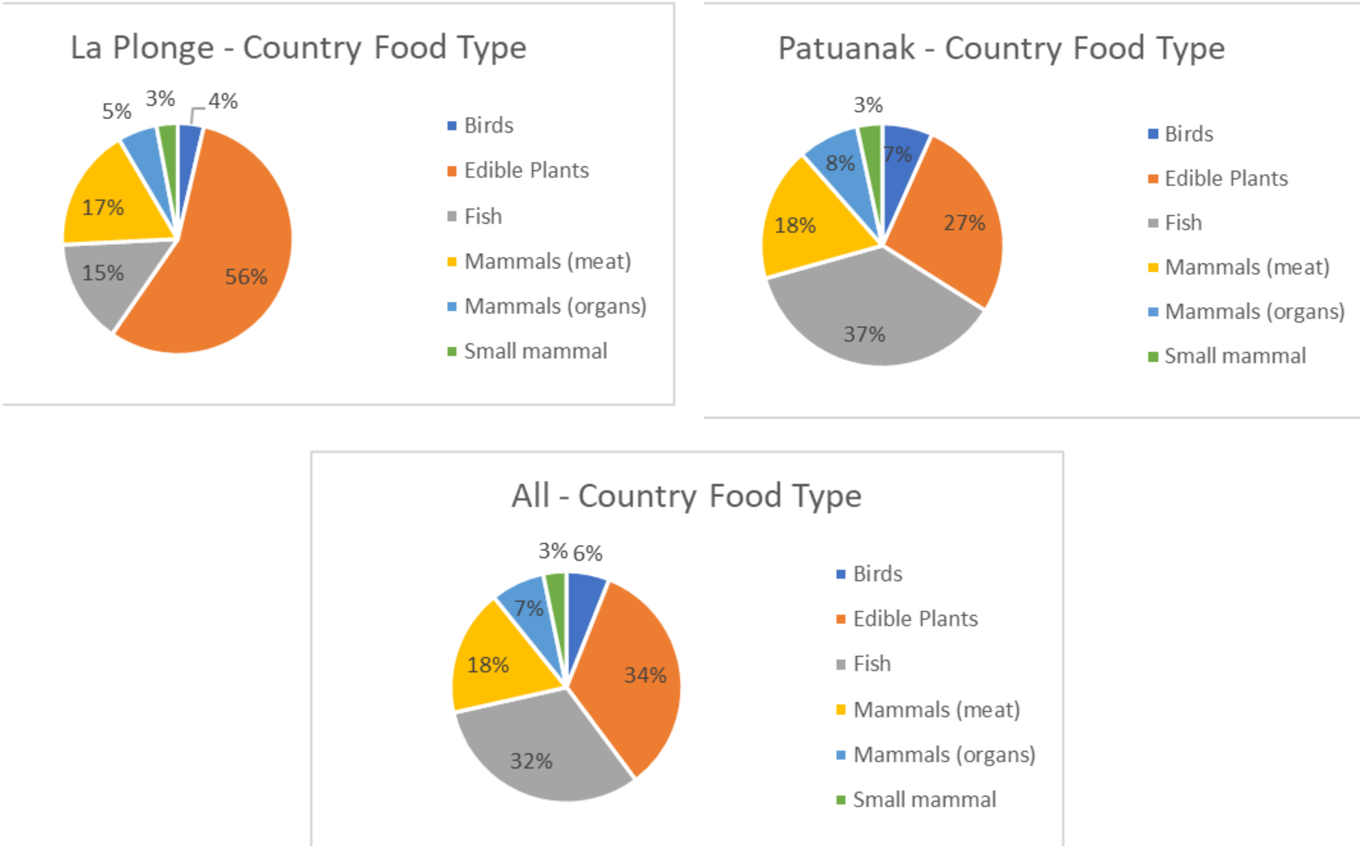


Figure 4-3: Proportion of Food Types in ERFN Traditional Food Diet

For the high traditional foods consumer, the dietary assumptions were from resource use information from a local fisher/trapper that has been used for past assessments in the area. The overall assumptions regarding types of food consumed and general proportions were re-confirmed with the local fisher/trapper during an interview with Denison on October 29, 2019 (KPI Program, 2019).

A detailed breakdown of diet by food type for each Traditional Foods consumer, as modelled in the HHRA, is shown in Table 4-4. Representative ecological receptors were selected from the IMPACT model to represent each Traditional Foods group. The Total Food Intake row is the total food intake from both traditional foods and store-bought foods. Since it is assumed that someone would obtain a portion of their overall diet from traditional foods and the rest from store bought foods, Table 4-4 shows the breakdown between the total food intake from traditional foods and the remaining food intake from store bought foods.

Table 4-4: Annual Food Intakes for Components of the Human Receptors' Diet

Food Components	Unit	Average Traditional Foods Consumer				High Traditional Foods Consumer			
		Adult [1]		One-year-old [2]		Adult [1]		One-year-old [2]	
Country Meat and Fish	kg/yr	52.82	-	9.34	-	366.88	-	63.50	-
Caribou	kg/yr	-	2.63	-	0.33	-	175.28	-	21.79
Moose	kg/yr	-	11.75	-	1.46	-	4.65	-	0.58
Moose (organs)	kg/yr	-	4.49	-	0.56	-	0	-	0
Small Mammals [4]	kg/yr	-	2.45	-	0.23	-	0.87	-	0.08
Mallard [5]	kg/yr	-	2.99	-	0.53	-	1.55	-	0.28
Canada Goose [6]	kg/yr	-	1.86	-	0.33	-	1.09	-	0.19
Fish [7]	kg/yr	-	26.65	-	5.89	-	183.44	-	40.58
Country Plants [8]	kg/yr	19.82	-	10.83	-	0	-	0	-
Blueberries	kg/yr	-	19.64	-	10.79	-	0	-	0
Labrador Tea	kg/yr	-	0.18	-	0.04	-	0	-	0
Store Foods	kg/yr	633.38		389.28		339.13		345.95	
Total Food Intake [3] (fresh weight)	kg/yr	706.01	-	409.45	-	706.01	-	409.45	-

Notes:

[1] Food intake for human receptors that are average Traditional Foods consumers were developed from the results of a dietary survey of the English River First Nation (CanNorth, 2017).

[2] CanNorth (2017) provides survey results for adults. Food intake for one-year-olds was proportioned from the adult receptor group using Central Adult - to Central 1-Year-Old derived from the N288.1-20 Human Diet (Table G.9b).

[3] The total food intake is from Table G.9b in CSA N288.1-20 (2020) which represents the central dietary intake based on reference energy intakes.

[4] While ERFN predominantly eat hare, modelling for small mammals is represented by muskrat to have a stronger link to the aquatic environment.

[5] Mallard was selected to represent all waterbirds in the country food diet.

[6] Canada goose was selected to represent upland birds in the country food diet.

[7] Assumed to include 50% predator fish (northern pike) and 50% forage fish (white sucker) based on ERFN dietary survey (CanNorth, 2017).

[8] Blueberries include edible fruits and berries. Labrador Tea includes edible plants other than fruits and berries.

4.2.5 Exposure Point Concentrations and Doses

Concentrations of COPCs in environmental media including water, sediment, soil, and Traditional Food items were predicted using the environmental pathways model IMPACT at defined human receptor locations. Air concentrations at human receptor locations were obtained from the air quality model (Section 8 of the EIS) and dictated into the IMPACT model. Concentrations of COPCs in environmental media were predicted over all Project phases. Water and sediment concentrations at exposure locations (Whitefish Lake Middle, Whitefish Lake South, McGowan Lake, and Russell Lake) and reference locations (Kratchkowsky Lake and Whitefish Lake North) are summarized in Figure 3-2 and Figure 3-3 showing the variation of concentrations over time. Maximum water and sediment concentrations are shown in Table 3-3. Maximum air and soil concentrations are shown in Table 3-14. The estimated non-radiological and radiological concentrations in environmental media and biota tissue concentrations relevant to human ingestion pathways are also summarized in Appendix B, Model Results in Support of the ERA.

Assessment of radiation exposures to members of the public is commonly based on estimation of the incremental effects of the project or site. Assessments consider the radiation dose received from external exposure to radiation as well as the dose received from inhalation and ingestion of radionuclides. The radionuclide dose to human receptors from all pathways is converted into a dose that is presented in millisieverts per year (mSv/yr).

Assessment of non-radiological exposures to members of the public is commonly based on estimation of the total effects of the project or site. Assessments consider the dose received from ingestion of constituents of concern as well as dermal absorption due to contact with soil. The inhalation dose was not included as no air COPCs were identified in the screening. This is presented as a dose in milligrams per kilogram per day (mg/kg/d) for each pathway.

The estimated non-radiological doses and radiological doses to human receptors due to releases from the Project during all phases are presented in the following subsections. Non-radiological doses are presented as baseline doses (based on existing exposures prior to the Project), Project doses (includes the Project dose in addition to the baseline dose), as well as incremental Project doses (includes the Project dose only with baseline component removed). For radiological doses, only the incremental doses are presented, as the dose limit is based on an incremental dose. Doses from ingestion of store-bought foods are considered as a portion of the baseline dose.

The results represent the expected EA case based on the source term presented in Section 3.0, Source Term Characterization for the COPCs identified. Sample calculations for radiological and non-radiological dose are presented in Appendix B.

4.2.5.1 Non-radiological Dose to Human Receptors

4.2.5.1.1 Non-carcinogen Dose

The estimated non-radiological doses to human receptors due to releases from the Project during all phases are presented in Table 4-5. The doses are presented for existing conditions (baseline) as well as for the Project, and represent the maximum dose predicted during the Project phases. This is a conservative representation as exposure varies over the different Project phases. The non-carcinogens evaluated include: cadmium, cobalt, chromium, copper, molybdenum, selenium, uranium, vanadium, and zinc. Doses are presented for the camp worker, recreational fisher/hunter, fisher/trapper, and seasonal resident for the Project phases (Table 4-5). Doses are presented for the future permanent resident, recreational fisher/hunter, fisher/trapper, and seasonal resident for the future centuries (Table 4-6).

Table 4-5: Estimated Non-radiological Doses to Human Receptors – Project Phases

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		Average Baseline Dose									
Camp Worker Adult (Whitefish Lake)	Cadmium	3.40E-07	7.55E-09	3.46E-08	2.35E-09	1.08E-08	0.00E+00	3.57E-08	3.51E-06	2.05E-04	**2.09E-04**
	Chromium	7.62E-06	6.93E-08	3.17E-06	4.08E-08	1.87E-06	0.00E+00	1.47E-05	5.58E-06	1.50E-05	**4.80E-05**
	Cobalt	1.48E-06	5.55E-09	2.54E-08	1.76E-09	8.04E-09	0.00E+00	6.25E-07	3.14E-05	1.64E-04	**1.97E-04**
	Copper	9.09E-06	3.05E-08	8.37E-07	1.29E-08	3.54E-07	0.00E+00	1.59E-04	2.19E-03	2.06E-02	**2.29E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-08	2.35E-09	1.08E-08	0.00E+00	5.51E-09	2.59E-05	2.53E-03	**2.56E-03**
	Selenium	4.74E-07	2.24E-09	1.03E-08	4.33E-09	1.98E-08	0.00E+00	8.37E-05	2.19E-05	1.69E-03	**1.79E-03**
	Uranium	4.41E-07	8.00E-09	3.66E-07	4.03E-09	1.84E-07	0.00E+00	3.08E-07	1.36E-05	3.67E-05	**5.17E-05**
	Vanadium	2.13E-06	1.01E-07	4.61E-06	7.79E-08	3.57E-06	0.00E+00	7.12E-06	3.60E-06	3.62E-04	**3.83E-04**
	Zinc	9.99E-06	1.11E-07	5.09E-06	6.92E-08	3.17E-06	0.00E+00	6.99E-04	5.35E-03	1.21E-01	**1.27E-01**
		Project Total Dose - Project Phases									
	Cadmium	4.56E-07	7.55E-09	3.46E-08	2.91E-09	1.33E-08	0.00E+00	5.01E-08	3.51E-06	2.05E-04	**2.09E-04**
	Chromium	9.19E-06	6.93E-08	3.17E-06	4.69E-08	2.15E-06	0.00E+00	1.84E-05	5.58E-06	1.63E-05	**5.49E-05**
	Cobalt	1.68E-06	5.56E-09	2.54E-08	1.94E-09	8.88E-09	0.00E+00	7.34E-07	3.15E-05	1.64E-04	**1.98E-04**
	Copper	1.06E-05	3.07E-08	8.44E-07	1.45E-08	3.98E-07	0.00E+00	1.93E-04	2.20E-03	2.06E-02	**2.30E-02**
	Molybdenum	1.79E-04	2.41E-09	1.10E-08	2.01E-07	9.18E-07	0.00E+00	7.95E-07	2.59E-05	2.57E-03	**2.78E-03**
	Selenium	3.41E-06	2.25E-09	1.03E-08	2.13E-08	9.74E-08	0.00E+00	5.39E-04	2.19E-05	1.75E-03	**2.31E-03**
	Uranium	4.43E-06	2.16E-08	9.88E-07	2.70E-08	1.24E-06	0.00E+00	3.36E-06	3.03E-05	3.93E-05	**7.96E-05**
	Vanadium	5.86E-06	1.01E-07	4.61E-06	1.69E-07	7.72E-06	0.00E+00	1.59E-05	3.61E-06	3.70E-04	**4.08E-04**
	Zinc	1.26E-05	1.11E-07	5.09E-06	8.21E-08	3.76E-06	0.00E+00	9.20E-04	5.35E-03	1.21E-01	**1.27E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	1.16E-07	1.13E-12	5.19E-12	5.56E-10	2.55E-09	0.00E+00	1.44E-08	1.66E-09	1.22E-07	**2.58E-07**
	Chromium	1.57E-06	6.66E-12	3.05E-10	6.07E-09	2.78E-07	0.00E+00	3.72E-06	6.63E-09	1.29E-06	**6.87E-06**
	Cobalt	1.99E-07	5.98E-12	2.74E-11	1.85E-10	8.46E-10	0.00E+00	1.09E-07	1.72E-08	3.71E-07	**6.98E-07**
	Copper	1.47E-06	2.72E-10	7.47E-09	1.61E-09	4.42E-08	0.00E+00	3.33E-05	8.27E-06	3.60E-05	**7.92E-05**
	Molybdenum	1.78E-04	1.85E-12	8.46E-12	1.98E-07	9.08E-07	0.00E+00	7.90E-07	9.28E-09	4.11E-05	**2.21E-04**
	Selenium	2.94E-06	2.38E-12	1.09E-11	1.70E-08	7.76E-08	0.00E+00	4.55E-04	1.38E-08	6.36E-05	**5.21E-04**
	Uranium	3.99E-06	1.36E-08	6.22E-07	2.30E-08	1.05E-06	0.00E+00	3.05E-06	1.66E-05	2.50E-06	**2.79E-05**
	Vanadium	3.73E-06	3.03E-11	1.39E-09	9.08E-08	4.16E-06	0.00E+00	8.77E-06	1.12E-08	7.65E-06	**2.44E-05**
	Zinc	2.65E-06	9.51E-11	4.36E-09	1.29E-08	5.92E-07	0.00E+00	2.21E-04	1.87E-06	1.01E-04	**3.27E-04**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
Rec F/H Adult (McGowan Lake)		Average Baseline Dose									
	Cadmium	3.40E-07	7.55E-09	3.46E-09	2.35E-09	1.08E-09	0.00E+00	7.14E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.62E-06	6.93E-08	3.17E-07	4.08E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.90E-05**
	Cobalt	1.48E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.74E-07	2.24E-09	1.03E-09	4.33E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.41E-07	8.00E-09	3.66E-08	4.03E-09	1.84E-08	0.00E+00	6.16E-07	2.73E-05	3.52E-05	**6.36E-05**
	Vanadium	2.13E-06	1.01E-07	4.61E-07	7.79E-08	3.57E-07	0.00E+00	1.42E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	9.99E-06	1.11E-07	5.09E-07	6.92E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Total Dose - Project Phases									
	Cadmium	3.82E-07	7.55E-09	3.46E-09	2.57E-09	1.18E-09	0.00E+00	1.00E-07	7.03E-06	1.99E-04	**2.06E-04**
	Chromium	8.25E-06	6.93E-08	3.17E-07	4.33E-08	1.98E-07	0.00E+00	3.68E-05	1.12E-05	3.29E-05	**8.97E-05**
	Cobalt	1.56E-06	5.55E-09	2.54E-09	1.84E-09	8.40E-10	0.00E+00	1.47E-06	6.29E-05	1.77E-04	**2.43E-04**
	Copper	9.63E-06	3.05E-08	8.38E-08	1.36E-08	3.73E-08	0.00E+00	3.86E-04	4.39E-03	2.55E-02	**3.03E-02**
	Molybdenum	7.07E-05	2.40E-09	1.10E-09	8.77E-08	4.02E-08	0.00E+00	1.59E-06	5.17E-05	2.50E-03	**2.62E-03**
	Selenium	1.46E-06	2.24E-09	1.03E-09	1.08E-08	4.94E-09	0.00E+00	1.08E-03	4.39E-05	1.78E-03	**2.90E-03**
	Uranium	1.79E-06	1.01E-08	4.61E-08	1.28E-08	5.87E-08	0.00E+00	6.71E-06	6.05E-05	4.02E-05	**1.09E-04**
	Vanadium	3.12E-06	1.01E-07	4.61E-07	1.01E-07	4.62E-07	0.00E+00	3.18E-05	7.22E-06	3.76E-04	**4.19E-04**
	Zinc	1.10E-05	1.11E-07	5.09E-07	7.43E-08	3.40E-07	0.00E+00	1.84E-03	1.07E-02	1.34E-01	**1.46E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	4.22E-08	1.58E-13	7.19E-14	2.20E-10	1.01E-10	0.00E+00	2.88E-08	3.32E-09	2.47E-07	**3.21E-07**
	Chromium	6.24E-07	1.03E-12	4.72E-12	2.47E-09	1.13E-08	0.00E+00	7.44E-06	1.33E-08	2.59E-06	**1.07E-05**
	Cobalt	7.28E-08	8.30E-13	3.80E-13	8.01E-11	3.66E-11	0.00E+00	2.18E-07	3.44E-08	7.40E-07	**1.07E-06**
	Copper	5.35E-07	3.79E-11	1.04E-10	6.96E-10	1.91E-09	0.00E+00	6.67E-05	1.65E-05	7.20E-05	**1.56E-04**
	Molybdenum	6.91E-05	1.85E-13	8.48E-14	8.54E-08	3.91E-08	0.00E+00	1.58E-06	1.86E-08	8.21E-05	**1.53E-04**
	Selenium	9.85E-07	3.33E-13	1.52E-13	6.47E-09	2.96E-09	0.00E+00	9.10E-04	2.75E-08	1.28E-04	**1.04E-03**
	Uranium	1.34E-06	2.07E-09	9.47E-09	8.79E-09	4.02E-08	0.00E+00	6.10E-06	3.32E-05	5.02E-06	**4.58E-05**
	Vanadium	9.91E-07	4.21E-12	1.93E-11	2.31E-08	1.06E-07	0.00E+00	1.75E-05	2.24E-08	1.53E-05	**3.40E-05**
	Zinc	1.03E-06	1.33E-11	6.07E-11	5.13E-09	2.35E-08	0.00E+00	4.42E-04	3.74E-06	2.02E-04	**6.49E-04**
Rec F/H One-year-old		Average Baseline Dose									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.84E-09	0.00E+00	6.76E-08	1.57E-05	5.03E-04	**5.20E-04**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
(McGowan Lake)	Chromium	8.51E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.37E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.30E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.93E-07	5.22E-07	6.26E-08	2.63E-07	3.15E-08	0.00E+00	5.84E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.38E-06	6.58E-06	7.89E-07	5.09E-06	6.10E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.52E-06	5.42E-07	0.00E+00	1.32E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Total Dose - Project Phases									
	Cadmium	4.27E-07	4.93E-07	5.91E-09	1.68E-07	2.02E-09	0.00E+00	9.49E-08	1.58E-05	5.03E-04	**5.20E-04**
	Chromium	9.21E-06	4.53E-06	5.42E-07	2.83E-06	3.39E-07	0.00E+00	3.48E-05	2.58E-05	1.93E-05	**9.74E-05**
	Cobalt	1.74E-06	3.63E-07	4.35E-09	1.20E-07	1.44E-09	0.00E+00	1.39E-06	1.46E-04	3.78E-04	**5.28E-04**
	Copper	1.07E-05	1.99E-06	1.43E-07	8.87E-07	6.38E-08	0.00E+00	3.65E-04	1.01E-02	4.29E-02	**5.35E-02**
	Molybdenum	7.89E-05	1.57E-07	1.88E-09	5.73E-06	6.87E-08	0.00E+00	1.51E-06	1.20E-04	6.33E-03	**6.54E-03**
	Selenium	1.63E-06	1.47E-07	1.76E-09	7.06E-07	8.46E-09	0.00E+00	1.02E-03	1.03E-04	4.21E-03	**5.34E-03**
	Uranium	1.99E-06	6.58E-07	7.88E-08	8.37E-07	1.00E-07	0.00E+00	6.36E-06	1.29E-04	9.42E-05	**2.33E-04**
	Vanadium	3.49E-06	6.58E-06	7.89E-07	6.60E-06	7.91E-07	0.00E+00	3.01E-05	1.31E-05	8.86E-04	**9.48E-04**
	Zinc	1.23E-05	7.26E-06	8.70E-07	4.86E-06	5.82E-07	0.00E+00	1.74E-03	2.46E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	4.71E-08	1.03E-11	1.23E-13	1.44E-08	1.73E-10	0.00E+00	2.73E-08	6.84E-09	1.71E-07	**2.66E-07**
	Chromium	6.97E-07	6.73E-11	8.07E-12	1.61E-07	1.93E-08	0.00E+00	7.05E-06	1.73E-08	1.71E-06	**9.65E-06**
	Cobalt	8.13E-08	5.42E-11	6.50E-13	5.23E-09	6.27E-11	0.00E+00	2.07E-07	7.64E-08	4.22E-07	**7.92E-07**
	Copper	5.97E-07	2.48E-09	1.78E-10	4.54E-08	3.27E-09	0.00E+00	6.32E-05	3.87E-05	4.19E-05	**1.44E-04**
	Molybdenum	7.71E-05	1.21E-11	1.45E-13	5.58E-06	6.69E-08	0.00E+00	1.50E-06	4.15E-08	4.67E-05	**1.31E-04**
	Selenium	1.10E-06	2.18E-11	2.61E-13	4.23E-07	5.07E-09	0.00E+00	8.62E-04	6.26E-08	8.15E-05	**9.45E-04**
	Uranium	1.50E-06	1.35E-07	1.62E-08	5.74E-07	6.88E-08	0.00E+00	5.77E-06	6.60E-05	3.17E-06	**7.73E-05**
	Vanadium	1.11E-06	2.76E-10	3.30E-11	1.51E-06	1.81E-07	0.00E+00	1.66E-05	2.88E-08	8.46E-06	**2.79E-05**
	Zinc	1.15E-06	8.65E-10	1.04E-10	3.35E-07	4.02E-08	0.00E+00	4.19E-04	8.72E-06	1.02E-04	**5.30E-04**
Rec F/H Adult (Russell Lake)		Average Baseline Dose									
	Cadmium	3.40E-07	7.55E-09	3.46E-09	2.35E-09	1.08E-09	0.00E+00	7.14E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.62E-06	6.93E-08	3.17E-07	4.08E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.90E-05**
	Cobalt	1.48E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.74E-07	2.24E-09	1.03E-09	4.33E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.41E-07	8.00E-09	3.66E-08	4.03E-09	1.84E-08	0.00E+00	6.16E-07	2.73E-05	3.52E-05	**6.36E-05**
	Vanadium	2.13E-06	1.01E-07	4.61E-07	7.79E-08	3.57E-07	0.00E+00	1.42E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	9.99E-06	1.11E-07	5.09E-07	6.92E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
Rec F/H One-year-old (Russell Lake)		Project Total Dose - Project Phases									
	Cadmium	3.74E-07	7.55E-09	3.46E-09	2.52E-09	1.15E-09	0.00E+00	9.23E-08	7.03E-06	1.99E-04	**2.06E-04**
	Chromium	8.14E-06	6.93E-08	3.17E-07	4.27E-08	1.95E-07	0.00E+00	3.48E-05	1.12E-05	3.22E-05	**8.70E-05**
	Cobalt	1.54E-06	5.55E-09	2.54E-09	1.82E-09	8.31E-10	0.00E+00	1.41E-06	6.29E-05	1.77E-04	**2.43E-04**
	Copper	9.49E-06	3.05E-08	8.37E-08	1.34E-08	3.68E-08	0.00E+00	3.69E-04	4.38E-03	2.55E-02	**3.03E-02**
	Molybdenum	5.34E-05	2.40E-09	1.10E-09	6.71E-08	3.07E-08	0.00E+00	1.20E-06	5.17E-05	2.48E-03	**2.58E-03**
	Selenium	1.18E-06	2.24E-09	1.03E-09	9.06E-09	4.15E-09	0.00E+00	8.36E-04	4.39E-05	1.74E-03	**2.62E-03**
	Uranium	1.41E-06	8.55E-09	3.91E-08	1.04E-08	4.78E-08	0.00E+00	5.01E-06	3.62E-05	3.81E-05	**8.08E-05**
	Vanadium	2.89E-06	1.01E-07	4.61E-07	9.26E-08	4.24E-07	0.00E+00	2.60E-05	7.20E-06	3.71E-04	**4.08E-04**
	Zinc	1.08E-05	1.11E-07	5.09E-07	7.30E-08	3.34E-07	0.00E+00	1.72E-03	1.07E-02	1.33E-01	**1.46E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	3.42E-08	4.09E-14	1.82E-14	1.63E-10	7.44E-11	0.00E+00	2.09E-08	8.54E-10	1.83E-07	**2.39E-07**
	Chromium	5.12E-07	2.70E-13	1.22E-12	1.83E-09	8.40E-09	0.00E+00	5.45E-06	3.45E-09	1.95E-06	**7.93E-06**
	Cobalt	5.45E-08	2.13E-13	9.75E-14	6.09E-11	2.79E-11	0.00E+00	1.64E-07	8.85E-09	5.35E-07	**7.63E-07**
	Copper	4.00E-07	9.75E-12	2.68E-11	5.28E-10	1.45E-09	0.00E+00	5.01E-05	4.26E-06	3.94E-05	**9.41E-05**
	Molybdenum	5.18E-05	3.73E-14	1.70E-14	6.48E-08	2.97E-08	0.00E+00	1.19E-06	3.71E-09	6.22E-05	**1.15E-04**
	Selenium	7.07E-07	8.57E-14	3.92E-14	4.73E-09	2.16E-09	0.00E+00	6.68E-04	7.08E-09	9.41E-05	**7.63E-04**
	Uranium	9.66E-07	5.52E-10	2.53E-09	6.42E-09	2.94E-08	0.00E+00	4.40E-06	8.88E-06	2.95E-06	**1.72E-05**
	Vanadium	7.62E-07	1.08E-12	4.95E-12	1.47E-08	6.71E-08	0.00E+00	1.18E-05	5.77E-09	1.03E-05	**2.30E-05**
	Zinc	8.49E-07	3.40E-12	1.56E-11	3.78E-09	1.73E-08	0.00E+00	3.21E-04	9.64E-07	1.48E-04	**4.71E-04**
		Average Baseline Dose									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.84E-09	0.00E+00	6.76E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.51E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.37E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
Seasonal Resident Adult (Russell Lake)	Selenium	5.30E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.93E-07	5.22E-07	6.26E-08	2.63E-07	3.15E-08	0.00E+00	5.84E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.38E-06	6.58E-06	7.89E-07	5.09E-06	6.10E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.52E-06	5.42E-07	0.00E+00	1.32E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Total Dose - Project Phases									
	Cadmium	4.18E-07	4.93E-07	5.91E-09	1.64E-07	1.97E-09	0.00E+00	8.74E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	9.08E-06	4.53E-06	5.42E-07	2.79E-06	3.34E-07	0.00E+00	3.30E-05	2.58E-05	1.89E-05	**9.49E-05**
	Cobalt	1.72E-06	3.63E-07	4.35E-09	1.19E-07	1.42E-09	0.00E+00	1.34E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.06E-05	1.99E-06	1.43E-07	8.76E-07	6.30E-08	0.00E+00	3.49E-04	1.01E-02	4.29E-02	**5.34E-02**
	Molybdenum	5.96E-05	1.57E-07	1.88E-09	4.39E-06	5.26E-08	0.00E+00	1.13E-06	1.20E-04	6.32E-03	**6.51E-03**
	Selenium	1.32E-06	1.47E-07	1.76E-09	5.92E-07	7.09E-09	0.00E+00	7.91E-04	1.03E-04	4.19E-03	**5.09E-03**
	Uranium	1.57E-06	5.59E-07	6.69E-08	6.82E-07	8.18E-08	0.00E+00	4.75E-06	8.01E-05	9.29E-05	**1.81E-04**
	Vanadium	3.23E-06	6.58E-06	7.89E-07	6.05E-06	7.25E-07	0.00E+00	2.47E-05	1.30E-05	8.84E-04	**9.39E-04**
	Zinc	1.21E-05	7.26E-06	8.70E-07	4.77E-06	5.71E-07	0.00E+00	1.63E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	3.82E-08	2.67E-12	3.15E-14	1.06E-08	1.27E-10	0.00E+00	1.98E-08	1.76E-09	1.26E-07	**1.97E-07**
	Chromium	5.72E-07	1.77E-11	2.10E-12	1.20E-07	1.44E-08	0.00E+00	5.17E-06	4.50E-09	1.29E-06	**7.16E-06**
	Cobalt	6.08E-08	1.40E-11	1.67E-13	3.98E-09	4.77E-11	0.00E+00	1.55E-07	1.96E-08	3.06E-07	**5.46E-07**
	Copper	4.47E-07	6.37E-10	4.58E-11	3.45E-08	2.48E-09	0.00E+00	4.74E-05	9.94E-06	2.38E-05	**8.16E-05**
	Molybdenum	5.79E-05	2.43E-12	2.89E-14	4.23E-06	5.07E-08	0.00E+00	1.12E-06	8.30E-09	3.54E-05	**9.87E-05**
	Selenium	7.90E-07	5.60E-12	6.72E-14	3.09E-07	3.70E-09	0.00E+00	6.33E-04	1.61E-08	6.00E-05	**6.94E-04**
	Uranium	1.08E-06	3.61E-08	4.32E-09	4.19E-07	5.03E-08	0.00E+00	4.16E-06	1.76E-05	1.86E-06	**2.52E-05**
	Vanadium	8.51E-07	7.09E-11	8.47E-12	9.58E-07	1.15E-07	0.00E+00	1.12E-05	7.42E-09	5.67E-06	**1.88E-05**
	Zinc	9.48E-07	2.22E-10	2.67E-11	2.47E-07	2.96E-08	0.00E+00	3.04E-04	2.24E-06	7.44E-05	**3.82E-04**
		Average Baseline Dose									
	Cadmium	3.40E-07	7.55E-09	3.46E-09	2.35E-09	1.08E-09	0.00E+00	7.14E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.62E-06	6.93E-08	3.17E-07	4.08E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.90E-05**
	Cobalt	1.48E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.74E-07	2.24E-09	1.03E-09	4.33E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.41E-07	8.00E-09	3.66E-08	4.03E-09	1.84E-08	0.00E+00	6.16E-07	2.73E-05	3.52E-05	**6.36E-05**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Vanadium	2.13E-06	1.01E-07	4.61E-07	7.79E-08	3.57E-07	0.00E+00	1.42E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	9.99E-06	1.11E-07	5.09E-07	6.92E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Total Dose - Project Phases									
Seasonal Resident One-year-old (Russell Lake)	Cadmium	3.74E-07	7.55E-09	3.46E-09	2.52E-09	1.15E-09	0.00E+00	7.83E-08	7.03E-06	1.99E-04	**2.06E-04**
	Chromium	8.14E-06	6.93E-08	3.17E-07	4.27E-08	1.95E-07	0.00E+00	3.12E-05	1.12E-05	3.09E-05	**8.21E-05**
	Cobalt	1.54E-06	5.55E-09	2.54E-09	1.82E-09	8.31E-10	0.00E+00	1.30E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.49E-06	3.05E-08	8.37E-08	1.34E-08	3.68E-08	0.00E+00	3.33E-04	4.38E-03	2.55E-02	**3.02E-02**
	Molybdenum	5.34E-05	2.40E-09	1.10E-09	6.71E-08	3.07E-08	0.00E+00	3.67E-07	5.17E-05	2.43E-03	**2.54E-03**
	Selenium	1.18E-06	2.24E-09	1.03E-09	9.06E-09	4.15E-09	0.00E+00	3.64E-04	4.39E-05	1.68E-03	**2.09E-03**
	Uranium	1.41E-06	8.55E-09	3.91E-08	1.04E-08	4.78E-08	0.00E+00	1.92E-06	3.00E-05	3.65E-05	**6.99E-05**
	Vanadium	2.89E-06	1.01E-07	4.61E-07	9.26E-08	4.24E-07	0.00E+00	1.91E-05	7.20E-06	3.64E-04	**3.94E-04**
	Zinc	1.08E-05	1.11E-07	5.09E-07	7.30E-08	3.34E-07	0.00E+00	1.51E-03	1.07E-02	1.33E-01	**1.46E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	3.42E-08	4.09E-14	1.82E-14	1.63E-10	7.44E-11	0.00E+00	6.90E-09	2.56E-10	5.90E-08	**1.01E-07**
	Chromium	5.12E-07	2.70E-13	1.22E-12	1.83E-09	8.40E-09	0.00E+00	1.89E-06	1.05E-09	6.36E-07	**3.05E-06**
	Cobalt	5.45E-08	2.13E-13	9.75E-14	6.09E-11	2.79E-11	0.00E+00	4.55E-08	2.66E-09	1.49E-07	**2.51E-07**
	Copper	4.00E-07	9.75E-12	2.68E-11	5.28E-10	1.45E-09	0.00E+00	1.39E-05	1.28E-06	1.16E-05	**2.72E-05**
	Molybdenum	5.18E-05	3.73E-14	1.70E-14	6.48E-08	2.97E-08	0.00E+00	3.56E-07	1.12E-09	1.86E-05	**7.09E-05**
	Selenium	7.07E-07	8.57E-14	3.92E-14	4.73E-09	2.16E-09	0.00E+00	1.97E-04	2.12E-09	2.99E-05	**2.27E-04**
	Uranium	9.66E-07	5.52E-10	2.53E-09	6.42E-09	2.94E-08	0.00E+00	1.30E-06	2.67E-06	1.33E-06	**6.32E-06**
	Vanadium	7.62E-07	1.08E-12	4.95E-12	1.47E-08	6.71E-08	0.00E+00	4.82E-06	1.75E-09	3.98E-06	**9.65E-06**
	Zinc	8.49E-07	3.40E-12	1.56E-11	3.78E-09	1.73E-08	0.00E+00	1.14E-04	2.89E-07	5.70E-05	**1.72E-04**
		Average Baseline Dose									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.84E-09	0.00E+00	6.76E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.51E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.37E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.30E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.93E-07	5.22E-07	6.26E-08	2.63E-07	3.15E-08	0.00E+00	5.84E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.38E-06	6.58E-06	7.89E-07	5.09E-06	6.10E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.52E-06	5.42E-07	0.00E+00	1.32E-03	2.45E-02	2.76E-01	**3.02E-01**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		Project Total Dose - Project Phases									
	Cadmium	4.18E-07	4.93E-07	5.91E-09	1.64E-07	1.97E-09	0.00E+00	7.41E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	9.08E-06	4.53E-06	5.42E-07	2.79E-06	3.34E-07	0.00E+00	2.96E-05	2.58E-05	1.80E-05	**9.07E-05**
	Cobalt	1.72E-06	3.63E-07	4.35E-09	1.19E-07	1.42E-09	0.00E+00	1.23E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.06E-05	1.99E-06	1.43E-07	8.76E-07	6.30E-08	0.00E+00	3.15E-04	1.01E-02	4.29E-02	**5.34E-02**
	Molybdenum	5.96E-05	1.57E-07	1.88E-09	4.39E-06	5.26E-08	0.00E+00	3.47E-07	1.20E-04	6.30E-03	**6.48E-03**
	Selenium	1.32E-06	1.47E-07	1.76E-09	5.92E-07	7.09E-09	0.00E+00	3.45E-04	1.03E-04	4.15E-03	**4.60E-03**
	Uranium	1.57E-06	5.59E-07	6.69E-08	6.82E-07	8.18E-08	0.00E+00	1.82E-06	6.78E-05	9.18E-05	**1.64E-04**
	Vanadium	3.23E-06	6.58E-06	7.89E-07	6.05E-06	7.25E-07	0.00E+00	1.81E-05	1.30E-05	8.80E-04	**9.29E-04**
	Zinc	1.21E-05	7.26E-06	8.70E-07	4.77E-06	5.71E-07	0.00E+00	1.43E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	3.82E-08	2.67E-12	3.15E-14	1.06E-08	1.27E-10	0.00E+00	6.53E-09	5.28E-10	3.87E-08	**9.47E-08**
	Chromium	5.72E-07	1.77E-11	2.10E-12	1.20E-07	1.44E-08	0.00E+00	1.79E-06	1.34E-09	4.03E-07	**2.90E-06**
	Cobalt	6.08E-08	1.40E-11	1.67E-13	3.98E-09	4.77E-11	0.00E+00	4.31E-08	5.88E-09	8.25E-08	**1.96E-07**
	Copper	4.47E-07	6.37E-10	4.58E-11	3.45E-08	2.48E-09	0.00E+00	1.32E-05	2.98E-06	6.81E-06	**2.34E-05**
	Molybdenum	5.79E-05	2.43E-12	2.89E-14	4.23E-06	5.07E-08	0.00E+00	3.37E-07	2.49E-09	1.03E-05	**7.27E-05**
	Selenium	7.90E-07	5.60E-12	6.72E-14	3.09E-07	3.70E-09	0.00E+00	1.86E-04	4.83E-09	1.85E-05	**2.06E-04**
	Uranium	1.08E-06	3.61E-08	4.32E-09	4.19E-07	5.03E-08	0.00E+00	1.24E-06	5.28E-06	8.05E-07	**8.91E-06**
	Vanadium	8.51E-07	7.09E-11	8.47E-12	9.58E-07	1.15E-07	0.00E+00	4.57E-06	2.21E-09	2.19E-06	**8.69E-06**
	Zinc	9.48E-07	2.22E-10	2.67E-11	2.47E-07	2.96E-08	0.00E+00	1.07E-04	6.76E-07	2.94E-05	**1.39E-04**
		Average Baseline Dose									
	Cadmium	3.40E-07	7.55E-09	3.46E-09	2.35E-09	1.08E-09	0.00E+00	4.91E-07	0.00E+00	1.61E-04	**1.62E-04**
	Chromium	7.62E-06	6.93E-08	3.17E-07	4.08E-08	1.87E-07	0.00E+00	2.02E-04	0.00E+00	8.27E-04	**1.04E-03**
	Cobalt	1.48E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	8.60E-06	0.00E+00	7.79E-05	**8.80E-05**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	2.19E-03	0.00E+00	1.19E-02	**1.41E-02**
Fisher/Trapper Adult (Russell Lake)	**Molybdenum**	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	7.58E-08	0.00E+00	1.28E-03	**1.28E-03**
	Selenium	4.74E-07	2.24E-09	1.03E-09	4.33E-09	1.98E-09	0.00E+00	1.15E-03	0.00E+00	1.58E-03	**2.73E-03**
	Uranium	4.41E-07	8.00E-09	3.66E-08	4.03E-09	1.84E-08	0.00E+00	4.24E-06	0.00E+00	2.19E-05	**2.66E-05**
	Vanadium	2.13E-06	1.01E-07	4.61E-07	7.79E-08	3.57E-07	0.00E+00	9.80E-05	0.00E+00	7.72E-04	**8.73E-04**
	Zinc	9.99E-06	1.11E-07	5.09E-07	6.92E-08	3.17E-07	0.00E+00	9.62E-03	0.00E+00	3.08E-01	**3.18E-01**
		Project Total Dose - Project Phases									
	Cadmium	3.90E-07	7.55E-09	3.46E-09	2.63E-09	1.20E-09	0.00E+00	6.35E-07	0.00E+00	1.62E-04	**1.63E-04**

Human Receptor	COPC	Non-radiological Dose by Pathway during Project Phases (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Chromium	8.36E-06	6.93E-08	3.17E-07	4.39E-08	2.01E-07	0.00E+00	2.40E-04	0.00E+00	8.37E-04	**1.09E-03**
	Cobalt	1.58E-06	5.55E-09	2.54E-09	1.86E-09	8.50E-10	0.00E+00	9.73E-06	0.00E+00	7.80E-05	**8.94E-05**
	Copper	9.79E-06	3.05E-08	8.37E-08	1.38E-08	3.78E-08	0.00E+00	2.54E-03	0.00E+00	1.20E-02	**1.46E-02**
	Molybdenum	8.79E-05	2.40E-09	1.10E-09	1.10E-07	5.05E-08	0.00E+00	8.24E-06	0.00E+00	1.32E-03	**1.41E-03**
	Selenium	1.66E-06	2.24E-09	1.03E-09	1.22E-08	5.59E-09	0.00E+00	5.75E-03	0.00E+00	1.91E-03	**7.67E-03**
	Uranium	2.06E-06	8.92E-09	4.08E-08	1.47E-08	6.74E-08	0.00E+00	3.45E-05	0.00E+00	9.70E-05	**1.34E-04**
	Vanadium	3.18E-06	1.01E-07	4.61E-07	1.02E-07	4.68E-07	0.00E+00	1.79E-04	0.00E+00	8.55E-04	**1.04E-03**
	Zinc	1.12E-05	1.11E-07	5.09E-07	7.55E-08	3.46E-07	0.00E+00	1.18E-02	0.00E+00	3.09E-01	**3.21E-01**
		Project Incremental Dose - Project Phases									
	Cadmium	5.04E-08	6.75E-14	3.09E-14	2.71E-10	1.24E-10	0.00E+00	1.44E-07	0.00E+00	5.73E-07	**7.68E-07**
	Chromium	7.37E-07	4.48E-13	2.02E-12	3.05E-09	1.40E-08	0.00E+00	3.75E-05	0.00E+00	1.01E-05	**4.84E-05**
	Cobalt	9.49E-08	3.56E-13	1.63E-13	1.01E-10	4.64E-11	0.00E+00	1.13E-06	0.00E+00	1.37E-07	**1.36E-06**
	Copper	6.96E-07	1.63E-11	4.46E-11	8.80E-10	2.42E-09	0.00E+00	3.45E-04	0.00E+00	6.32E-05	**4.08E-04**
	Molybdenum	8.64E-05	6.22E-14	2.82E-14	1.08E-07	4.94E-08	0.00E+00	8.17E-06	0.00E+00	3.40E-05	**1.29E-04**
	Selenium	1.19E-06	1.43E-13	6.54E-14	7.88E-09	3.61E-09	0.00E+00	4.60E-03	0.00E+00	3.35E-04	**4.93E-03**
	Uranium	1.62E-06	9.20E-10	4.21E-09	1.07E-08	4.90E-08	0.00E+00	3.03E-05	0.00E+00	7.52E-05	**1.07E-04**
	Vanadium	1.05E-06	1.80E-12	8.27E-12	2.44E-08	1.12E-07	0.00E+00	8.12E-05	0.00E+00	8.30E-05	**1.65E-04**
	Zinc	1.22E-06	5.68E-12	2.60E-11	6.30E-09	2.88E-08	0.00E+00	2.21E-03	0.00E+00	1.07E-03	**3.28E-03**

COPC = constituent of potential concern.

Table 4-6: Estimated Non-radiological Doses to Human Receptors – Future Centuries

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
Permanent Resident (Whitefish Lake)		Baseline Dose									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.15E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.63E-06	6.93E-08	3.17E-07	4.09E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.91E-05**
	Cobalt	1.49E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.75E-07	2.24E-09	1.03E-09	4.34E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.42E-07	8.00E-09	3.66E-08	4.03E-09	1.85E-08	0.00E+00	6.18E-07	2.73E-05	3.52E-05	**6.36E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	1.43E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.00E-05	1.11E-07	5.09E-07	6.93E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.43E-07	7.55E-09	3.46E-09	2.37E-09	1.09E-09	0.00E+00	7.19E-08	7.03E-06	1.99E-04	**2.06E-04**
	Chromium	7.73E-06	6.93E-08	3.17E-07	4.14E-08	1.90E-07	0.00E+00	2.98E-05	1.12E-05	3.05E-05	**7.97E-05**
	Cobalt	1.56E-06	5.56E-09	2.54E-09	1.85E-09	8.47E-10	0.00E+00	1.32E-06	6.30E-05	1.77E-04	**2.43E-04**
	Copper	9.22E-06	3.05E-08	8.37E-08	1.31E-08	3.59E-08	0.00E+00	3.23E-04	4.38E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.71E-06	2.40E-09	1.10E-09	2.56E-09	1.17E-09	0.00E+00	1.20E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	6.33E-07	2.24E-09	1.03E-09	5.77E-09	2.64E-09	0.00E+00	2.17E-04	4.39E-05	1.66E-03	**1.92E-03**
	Uranium	5.41E-07	9.53E-09	4.36E-08	4.93E-09	2.26E-08	0.00E+00	7.56E-07	3.69E-05	3.53E-05	**7.36E-05**
	Vanadium	2.16E-06	1.01E-07	4.61E-07	7.89E-08	3.61E-07	0.00E+00	1.44E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.09E-05	1.11E-07	5.09E-07	7.53E-08	3.45E-07	0.00E+00	1.52E-03	1.07E-02	1.33E-01	**1.46E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	1.97E-09	1.26E-13	5.75E-14	1.37E-11	6.25E-12	0.00E+00	4.14E-10	2.29E-10	4.19E-09	**6.83E-09**
	Chromium	9.89E-08	0.00E+00	0.00E+00	5.29E-10	2.42E-09	0.00E+00	3.81E-07	0.00E+00	1.58E-07	**6.41E-07**
	Cobalt	7.89E-08	5.50E-12	2.52E-12	9.33E-11	4.27E-11	0.00E+00	6.64E-08	1.29E-07	1.80E-07	**4.55E-07**
	Copper	1.21E-07	1.72E-11	4.71E-11	1.71E-10	4.70E-10	0.00E+00	4.24E-06	4.64E-06	3.31E-06	**1.23E-05**
	Molybdenum	1.42E-07	0.00E+00	0.00E+00	2.13E-10	9.73E-11	0.00E+00	9.97E-10	0.00E+00	4.63E-08	**1.90E-07**
	Selenium	1.58E-07	2.35E-14	1.08E-14	1.44E-09	6.59E-10	0.00E+00	4.96E-05	9.64E-10	7.47E-06	**5.73E-05**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Uranium	9.87E-08	1.53E-09	7.02E-09	9.00E-10	4.12E-09	0.00E+00	1.38E-07	9.63E-06	1.03E-07	**9.98E-06**
	Vanadium	1.93E-08	8.39E-12	3.85E-11	7.04E-10	3.22E-09	0.00E+00	1.29E-07	6.47E-10	1.24E-07	**2.77E-07**
	Zinc	8.67E-07	1.06E-11	4.86E-11	6.00E-09	2.74E-08	0.00E+00	1.21E-04	1.82E-06	5.55E-05	**1.79E-04**
Permanent Resident One-year-old (Whitefish Lake)		Baseline Dose									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.77E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.52E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.38E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.31E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.94E-07	5.22E-07	6.26E-08	2.63E-07	3.16E-08	0.00E+00	5.85E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.11E-06	6.12E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.53E-06	5.42E-07	0.00E+00	1.33E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.83E-07	4.93E-07	5.91E-09	1.55E-07	1.86E-09	0.00E+00	6.81E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.63E-06	4.53E-06	5.42E-07	2.71E-06	3.24E-07	0.00E+00	2.82E-05	2.58E-05	1.77E-05	**8.84E-05**
	Cobalt	1.75E-06	3.63E-07	4.35E-09	1.21E-07	1.45E-09	0.00E+00	1.25E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.03E-05	1.99E-06	1.43E-07	8.53E-07	6.13E-08	0.00E+00	3.06E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.91E-06	1.57E-07	1.88E-09	1.68E-07	2.01E-09	0.00E+00	1.14E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	7.07E-07	1.47E-07	1.76E-09	3.77E-07	4.52E-09	0.00E+00	2.06E-04	1.03E-04	4.13E-03	**4.44E-03**
	Uranium	6.04E-07	6.23E-07	7.46E-08	3.22E-07	3.86E-08	0.00E+00	7.16E-07	8.51E-05	9.11E-05	**1.79E-04**
	Vanadium	2.41E-06	6.58E-06	7.89E-07	5.16E-06	6.18E-07	0.00E+00	1.37E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.21E-05	7.26E-06	8.70E-07	4.92E-06	5.89E-07	0.00E+00	1.44E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	2.20E-09	8.24E-12	9.81E-14	8.92E-10	1.07E-11	0.00E+00	3.92E-10	5.17E-10	2.91E-09	**6.93E-09**
	Chromium	1.10E-07	0.00E+00	0.00E+00	3.46E-08	4.14E-09	0.00E+00	3.60E-07	0.00E+00	1.05E-07	**6.14E-07**
	Cobalt	8.81E-08	3.59E-10	4.30E-12	6.10E-09	7.31E-11	0.00E+00	6.29E-08	3.03E-07	1.06E-07	**5.67E-07**
	Copper	1.35E-07	1.12E-09	8.06E-11	1.12E-08	8.04E-10	0.00E+00	4.01E-06	1.09E-05	2.04E-06	**1.71E-05**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Molybdenum	1.59E-07	0.00E+00	0.00E+00	1.39E-08	1.67E-10	0.00E+00	9.44E-10	0.00E+00	2.70E-08	**2.01E-07**
	Selenium	1.76E-07	1.53E-12	1.84E-14	9.41E-08	1.13E-09	0.00E+00	4.70E-05	2.26E-09	4.90E-06	**5.22E-05**
	Uranium	1.10E-07	1.00E-07	1.20E-08	5.88E-08	7.05E-09	0.00E+00	1.31E-07	2.26E-05	7.20E-08	**2.31E-05**
	Vanadium	2.15E-08	5.49E-10	6.58E-11	4.60E-08	5.51E-09	0.00E+00	1.22E-07	1.52E-09	6.90E-08	**2.66E-07**
	Zinc	9.68E-07	6.93E-10	8.31E-11	3.92E-07	4.70E-08	0.00E+00	1.15E-04	4.27E-06	2.81E-05	**1.49E-04**
Rec F/H (McGowan Lake)		**Baseline Dose**									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.15E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.63E-06	6.93E-08	3.17E-07	4.09E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.91E-05**
	Cobalt	1.49E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.75E-07	2.24E-09	1.03E-09	4.34E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.42E-07	8.00E-09	3.66E-08	4.03E-09	1.85E-08	0.00E+00	6.18E-07	2.73E-05	3.52E-05	**6.36E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	1.43E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.00E-05	1.11E-07	5.09E-07	6.93E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.18E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.66E-06	6.93E-08	3.17E-07	4.10E-08	1.88E-07	0.00E+00	2.97E-05	1.12E-05	3.04E-05	**7.95E-05**
	Cobalt	1.50E-06	5.55E-09	2.54E-09	1.78E-09	8.13E-10	0.00E+00	1.30E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.12E-06	3.05E-08	8.37E-08	1.29E-08	3.55E-08	0.00E+00	3.22E-04	4.38E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.60E-06	2.40E-09	1.10E-09	2.40E-09	1.10E-09	0.00E+00	1.18E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	5.07E-07	2.24E-09	1.03E-09	4.62E-09	2.12E-09	0.00E+00	2.01E-04	4.39E-05	1.65E-03	**1.90E-03**
	Uranium	4.62E-07	8.11E-09	3.71E-08	4.21E-09	1.93E-08	0.00E+00	7.09E-07	2.86E-05	3.52E-05	**6.50E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.83E-08	3.58E-07	0.00E+00	1.44E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.02E-05	1.11E-07	5.09E-07	7.05E-08	3.23E-07	0.00E+00	1.48E-03	1.07E-02	1.33E-01	**1.46E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	4.06E-10	8.88E-15	3.77E-15	2.81E-12	1.29E-12	0.00E+00	2.84E-10	2.50E-11	3.04E-09	**3.76E-09**
	Chromium	2.09E-08	0.00E+00	0.00E+00	1.12E-10	5.11E-10	0.00E+00	2.68E-07	0.00E+00	1.16E-07	**4.05E-07**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Cobalt	1.77E-08	3.81E-13	1.75E-13	2.10E-11	9.61E-12	0.00E+00	4.98E-08	1.40E-08	1.68E-07	**2.49E-07**
	Copper	2.71E-08	1.20E-12	3.29E-12	3.83E-11	1.05E-10	0.00E+00	3.16E-06	5.02E-07	2.65E-06	**6.34E-06**
	Molybdenum	3.18E-08	0.00E+00	0.00E+00	4.76E-11	2.18E-11	0.00E+00	7.43E-10	0.00E+00	4.33E-08	**7.59E-08**
	Selenium	3.15E-08	1.55E-15	6.66E-16	2.87E-10	1.31E-10	0.00E+00	3.31E-05	1.06E-10	5.14E-06	**3.83E-05**
	Uranium	1.97E-08	1.17E-10	5.34E-10	1.79E-10	8.21E-10	0.00E+00	9.16E-08	1.25E-06	4.54E-08	**1.41E-06**
	Vanadium	2.54E-09	5.76E-13	2.67E-12	9.29E-11	4.25E-10	0.00E+00	5.66E-08	7.05E-11	5.72E-08	**1.17E-07**
	Zinc	1.79E-07	7.46E-13	3.41E-12	1.24E-09	5.66E-09	0.00E+00	8.33E-05	1.97E-07	3.81E-05	**1.22E-04**
Rec F/H One-year-old (McGowan Lake)		**Baseline Dose**									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.77E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.52E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.38E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.31E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.94E-07	5.22E-07	6.26E-08	2.63E-07	3.16E-08	0.00E+00	5.85E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.11E-06	6.12E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.53E-06	5.42E-07	0.00E+00	1.33E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.81E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.80E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.55E-06	4.53E-06	5.42E-07	2.68E-06	3.21E-07	0.00E+00	2.81E-05	2.58E-05	1.77E-05	**8.82E-05**
	Cobalt	1.68E-06	3.63E-07	4.35E-09	1.16E-07	1.39E-09	0.00E+00	1.23E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.44E-07	6.07E-08	0.00E+00	3.05E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.79E-06	1.57E-07	1.88E-09	1.57E-07	1.88E-09	0.00E+00	1.11E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.66E-07	1.47E-07	1.76E-09	3.02E-07	3.62E-09	0.00E+00	1.90E-04	1.03E-04	4.13E-03	**4.43E-03**
	Uranium	5.16E-07	5.30E-07	6.35E-08	2.75E-07	3.30E-08	0.00E+00	6.72E-07	6.55E-05	9.11E-05	**1.59E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.12E-06	6.13E-07	0.00E+00	1.36E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.14E-05	7.26E-06	8.70E-07	4.61E-06	5.52E-07	0.00E+00	1.41E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Future Centuries									

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Cadmium	4.54E-10	5.68E-13	6.66E-15	1.84E-10	2.20E-12	0.00E+00	2.69E-10	5.64E-11	2.10E-09	**3.06E-09**
	Chromium	2.33E-08	0.00E+00	0.00E+00	7.30E-09	8.75E-10	0.00E+00	2.54E-07	0.00E+00	7.68E-08	**3.62E-07**
	Cobalt	1.98E-08	2.49E-11	2.98E-13	1.37E-09	1.64E-11	0.00E+00	4.72E-08	3.29E-08	9.69E-08	**1.98E-07**
	Copper	3.02E-08	7.82E-11	5.61E-12	2.50E-09	1.80E-10	0.00E+00	3.00E-06	1.18E-06	1.62E-06	**5.83E-06**
	Molybdenum	3.55E-08	0.00E+00	0.00E+00	3.11E-09	3.73E-11	0.00E+00	7.04E-10	0.00E+00	2.47E-08	**6.40E-08**
	Selenium	3.51E-08	9.95E-14	1.22E-15	1.88E-08	2.25E-10	0.00E+00	3.14E-05	2.47E-10	3.35E-06	**3.48E-05**
	Uranium	2.20E-08	7.63E-09	9.14E-10	1.17E-08	1.40E-09	0.00E+00	8.68E-08	2.95E-06	3.30E-08	**3.11E-06**
	Vanadium	2.84E-09	3.87E-11	4.55E-12	6.07E-09	7.27E-10	0.00E+00	5.36E-08	1.65E-10	3.18E-08	**9.53E-08**
	Zinc	1.99E-07	4.77E-11	5.80E-12	8.07E-08	9.68E-09	0.00E+00	7.89E-05	4.62E-07	1.93E-05	**9.89E-05**
Rec F/H (Russell Lake)		Baseline Dose									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.15E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.63E-06	6.93E-08	3.17E-07	4.09E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.91E-05**
	Cobalt	1.49E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.75E-07	2.24E-09	1.03E-09	4.34E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.42E-07	8.00E-09	3.66E-08	4.03E-09	1.85E-08	0.00E+00	6.18E-07	2.73E-05	3.52E-05	**6.36E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	1.43E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.00E-05	1.11E-07	5.09E-07	6.93E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.17E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.65E-06	6.93E-08	3.17E-07	4.10E-08	1.87E-07	0.00E+00	2.96E-05	1.12E-05	3.04E-05	**7.94E-05**
	Cobalt	1.50E-06	5.55E-09	2.54E-09	1.77E-09	8.11E-10	0.00E+00	1.29E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.12E-06	3.05E-08	8.37E-08	1.29E-08	3.55E-08	0.00E+00	3.21E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.60E-06	2.40E-09	1.10E-09	2.39E-09	1.09E-09	0.00E+00	1.16E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.98E-07	2.24E-09	1.03E-09	4.55E-09	2.08E-09	0.00E+00	1.92E-04	4.39E-05	1.65E-03	**1.89E-03**
	Uranium	4.57E-07	8.03E-09	3.67E-08	4.16E-09	1.91E-08	0.00E+00	6.85E-07	2.76E-05	3.52E-05	**6.41E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	1.43E-05	7.20E-06	3.60E-04	**3.85E-04**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Zinc	1.01E-05	1.11E-07	5.09E-07	7.02E-08	3.21E-07	0.00E+00	1.46E-03	1.07E-02	1.33E-01	**1.46E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	3.02E-10	2.66E-15	1.11E-15	2.09E-12	9.55E-13	0.00E+00	2.11E-10	6.37E-12	2.27E-09	**2.79E-09**
	Chromium	1.56E-08	0.00E+00	0.00E+00	8.35E-11	3.82E-10	0.00E+00	2.00E-07	0.00E+00	8.78E-08	**3.04E-07**
	Cobalt	1.35E-08	9.81E-14	4.46E-14	1.60E-11	7.32E-12	0.00E+00	3.80E-08	3.59E-09	1.25E-07	**1.81E-07**
	Copper	2.06E-08	3.09E-13	8.53E-13	2.92E-11	8.02E-11	0.00E+00	2.41E-06	1.29E-07	1.74E-06	**4.30E-06**
	Molybdenum	2.42E-08	0.00E+00	0.00E+00	3.62E-11	1.66E-11	0.00E+00	5.66E-10	0.00E+00	3.28E-08	**5.77E-08**
	Selenium	2.31E-08	2.22E-16	1.11E-16	2.11E-10	9.65E-11	0.00E+00	2.44E-05	2.55E-11	3.82E-06	**2.82E-05**
	Uranium	1.44E-08	3.11E-11	1.42E-10	1.32E-10	6.03E-10	0.00E+00	6.73E-08	3.35E-07	3.04E-08	**4.48E-07**
	Vanadium	1.63E-09	1.42E-13	7.11E-13	5.94E-11	2.72E-10	0.00E+00	3.62E-08	1.77E-11	3.82E-08	**7.64E-08**
	Zinc	1.33E-07	1.92E-13	8.53E-13	9.17E-10	4.20E-09	0.00E+00	6.18E-05	5.03E-08	2.89E-05	**9.09E-05**
Rec F/H One-year-old (Russell Lake)		**Baseline Dose**									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.77E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.52E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.38E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.31E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.94E-07	5.22E-07	6.26E-08	2.63E-07	3.16E-08	0.00E+00	5.85E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.11E-06	6.12E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.53E-06	5.42E-07	0.00E+00	1.33E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.81E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.79E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.54E-06	4.53E-06	5.42E-07	2.68E-06	3.21E-07	0.00E+00	2.80E-05	2.58E-05	1.77E-05	**8.81E-05**
	Cobalt	1.67E-06	3.63E-07	4.35E-09	1.16E-07	1.39E-09	0.00E+00	1.22E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.44E-07	6.07E-08	0.00E+00	3.04E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.78E-06	1.57E-07	1.88E-09	1.56E-07	1.87E-09	0.00E+00	1.10E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.57E-07	1.47E-07	1.76E-09	2.97E-07	3.56E-09	0.00E+00	1.82E-04	1.03E-04	4.13E-03	**4.42E-03**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Uranium	5.10E-07	5.25E-07	6.29E-08	2.72E-07	3.26E-08	0.00E+00	6.49E-07	6.33E-05	9.10E-05	**1.56E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.11E-06	6.13E-07	0.00E+00	1.36E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.13E-05	7.26E-06	8.70E-07	4.59E-06	5.50E-07	0.00E+00	1.38E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	3.37E-10	1.71E-13	1.78E-15	1.36E-10	1.63E-12	0.00E+00	2.00E-10	1.46E-11	1.57E-09	**2.26E-09**
	Chromium	1.74E-08	0.00E+00	0.00E+00	5.46E-09	6.54E-10	0.00E+00	1.90E-07	0.00E+00	5.81E-08	**2.71E-07**
	Cobalt	1.51E-08	6.39E-12	7.64E-14	1.05E-09	1.25E-11	0.00E+00	3.60E-08	8.44E-09	7.26E-08	**1.33E-07**
	Copper	2.30E-08	2.00E-11	1.45E-12	1.91E-09	1.37E-10	0.00E+00	2.28E-06	3.04E-07	1.09E-06	**3.70E-06**
	Molybdenum	2.70E-08	0.00E+00	0.00E+00	2.37E-09	2.84E-11	0.00E+00	5.36E-10	0.00E+00	1.91E-08	**4.91E-08**
	Selenium	2.58E-08	1.42E-14	2.22E-16	1.38E-08	1.65E-10	0.00E+00	2.31E-05	6.55E-11	2.49E-06	**2.56E-05**
	Uranium	1.61E-08	2.03E-09	2.44E-10	8.61E-09	1.03E-09	0.00E+00	6.37E-08	7.87E-07	2.25E-08	**9.01E-07**
	Vanadium	1.82E-09	1.00E-11	1.19E-12	3.88E-09	4.65E-10	0.00E+00	3.43E-08	4.18E-11	2.11E-08	**6.16E-08**
	Zinc	1.48E-07	1.23E-11	1.53E-12	5.99E-08	7.18E-09	0.00E+00	5.85E-05	1.21E-07	1.46E-05	**7.35E-05**
Seasonal Resident (Russell Lake)		**Baseline Dose**									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.15E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.63E-06	6.93E-08	3.17E-07	4.09E-08	1.87E-07	0.00E+00	2.94E-05	1.12E-05	3.03E-05	**7.91E-05**
	Cobalt	1.49E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	1.25E-06	6.29E-05	1.77E-04	**2.42E-04**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	3.19E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	1.10E-08	5.17E-05	2.41E-03	**2.47E-03**
	Sulphate	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
	Selenium	4.75E-07	2.24E-09	1.03E-09	4.34E-09	1.98E-09	0.00E+00	1.68E-04	4.39E-05	1.65E-03	**1.86E-03**
	Uranium	4.42E-07	8.00E-09	3.66E-08	4.03E-09	1.85E-08	0.00E+00	6.18E-07	2.73E-05	3.52E-05	**6.36E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	1.43E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.00E-05	1.11E-07	5.09E-07	6.93E-08	3.17E-07	0.00E+00	1.40E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	7.16E-08	7.02E-06	1.99E-04	**2.06E-04**
	Chromium	7.65E-06	6.93E-08	3.17E-07	4.10E-08	1.87E-07	0.00E+00	2.95E-05	1.12E-05	3.03E-05	**7.92E-05**
	Cobalt	1.50E-06	5.55E-09	2.54E-09	1.77E-09	8.11E-10	0.00E+00	1.26E-06	6.29E-05	1.77E-04	**2.42E-04**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Copper	9.12E-06	3.05E-08	8.37E-08	1.29E-08	3.55E-08	0.00E+00	3.20E-04	4.37E-03	2.55E-02	**3.02E-02**
	Molybdenum	1.60E-06	2.40E-09	1.10E-09	2.39E-09	1.09E-09	0.00E+00	1.12E-08	5.17E-05	2.41E-03	**2.47E-03**
	Selenium	4.98E-07	2.24E-09	1.03E-09	4.55E-09	2.08E-09	0.00E+00	1.75E-04	4.39E-05	1.65E-03	**1.87E-03**
	Uranium	4.57E-07	8.03E-09	3.67E-08	4.16E-09	1.91E-08	0.00E+00	6.38E-07	2.74E-05	3.52E-05	**6.38E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	1.43E-05	7.20E-06	3.60E-04	**3.85E-04**
	Zinc	1.01E-05	1.11E-07	5.09E-07	7.02E-08	3.21E-07	0.00E+00	1.42E-03	1.07E-02	1.33E-01	**1.45E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	3.02E-10	2.66E-15	1.11E-15	2.09E-12	9.55E-13	0.00E+00	6.33E-11	1.82E-12	7.13E-10	**1.08E-09**
	Chromium	1.56E-08	0.00E+00	0.00E+00	8.35E-11	3.82E-10	0.00E+00	6.01E-08	0.00E+00	2.85E-08	**1.05E-07**
	Cobalt	1.35E-08	9.81E-14	4.46E-14	1.60E-11	7.32E-12	0.00E+00	1.14E-08	1.08E-09	3.73E-08	**6.33E-08**
	Copper	2.06E-08	3.09E-13	8.53E-13	2.92E-11	8.02E-11	0.00E+00	7.23E-07	3.86E-08	5.22E-07	**1.30E-06**
	Molybdenum	2.42E-08	0.00E+00	0.00E+00	3.62E-11	1.66E-11	0.00E+00	1.70E-10	0.00E+00	9.78E-09	**3.42E-08**
	Selenium	2.31E-08	2.22E-16	1.11E-16	2.11E-10	9.65E-11	0.00E+00	7.31E-06	7.28E-12	1.22E-06	**8.56E-06**
	Uranium	1.44E-08	3.11E-11	1.42E-10	1.32E-10	6.03E-10	0.00E+00	2.02E-08	1.00E-07	9.43E-09	**1.45E-07**
	Vanadium	1.63E-09	1.42E-13	7.11E-13	5.94E-11	2.72E-10	0.00E+00	1.09E-08	5.00E-12	1.33E-08	**2.61E-08**
	Zinc	1.33E-07	1.92E-13	8.53E-13	9.17E-10	4.20E-09	0.00E+00	1.85E-05	1.49E-08	9.63E-06	**2.83E-05**
Seasonal Resident One-year-old (Russell Lake)		**Baseline Dose**									
	Cadmium	3.80E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.77E-08	1.57E-05	5.03E-04	**5.20E-04**
	Chromium	8.52E-06	4.53E-06	5.42E-07	2.67E-06	3.20E-07	0.00E+00	2.78E-05	2.58E-05	1.76E-05	**8.78E-05**
	Cobalt	1.66E-06	3.63E-07	4.35E-09	1.15E-07	1.38E-09	0.00E+00	1.18E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.42E-07	6.05E-08	0.00E+00	3.02E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.75E-06	1.57E-07	1.88E-09	1.54E-07	1.84E-09	0.00E+00	1.04E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.31E-07	1.47E-07	1.76E-09	2.83E-07	3.39E-09	0.00E+00	1.59E-04	1.03E-04	4.13E-03	**4.39E-03**
	Uranium	4.94E-07	5.22E-07	6.26E-08	2.63E-07	3.16E-08	0.00E+00	5.85E-07	6.25E-05	9.10E-05	**1.55E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.11E-06	6.12E-07	0.00E+00	1.35E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.12E-05	7.26E-06	8.70E-07	4.53E-06	5.42E-07	0.00E+00	1.33E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Total Dose - Future Centuries									
	Cadmium	3.81E-07	4.93E-07	5.91E-09	1.54E-07	1.85E-09	0.00E+00	6.78E-08	1.57E-05	5.03E-04	**5.20E-04**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Chromium	8.54E-06	4.53E-06	5.42E-07	2.68E-06	3.21E-07	0.00E+00	2.79E-05	2.58E-05	1.76E-05	**8.79E-05**
	Cobalt	1.67E-06	3.63E-07	4.35E-09	1.16E-07	1.39E-09	0.00E+00	1.19E-06	1.46E-04	3.78E-04	**5.27E-04**
	Copper	1.02E-05	1.99E-06	1.43E-07	8.44E-07	6.07E-08	0.00E+00	3.03E-04	1.01E-02	4.29E-02	**5.33E-02**
	Molybdenum	1.78E-06	1.57E-07	1.88E-09	1.56E-07	1.87E-09	0.00E+00	1.06E-08	1.20E-04	6.29E-03	**6.41E-03**
	Selenium	5.57E-07	1.47E-07	1.76E-09	2.97E-07	3.56E-09	0.00E+00	1.66E-04	1.03E-04	4.13E-03	**4.40E-03**
	Uranium	5.10E-07	5.25E-07	6.29E-08	2.72E-07	3.26E-08	0.00E+00	6.04E-07	6.27E-05	9.10E-05	**1.56E-04**
	Vanadium	2.39E-06	6.58E-06	7.89E-07	5.11E-06	6.13E-07	0.00E+00	1.36E-05	1.30E-05	8.78E-04	**9.20E-04**
	Zinc	1.13E-05	7.26E-06	8.70E-07	4.59E-06	5.50E-07	0.00E+00	1.34E-03	2.45E-02	2.76E-01	**3.02E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	3.37E-10	1.71E-13	1.78E-15	1.36E-10	1.63E-12	0.00E+00	5.99E-11	3.64E-12	4.66E-10	**1.00E-09**
	Chromium	1.74E-08	0.00E+00	0.00E+00	5.46E-09	6.54E-10	0.00E+00	5.69E-08	0.00E+00	1.82E-08	**9.86E-08**
	Cobalt	1.51E-08	6.39E-12	7.64E-14	1.05E-09	1.25E-11	0.00E+00	1.08E-08	2.52E-09	2.08E-08	**5.03E-08**
	Copper	2.30E-08	2.00E-11	1.45E-12	1.91E-09	1.37E-10	0.00E+00	6.84E-07	9.22E-08	3.13E-07	**1.11E-06**
	Molybdenum	2.70E-08	0.00E+00	0.00E+00	2.37E-09	2.84E-11	0.00E+00	1.61E-10	0.00E+00	5.59E-09	**3.52E-08**
	Selenium	2.58E-08	1.42E-14	2.22E-16	1.38E-08	1.65E-10	0.00E+00	6.93E-06	2.18E-11	7.66E-07	**7.73E-06**
	Uranium	1.61E-08	2.03E-09	2.44E-10	8.61E-09	1.03E-09	0.00E+00	1.91E-08	2.36E-07	6.59E-09	**2.90E-07**
	Vanadium	1.82E-09	1.00E-11	1.19E-12	3.88E-09	4.65E-10	0.00E+00	1.03E-08	1.18E-11	7.39E-09	**2.39E-08**
	Zinc	1.48E-07	1.23E-11	1.53E-12	5.99E-08	7.18E-09	0.00E+00	1.76E-05	3.54E-08	5.07E-06	**2.29E-05**
Fisher/Trapper (Russell Lake)		Baseline Dose									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	4.92E-07	0.00E+00	1.61E-04	**1.62E-04**
	Chromium	7.63E-06	6.93E-08	3.17E-07	4.09E-08	1.87E-07	0.00E+00	2.02E-04	0.00E+00	8.27E-04	**1.04E-03**
	Cobalt	1.49E-06	5.55E-09	2.54E-09	1.76E-09	8.04E-10	0.00E+00	8.61E-06	0.00E+00	7.79E-05	**8.80E-05**
	Copper	9.09E-06	3.05E-08	8.37E-08	1.29E-08	3.54E-08	0.00E+00	2.20E-03	0.00E+00	1.19E-02	**1.41E-02**
	Molybdenum	1.57E-06	2.40E-09	1.10E-09	2.35E-09	1.08E-09	0.00E+00	7.59E-08	0.00E+00	1.28E-03	**1.28E-03**
	Selenium	4.75E-07	2.24E-09	1.03E-09	4.34E-09	1.98E-09	0.00E+00	1.16E-03	0.00E+00	1.58E-03	**2.74E-03**
	Uranium	4.42E-07	8.00E-09	3.66E-08	4.03E-09	1.85E-08	0.00E+00	4.25E-06	0.00E+00	2.19E-05	**2.66E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.82E-08	3.58E-07	0.00E+00	9.85E-05	0.00E+00	7.72E-04	**8.74E-04**
	Zinc	1.00E-05	1.11E-07	5.09E-07	6.93E-08	3.17E-07	0.00E+00	9.64E-03	0.00E+00	3.08E-01	**3.18E-01**

Human Receptor	COPC	Maximum Dose by Pathway during Future Centuries (mg/kg/d)									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		Project Total Dose - Future Centuries									
	Cadmium	3.41E-07	7.55E-09	3.46E-09	2.36E-09	1.08E-09	0.00E+00	4.94E-07	0.00E+00	1.61E-04	**1.62E-04**
	Chromium	7.66E-06	6.93E-08	3.17E-07	4.10E-08	1.88E-07	0.00E+00	2.04E-04	0.00E+00	8.27E-04	**1.04E-03**
	Cobalt	1.51E-06	5.55E-09	2.54E-09	1.78E-09	8.16E-10	0.00E+00	8.87E-06	0.00E+00	7.79E-05	**8.83E-05**
	Copper	9.13E-06	3.05E-08	8.37E-08	1.29E-08	3.55E-08	0.00E+00	2.21E-03	0.00E+00	1.19E-02	**1.42E-02**
	Molybdenum	1.61E-06	2.40E-09	1.10E-09	2.41E-09	1.10E-09	0.00E+00	7.98E-08	0.00E+00	1.28E-03	**1.28E-03**
	Selenium	5.14E-07	2.24E-09	1.03E-09	4.69E-09	2.15E-09	0.00E+00	1.32E-03	0.00E+00	1.59E-03	**2.92E-03**
	Uranium	4.66E-07	8.05E-09	3.68E-08	4.25E-09	1.95E-08	0.00E+00	4.72E-06	0.00E+00	2.19E-05	**2.72E-05**
	Vanadium	2.14E-06	1.01E-07	4.61E-07	7.83E-08	3.58E-07	0.00E+00	9.87E-05	0.00E+00	7.73E-04	**8.74E-04**
	Zinc	1.02E-05	1.11E-07	5.09E-07	7.08E-08	3.24E-07	0.00E+00	1.01E-02	0.00E+00	3.08E-01	**3.18E-01**
		Project Incremental Dose - Future Centuries									
	Cadmium	5.03E-10	3.55E-15	1.55E-15	3.48E-12	1.59E-12	0.00E+00	1.45E-09	0.00E+00	6.43E-09	**8.39E-09**
	Chromium	2.60E-08	0.00E+00	0.00E+00	1.39E-10	6.37E-10	0.00E+00	1.38E-06	0.00E+00	3.77E-07	**1.78E-06**
	Cobalt	2.26E-08	1.63E-13	7.46E-14	2.67E-11	1.22E-11	0.00E+00	2.61E-07	0.00E+00	2.61E-08	**3.10E-07**
	Copper	3.43E-08	5.15E-13	1.41E-12	4.87E-11	1.34E-10	0.00E+00	1.66E-05	0.00E+00	1.07E-06	**1.77E-05**
	Molybdenum	4.03E-08	0.00E+00	0.00E+00	6.04E-11	2.76E-11	0.00E+00	3.90E-09	0.00E+00	1.84E-08	**6.27E-08**
	Selenium	3.85E-08	6.66E-16	3.33E-16	3.51E-10	1.61E-10	0.00E+00	1.68E-04	0.00E+00	1.31E-05	**1.81E-04**
	Uranium	2.41E-08	5.19E-11	2.37E-10	2.20E-10	1.00E-09	0.00E+00	4.63E-07	0.00E+00	5.65E-08	**5.45E-07**
	Vanadium	2.71E-09	2.49E-13	1.14E-12	9.89E-11	4.53E-10	0.00E+00	2.49E-07	0.00E+00	3.16E-07	**5.68E-07**
	Zinc	2.21E-07	3.13E-13	1.42E-12	1.53E-09	7.00E-09	0.00E+00	4.25E-04	0.00E+00	1.78E-04	**6.04E-04**

COPC = constituent of potential concern.

4.2.5.1.2 Carcinogen Dose

Arsenic was evaluated in the HHRA as a non-threshold carcinogen (i.e., a linear dose-response relationship); therefore, predicted exposure was averaged over the receptor's lifetime to estimate a lifetime average daily dose representing a combination of all life stages (Health Canada, 2021a). For this assessment, the lifetime average daily dose was estimated for various age groups (toddler, child, teen, adult) to permit estimation of the lifetime risk to a composite receptor for each of the recreational fisher/hunter, and seasonal resident (Table 4-7) for the Project phases. Therefore, a composite receptor was calculated assuming 4.5 years as a toddler, 7 years as a child, 8 years as a teen and 60 years as an adult. For the camp worker, an adult receptor was considered appropriate. The composite receptor represents a person exposed to the constituent throughout all stages of a lifetime. The lifetime average daily dose was estimated during the future centuries for a permanent resident, recreational fisher/hunter, seasonal resident, and fisher/trapper (Table 4-8).

Cadmium is considered a carcinogen due to inhalation exposure; however, since cadmium has not been identified as an air COPC, cadmium is not evaluated separately as a carcinogen.

Table 4-7: Estimated Carcinogen Doses for Arsenic to Human Receptors – Project Phases

	Lifetime Average Daily Dose (mg/kg/d)				
Age Group	**Camp Worker**	**Recreational Fisher/Hunter (LA-1)**	**Recreational Fisher/Hunter (Russell Lake)**	**Seasonal Resident (Russell Lake)**	**Fisher/Trapper (Russell Lake)**
1-year-old	n/a	8.81E-08	5.21E-08	1.56E-08	n/a
Child	n/a	2.04E-07	1.21E-07	3.63E-08	n/a
Teen	n/a	1.71E-07	1.03E-07	3.09E-08	n/a
Adult	5.54E-07	1.94E-06	1.17E-06	3.51E-07	6.55E-06

n/a = not applicable, life stage was not assessed for the receptor.

Table 4-8: Estimated Carcinogen Doses for Arsenic to Human Receptors – Future Centuries

	Lifetime Average Daily Dose (mg/kg/d)				
Age Group	**Permanent Resident (LA-5)**	**Recreational Fisher/Hunter (LA-1)**	**Recreational Fisher/Hunter (Russell Lake)**	**Seasonal Resident (Russell Lake)**	**Fisher/Trapper (Russell Lake)**
1-year-old	2.65E-08	1.26E-08	8.12E-09	2.43E-09	n/a
Child	6.13E-08	2.92E-08	1.89E-08	5.66E-09	n/a
Teen	5.03E-08	2.42E-08	1.57E-08	4.70E-09	n/a
Adult	5.65E-07	2.72E-07	1.76E-07	5.29E-08	9.67E-07

n/a = not applicable, life stage was not assessed for the receptor.

4.2.5.2 Radiological Dose

The estimated radiological doses to human receptors due to releases from the Project during all phases is presented in Table 4-9, and in the future centuries in Table 4-10. The doses shown represent the maximum annual dose over the assessment period. The tables present the dose breakdown by radionuclide and exposure pathway, as well as the total dose. The radiation dose is presented as an incremental dose (i.e., only considering Project effects) because the dose limit is an incremental value.

During the Project phases, the maximum predicted incremental dose is 0.06 mSv/yr for the fisher/trapper (adult) who fishes in the embayment at the inlet to Russell Lake and hunts in the area around Russell Lake. The main contribution to total dose is from polonium-210 from eating local fish (white sucker and northern pike). During the future centuries, the maximum predicted incremental dose is 0.04 mSv/yr for the permanent resident (one-year old) who lives on the former Project site and fishes and hunts around Whitefish Lake. The main contribution to total dose is from polonium-210 from consuming terrestrial animals hunted in the area.

Table 4-9: Estimated Radiological Doses to Human Receptor – Project Phases

Human Receptor	COPC	Maximum Incremental Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Camp Worker Adult (Whitefish Lake)	**Uranium-238**	1.83E-03	5.02E-12	5.69E-05	4.32E-10	1.95E-07	2.16E-03	3.28E-07	3.50E-06	0.00E+00	4.35E-05	2.38E-04	3.59E-05	**4.37E-03**
	Uranium-234	2.21E-03	1.23E-11	6.20E-05	7.53E-11	2.12E-07	1.09E-05	3.58E-07	1.27E-08	0.00E+00	4.73E-05	2.60E-04	3.90E-05	**2.63E-03**
	Thorium-230	0.00E+00	0.00E+00	3.40E-04	2.30E-10	1.99E-10	3.06E-09	2.85E-07	7.05E-09	0.00E+00	9.20E-05	2.97E-08	4.31E-04	**8.63E-04**
	Radium-226	0.00E+00	0.00E+00	6.14E-05	2.74E-08	1.82E-12	4.10E-08	2.68E-07	3.21E-05	0.00E+00	3.31E-05	4.66E-09	1.08E-05	**1.38E-04**
	Lead-210	0.00E+00	0.00E+00	4.82E-04	4.24E-10	0.00E+00	0.00E+00	1.15E-05	6.48E-07	0.00E+00	7.32E-04	0.00E+00	1.30E-03	**2.52E-03**
	Polonium-210	0.00E+00	0.00E+00	5.39E-04	1.62E-12	0.00E+00	0.00E+00	1.94E-05	2.66E-09	0.00E+00	2.04E-03	0.00E+00	1.21E-02	**1.47E-02**
	Total by Pathway	**4.03E-03**	**1.73E-11**	**1.54E-03**	**2.86E-08**	**4.07E-07**	**2.17E-03**	**3.21E-05**	**3.63E-05**	**0.00E+00**	**2.98E-03**	**4.98E-04**	**1.39E-02**	**2.52E-02**
Rec F/H Adult (McGowan Lake)	**Uranium-238**	2.84E-04	7.80E-13	1.92E-05	1.46E-10	2.97E-08	3.29E-04	1.25E-07	1.34E-06	0.00E+00	8.69E-05	4.77E-04	7.19E-05	**1.27E-03**
	Uranium-234	3.43E-04	1.91E-12	2.09E-05	2.54E-11	3.23E-08	1.66E-06	1.36E-07	4.85E-09	0.00E+00	9.47E-05	5.19E-04	7.82E-05	**1.06E-03**
	Thorium-230	0.00E+00	0.00E+00	1.31E-04	8.84E-11	3.00E-11	4.62E-10	1.24E-07	3.06E-09	0.00E+00	1.84E-04	5.94E-08	8.57E-04	**1.17E-03**
	Radium-226	0.00E+00	0.00E+00	3.21E-05	1.43E-08	2.27E-13	7.45E-09	1.09E-07	1.31E-05	0.00E+00	6.62E-05	9.31E-09	2.15E-05	**1.33E-04**
	Lead-210	0.00E+00	0.00E+00	2.92E-04	2.58E-10	0.00E+00	0.00E+00	2.63E-06	1.49E-07	0.00E+00	1.47E-03	0.00E+00	2.58E-03	**4.34E-03**
	Polonium-210	0.00E+00	0.00E+00	4.39E-04	1.32E-12	0.00E+00	0.00E+00	4.49E-06	6.16E-10	0.00E+00	4.07E-03	0.00E+00	2.45E-02	**2.90E-02**
	Total by Pathway	**6.28E-04**	**2.69E-12**	**9.34E-04**	**1.49E-08**	**6.20E-08**	**3.31E-04**	**7.61E-06**	**1.46E-05**	**0.00E+00**	**5.97E-03**	**9.96E-04**	**2.81E-02**	**3.70E-02**
Rec F/H One-year-old (McGowan Lake)	**Uranium-238**	2.84E-04	1.01E-12	1.33E-05	3.60E-11	1.21E-06	4.40E-04	5.10E-06	1.74E-06	0.00E+00	5.12E-05	5.90E-04	2.82E-05	**1.41E-03**
	Uranium-234	3.32E-04	2.48E-12	1.44E-05	6.28E-12	1.31E-06	2.22E-06	5.52E-06	6.30E-09	0.00E+00	5.55E-05	6.39E-04	3.06E-05	**1.08E-03**
	Thorium-230	0.00E+00	0.00E+00	6.64E-05	2.19E-11	9.02E-10	5.24E-10	3.68E-06	3.97E-09	0.00E+00	7.94E-05	6.37E-08	2.06E-04	**3.55E-04**
	Radium-226	0.00E+00	0.00E+00	2.87E-05	3.55E-09	1.46E-11	7.45E-09	5.70E-06	1.71E-05	0.00E+00	5.01E-05	2.24E-08	8.82E-06	**1.10E-04**
	Lead-210	0.00E+00	0.00E+00	3.97E-04	5.22E-11	0.00E+00	0.00E+00	2.09E-04	1.93E-07	0.00E+00	1.69E-03	0.00E+00	1.66E-03	**3.96E-03**
	Polonium-210	0.00E+00	0.00E+00	8.39E-04	3.27E-13	0.00E+00	0.00E+00	5.02E-04	8.00E-10	0.00E+00	6.60E-03	0.00E+00	3.21E-02	**4.00E-02**

Human Receptor	COPC	Maximum Incremental Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
	Total by Pathway	**6.15E-04**	**3.50E-12**	**1.36E-03**	**3.67E-09**	**2.51E-06**	**4.43E-04**	**7.31E-04**	**1.90E-05**	**0.00E+00**	**8.53E-03**	**1.23E-03**	**3.40E-02**	**4.69E-02**
Rec F/H Adult (Russell Lake)														
	Uranium-238	7.60E-05	2.08E-13	1.38E-05	1.05E-10	7.92E-09	8.79E-05	9.15E-08	9.76E-07	0.00E+00	6.27E-05	1.27E-04	4.23E-05	**4.11E-04**
	Uranium-234	9.17E-05	5.10E-13	1.50E-05	1.82E-11	8.63E-09	4.43E-07	9.97E-08	3.54E-09	0.00E+00	6.83E-05	1.39E-04	4.60E-05	**3.60E-04**
	Thorium-230	0.00E+00	0.00E+00	9.75E-05	6.61E-11	7.73E-12	1.20E-10	9.40E-08	2.32E-09	0.00E+00	1.39E-04	1.59E-08	6.45E-04	**8.81E-04**
	Radium-226	0.00E+00	0.00E+00	2.75E-05	1.23E-08	0.00E+00	0.00E+00	8.11E-08	9.72E-06	0.00E+00	4.99E-05	1.86E-09	1.66E-05	**1.04E-04**
	Lead-210	0.00E+00	0.00E+00	2.71E-04	2.39E-10	0.00E+00	0.00E+00	1.60E-06	9.03E-08	0.00E+00	1.17E-03	0.00E+00	2.03E-03	**3.47E-03**
	Polonium-210	0.00E+00	0.00E+00	4.30E-04	1.29E-12	0.00E+00	0.00E+00	2.72E-06	3.74E-10	0.00E+00	3.66E-03	0.00E+00	1.48E-02	**1.89E-02**
	Total by Pathway	**1.68E-04**	**7.18E-13**	**8.55E-04**	**1.27E-08**	**1.66E-08**	**8.83E-05**	**4.69E-06**	**1.08E-05**	**0.00E+00**	**5.15E-03**	**2.66E-04**	**1.76E-02**	**2.42E-02**
Rec F/H One-year-old (Russell Lake)														
	Uranium-238	7.57E-05	2.71E-13	9.58E-06	2.58E-11	3.22E-07	1.18E-04	3.72E-06	1.27E-06	0.00E+00	3.69E-05	1.57E-04	1.65E-05	**4.19E-04**
	Uranium-234	8.86E-05	6.63E-13	1.04E-05	4.51E-12	3.49E-07	5.93E-07	4.03E-06	4.60E-09	0.00E+00	4.00E-05	1.71E-04	1.79E-05	**3.32E-04**
	Thorium-230	0.00E+00	0.00E+00	4.96E-05	1.64E-11	2.40E-10	1.42E-10	2.80E-06	3.02E-09	0.00E+00	5.98E-05	1.70E-08	1.55E-04	**2.67E-04**
	Radium-226	0.00E+00	0.00E+00	2.46E-05	3.04E-09	0.00E+00	0.00E+00	4.24E-06	1.27E-05	0.00E+00	3.78E-05	3.73E-09	6.80E-06	**8.61E-05**
	Lead-210	0.00E+00	0.00E+00	3.68E-04	4.84E-11	0.00E+00	0.00E+00	1.27E-04	1.17E-07	0.00E+00	1.35E-03	0.00E+00	1.30E-03	**3.15E-03**
	Polonium-210	0.00E+00	0.00E+00	8.22E-04	3.20E-13	0.00E+00	0.00E+00	3.05E-04	4.86E-10	0.00E+00	5.94E-03	0.00E+00	1.94E-02	**2.64E-02**
	Total by Pathway	**1.64E-04**	**9.34E-13**	**1.28E-03**	**3.14E-09**	**6.71E-07**	**1.18E-04**	**4.46E-04**	**1.41E-05**	**0.00E+00**	**7.46E-03**	**3.28E-04**	**2.09E-02**	**3.07E-02**
Seasonal Resident Adult (Russell Lake)														
	Uranium-238	7.60E-05	2.08E-13	1.38E-05	1.05E-10	7.92E-09	8.79E-05	9.15E-08	9.76E-07	0.00E+00	1.86E-05	3.83E-05	1.91E-05	**2.55E-04**
	Uranium-234	9.17E-05	5.10E-13	1.50E-05	1.82E-11	8.63E-09	4.43E-07	9.97E-08	3.54E-09	0.00E+00	2.03E-05	4.18E-05	2.08E-05	**1.90E-04**
	Thorium-230	0.00E+00	0.00E+00	9.75E-05	6.61E-11	7.73E-12	1.20E-10	9.40E-08	2.32E-09	0.00E+00	4.05E-05	4.77E-09	1.85E-04	**3.23E-04**
	Radium-226	0.00E+00	0.00E+00	2.75E-05	1.23E-08	0.00E+00	0.00E+00	8.11E-08	9.72E-06	0.00E+00	2.17E-05	0.00E+00	7.15E-06	**6.62E-05**
	Lead-210	0.00E+00	0.00E+00	2.71E-04	2.39E-10	0.00E+00	0.00E+00	1.60E-06	9.03E-08	0.00E+00	1.01E-03	0.00E+00	1.67E-03	**2.96E-03**
	Polonium-210	0.00E+00	0.00E+00	4.30E-04	1.29E-12	0.00E+00	0.00E+00	2.72E-06	3.74E-10	0.00E+00	4.02E-03	0.00E+00	4.82E-03	**9.28E-03**

Human Receptor	COPC	Maximum Incremental Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
	Total by Pathway	**1.68E-04**	**7.18E-13**	**8.55E-04**	**1.27E-08**	**1.66E-08**	**8.83E-05**	**4.69E-06**	**1.08E-05**	**0.00E+00**	**5.13E-03**	**8.01E-05**	**6.73E-03**	**1.31E-02**
Seasonal Resident One-year-old (Russell Lake)	Uranium-238	7.57E-05	2.71E-13	9.58E-06	2.58E-11	3.22E-07	1.18E-04	3.72E-06	1.27E-06	0.00E+00	1.10E-05	4.71E-05	7.17E-06	**2.73E-04**
	Uranium-234	8.86E-05	6.63E-13	1.04E-05	4.51E-12	3.49E-07	5.93E-07	4.03E-06	4.60E-09	0.00E+00	1.19E-05	5.11E-05	7.77E-06	**1.75E-04**
	Thorium-230	0.00E+00	0.00E+00	4.96E-05	1.64E-11	2.40E-10	1.42E-10	2.80E-06	3.02E-09	0.00E+00	1.75E-05	5.12E-09	4.30E-05	**1.13E-04**
	Radium-226	0.00E+00	0.00E+00	2.46E-05	3.04E-09	0.00E+00	0.00E+00	4.24E-06	1.27E-05	0.00E+00	1.65E-05	3.73E-09	2.97E-06	**6.10E-05**
	Lead-210	0.00E+00	0.00E+00	3.68E-04	4.84E-11	0.00E+00	0.00E+00	1.27E-04	1.17E-07	0.00E+00	1.17E-03	0.00E+00	1.07E-03	**2.73E-03**
	Polonium-210	0.00E+00	0.00E+00	8.22E-04	3.20E-13	0.00E+00	0.00E+00	3.05E-04	4.86E-10	0.00E+00	6.52E-03	0.00E+00	5.86E-03	**1.35E-02**
	Total by Pathway	**1.64E-04**	**9.34E-13**	**1.28E-03**	**3.14E-09**	**6.71E-07**	**1.18E-04**	**4.46E-04**	**1.41E-05**	**0.00E+00**	**7.74E-03**	**9.82E-05**	**6.99E-03**	**1.69E-02**
Fisher/ Trapper Adult (Russell Lake)	Uranium-238	1.27E-04	3.47E-13	2.31E-05	1.76E-10	1.32E-08	1.46E-04	1.53E-07	1.63E-06	0.00E+00	4.32E-04	0.00E+00	1.08E-03	**1.81E-03**
	Uranium-234	1.53E-04	8.50E-13	2.52E-05	3.06E-11	1.44E-08	7.38E-07	1.66E-07	5.90E-09	0.00E+00	4.70E-04	0.00E+00	1.17E-03	**1.82E-03**
	Thorium-230	0.00E+00	0.00E+00	1.65E-04	1.12E-10	1.32E-11	2.04E-10	1.57E-07	3.88E-09	0.00E+00	9.53E-04	0.00E+00	6.56E-05	**1.18E-03**
	Radium-226	0.00E+00	0.00E+00	3.65E-05	1.63E-08	0.00E+00	0.00E+00	1.35E-07	1.62E-05	0.00E+00	3.43E-04	0.00E+00	1.04E-04	**5.00E-04**
	Lead-210	0.00E+00	0.00E+00	2.81E-04	2.47E-10	0.00E+00	0.00E+00	2.63E-06	1.49E-07	0.00E+00	8.06E-03	0.00E+00	2.25E-03	**1.06E-02**
	Polonium-210	0.00E+00	0.00E+00	4.15E-04	1.25E-12	0.00E+00	0.00E+00	4.48E-06	6.15E-10	0.00E+00	2.52E-02	0.00E+00	1.56E-02	**4.12E-02**
	Total by Pathway	**2.79E-04**	**1.20E-12**	**9.45E-04**	**1.68E-08**	**2.76E-08**	**1.47E-04**	**7.72E-06**	**1.80E-05**	**0.00E+00**	**3.55E-02**	**0.00E+00**	**2.02E-02**	**5.71E-02**

Table 4-10: Estimated Radiological Doses to Human Receptor – Future Centuries

Human Receptor	COPC	Maximum Incremental Dose by Pathway during Future Centuries (mSv/yr)										
		Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Permanent Resident Adult (Whitefish Lake)												
	Uranium-238	1.42E-06	1.07E-11	2.20E-08	2.44E-04	1.29E-08	1.38E-07	0.00E+00	1.98E-06	1.38E-04	1.48E-06	**3.87E-04**
	Uranium-234	1.54E-06	1.87E-12	2.40E-08	1.23E-06	1.41E-08	4.99E-10	0.00E+00	2.15E-06	1.50E-04	1.62E-06	**1.57E-04**
	Thorium-230	2.12E-05	1.44E-11	7.69E-10	1.18E-08	2.31E-08	5.71E-10	0.00E+00	8.93E-06	8.84E-07	3.11E-05	**6.22E-05**
	Radium-226	8.68E-05	3.87E-08	9.39E-11	2.43E-06	4.80E-07	5.75E-05	0.00E+00	7.28E-05	2.07E-06	2.40E-05	**2.46E-04**
	Lead-210	2.03E-04	1.79E-10	0.00E+00	0.00E+00	6.83E-06	3.86E-07	0.00E+00	8.12E-04	0.00E+00	7.09E-04	**1.73E-03**
	Polonium-210	3.59E-04	1.08E-12	0.00E+00	0.00E+00	1.21E-05	1.66E-09	0.00E+00	3.59E-03	0.00E+00	2.02E-02	**2.42E-02**
	Total by Pathway	**6.73E-04**	**3.89E-08**	**4.68E-08**	**2.48E-04**	**1.94E-05**	**5.81E-05**	**0.00E+00**	**4.49E-03**	**2.91E-04**	**2.10E-02**	**2.67E-02**
Permanent Resident One-year-old (Whitefish Lake)												
	Uranium-238	9.84E-07	2.66E-12	8.95E-07	3.27E-04	5.25E-07	1.79E-07	0.00E+00	1.17E-06	2.02E-04	6.43E-07	**5.33E-04**
	Uranium-234	1.07E-06	4.64E-13	9.70E-07	1.65E-06	5.69E-07	6.49E-10	0.00E+00	1.26E-06	2.19E-04	6.97E-07	**2.25E-04**
	Thorium-230	1.08E-05	3.56E-12	2.29E-08	1.34E-08	6.88E-07	7.42E-10	0.00E+00	3.85E-06	9.46E-07	7.46E-06	**2.38E-05**
	Radium-226	7.75E-05	9.59E-09	4.90E-09	3.26E-06	2.51E-05	7.51E-05	0.00E+00	5.52E-05	3.90E-06	9.87E-06	**2.50E-04**
	Lead-210	2.76E-04	3.63E-11	0.00E+00	0.00E+00	5.43E-04	5.02E-07	0.00E+00	9.36E-04	0.00E+00	4.63E-04	**2.22E-03**
	Polonium-210	6.87E-04	2.68E-13	0.00E+00	0.00E+00	1.35E-03	2.15E-09	0.00E+00	5.82E-03	0.00E+00	2.65E-02	**3.43E-02**
	Total by Pathway	**1.05E-03**	**9.63E-09**	**1.89E-06**	**3.32E-04**	**1.92E-03**	**7.58E-05**	**0.00E+00**	**6.82E-03**	**4.26E-04**	**2.69E-02**	**3.76E-02**
Rec F/H Adult (McGowan Lake)												
	Uranium-238	2.82E-07	2.14E-12	1.67E-09	1.86E-05	2.57E-09	2.75E-08	0.00E+00	1.31E-06	1.80E-05	6.51E-07	**3.89E-05**
	Uranium-234	3.07E-07	3.73E-13	1.82E-09	9.36E-08	2.80E-09	9.95E-11	0.00E+00	1.43E-06	1.96E-05	7.09E-07	**2.22E-05**
	Thorium-230	4.78E-06	3.24E-12	5.84E-11	8.91E-10	5.20E-09	1.29E-10	0.00E+00	6.70E-06	1.15E-07	3.09E-05	**4.25E-05**
	Radium-226	1.82E-05	8.15E-09	7.05E-12	1.83E-07	1.01E-07	1.21E-05	0.00E+00	5.11E-05	2.68E-07	1.76E-05	**9.96E-05**
	Lead-210	2.31E-05	2.03E-11	0.00E+00	0.00E+00	7.76E-07	4.39E-08	0.00E+00	3.07E-04	0.00E+00	5.62E-04	**8.93E-04**
	Polonium-210	4.08E-05	1.23E-13	0.00E+00	0.00E+00	1.37E-06	1.88E-10	0.00E+00	1.36E-03	0.00E+00	7.67E-03	**9.07E-03**
	Total by Pathway	**8.75E-05**	**8.17E-09**	**3.56E-09**	**1.88E-05**	**2.26E-06**	**1.22E-05**	**0.00E+00**	**1.73E-03**	**3.80E-05**	**8.28E-03**	**1.02E-02**

Human Receptor	COPC	Maximum Incremental Dose by Pathway during Future Centuries (mSv/yr)										
		Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Rec F/H One-year-old (McGowan Lake)	Uranium-238	1.96E-07	5.30E-13	6.81E-08	2.48E-05	1.05E-07	3.57E-08	0.00E+00	7.75E-07	2.63E-05	2.95E-07	**5.27E-05**
	Uranium-234	2.13E-07	9.24E-14	7.38E-08	1.25E-07	1.13E-07	1.29E-10	0.00E+00	8.39E-07	2.85E-05	3.19E-07	**3.02E-05**
	Thorium-230	2.43E-06	8.02E-13	1.75E-09	1.02E-09	1.55E-07	1.67E-10	0.00E+00	2.89E-06	1.23E-07	7.40E-06	**1.30E-05**
	Radium-226	1.63E-05	2.02E-09	3.78E-10	2.46E-07	5.28E-06	1.58E-05	0.00E+00	3.87E-05	5.07E-07	7.27E-06	**8.41E-05**
	Lead-210	3.14E-05	4.13E-12	0.00E+00	0.00E+00	6.17E-05	5.71E-08	0.00E+00	3.55E-04	0.00E+00	3.63E-04	**8.10E-04**
	Polonium-210	7.80E-05	3.04E-14	0.00E+00	0.00E+00	1.54E-04	2.45E-10	0.00E+00	2.20E-03	0.00E+00	1.00E-02	**1.25E-02**
	Total by Pathway	**1.29E-04**	**2.02E-09**	**1.44E-07**	**2.52E-05**	**2.21E-04**	**1.59E-05**	**0.00E+00**	**2.60E-03**	**5.55E-05**	**1.04E-02**	**1.35E-02**
Rec F/H Adult (Russell Lake)	Uranium-238	2.07E-07	1.57E-12	4.47E-10	4.95E-06	1.89E-09	2.02E-08	0.00E+00	9.65E-07	4.80E-06	4.36E-07	**1.14E-05**
	Uranium-234	2.26E-07	2.74E-13	4.86E-10	2.50E-08	2.06E-09	7.31E-11	0.00E+00	1.05E-06	5.23E-06	4.74E-07	**7.01E-06**
	Thorium-230	3.64E-06	2.47E-12	1.55E-11	2.40E-10	3.97E-09	9.81E-11	0.00E+00	5.11E-06	3.07E-08	2.35E-05	**3.23E-05**
	Radium-226	1.36E-05	6.08E-09	1.82E-12	4.84E-08	7.54E-08	9.04E-06	0.00E+00	3.81E-05	7.26E-08	1.35E-05	**7.45E-05**
	Lead-210	1.40E-05	1.23E-11	0.00E+00	0.00E+00	4.69E-07	2.65E-08	0.00E+00	1.86E-04	0.00E+00	3.42E-04	**5.42E-04**
	Polonium-210	2.33E-05	7.01E-14	0.00E+00	0.00E+00	8.27E-07	1.14E-10	0.00E+00	7.80E-04	0.00E+00	4.63E-03	**5.44E-03**
	Total by Pathway	**5.50E-05**	**6.10E-09**	**9.50E-10**	**5.03E-06**	**1.38E-06**	**9.09E-06**	**0.00E+00**	**1.01E-03**	**1.01E-05**	**5.01E-03**	**6.10E-03**
Rec F/H One-year-old (Russell Lake)	Uranium-238	1.44E-07	3.89E-13	1.82E-08	6.63E-06	7.69E-08	2.62E-08	0.00E+00	5.69E-07	7.02E-06	2.01E-07	**1.47E-05**
	Uranium-234	1.56E-07	6.79E-14	1.97E-08	3.34E-08	8.33E-08	9.50E-11	0.00E+00	6.16E-07	7.61E-06	2.17E-07	**8.74E-06**
	Thorium-230	1.85E-06	6.11E-13	4.66E-10	2.73E-10	1.18E-07	1.27E-10	0.00E+00	2.21E-06	3.28E-08	5.65E-06	**9.86E-06**
	Radium-226	1.22E-05	1.51E-09	9.46E-11	6.71E-08	3.94E-06	1.18E-05	0.00E+00	2.89E-05	1.38E-07	5.56E-06	**6.26E-05**
	Lead-210	1.90E-05	2.49E-12	0.00E+00	0.00E+00	3.73E-05	3.45E-08	0.00E+00	2.14E-04	0.00E+00	2.21E-04	**4.92E-04**
	Polonium-210	4.46E-05	1.74E-14	0.00E+00	0.00E+00	9.25E-05	1.48E-10	0.00E+00	1.26E-03	0.00E+00	6.06E-03	**7.46E-03**
	Total by Pathway	**7.79E-05**	**1.51E-09**	**3.84E-08**	**6.73E-06**	**1.34E-04**	**1.19E-05**	**0.00E+00**	**1.51E-03**	**1.48E-05**	**6.29E-03**	**8.04E-03**

Human Receptor	COPC	Maximum Incremental Dose by Pathway during Future Centuries (mSv/yr)										
		Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Seasonal Resident Adult (Russell Lake)	Uranium-238	2.07E-07	1.57E-12	4.47E-10	4.95E-06	1.89E-09	2.02E-08	0.00E+00	2.90E-07	1.44E-06	1.35E-07	**7.05E-06**
	Uranium-234	2.26E-07	2.74E-13	4.86E-10	2.50E-08	2.06E-09	7.31E-11	0.00E+00	3.15E-07	1.57E-06	1.47E-07	**2.28E-06**
	Thorium-230	3.64E-06	2.47E-12	1.55E-11	2.40E-10	3.97E-09	9.81E-11	0.00E+00	1.53E-06	9.31E-09	6.94E-06	**1.21E-05**
	Radium-226	1.36E-05	6.08E-09	1.82E-12	4.84E-08	7.54E-08	9.04E-06	0.00E+00	1.14E-05	2.05E-08	4.51E-06	**3.88E-05**
	Lead-210	1.40E-05	1.23E-11	0.00E+00	0.00E+00	4.69E-07	2.65E-08	0.00E+00	5.58E-05	0.00E+00	1.03E-04	**1.73E-04**
	Polonium-210	2.33E-05	7.01E-14	0.00E+00	0.00E+00	8.27E-07	1.14E-10	0.00E+00	2.34E-04	0.00E+00	1.42E-03	**1.68E-03**
	Total by Pathway	**5.50E-05**	**6.10E-09**	**9.50E-10**	**5.03E-06**	**1.38E-06**	**9.09E-06**	**0.00E+00**	**3.03E-04**	**3.04E-06**	**1.54E-03**	**1.91E-03**
Seasonal Resident One-year-old (Russell Lake)												
	Uranium-238	1.44E-07	3.89E-13	1.82E-08	6.63E-06	7.69E-08	2.62E-08	0.00E+00	1.71E-07	2.11E-06	5.89E-08	**9.23E-06**
	Uranium-234	1.56E-07	6.79E-14	1.97E-08	3.34E-08	8.33E-08	9.50E-11	0.00E+00	1.85E-07	2.28E-06	6.39E-08	**2.82E-06**
	Thorium-230	1.85E-06	6.11E-13	4.66E-10	2.73E-10	1.18E-07	1.27E-10	0.00E+00	6.62E-07	9.90E-09	1.62E-06	**4.26E-06**
	Radium-226	1.22E-05	1.51E-09	9.46E-11	6.71E-08	3.94E-06	1.18E-05	0.00E+00	8.67E-06	4.10E-08	1.91E-06	**3.86E-05**
	Lead-210	1.90E-05	2.49E-12	0.00E+00	0.00E+00	3.73E-05	3.45E-08	0.00E+00	6.43E-05	0.00E+00	6.53E-05	**1.86E-04**
	Polonium-210	4.46E-05	1.74E-14	0.00E+00	0.00E+00	9.25E-05	1.48E-10	0.00E+00	3.79E-04	0.00E+00	1.75E-03	**2.26E-03**
	Total by Pathway	**7.79E-05**	**1.51E-09**	**3.84E-08**	**6.73E-06**	**1.34E-04**	**1.19E-05**	**0.00E+00**	**4.53E-04**	**4.44E-06**	**1.82E-03**	**2.50E-03**
Fisher/ Trapper Adult (Russell Lake)												
	Uranium-238	3.45E-07	2.62E-12	7.44E-10	8.26E-06	3.15E-09	3.36E-08	0.00E+00	6.65E-06	0.00E+00	8.10E-07	**1.61E-05**
	Uranium-234	3.76E-07	4.57E-13	8.11E-10	4.16E-08	3.43E-09	1.22E-10	0.00E+00	7.24E-06	0.00E+00	8.82E-07	**8.54E-06**
	Thorium-230	6.07E-06	4.11E-12	2.57E-11	4.00E-10	6.61E-09	1.63E-10	0.00E+00	3.52E-05	0.00E+00	2.40E-06	**4.37E-05**
	Radium-226	2.27E-05	1.01E-08	3.18E-12	8.20E-08	1.26E-07	1.51E-05	0.00E+00	2.63E-04	0.00E+00	8.59E-05	**3.86E-04**
	Lead-210	2.33E-05	2.05E-11	0.00E+00	0.00E+00	7.82E-07	4.42E-08	0.00E+00	1.28E-03	0.00E+00	3.90E-04	**1.69E-03**
	Polonium-210	3.89E-05	1.17E-13	0.00E+00	0.00E+00	1.38E-06	1.89E-10	0.00E+00	5.37E-03	0.00E+00	4.57E-03	**9.98E-03**
	Total by Pathway	**9.16E-05**	**1.02E-08**	**1.58E-09**	**8.38E-06**	**2.30E-06**	**1.51E-05**	**0.00E+00**	**6.96E-03**	**0.00E+00**	**5.05E-03**	**1.21E-02**

4.2.5.3 Radon Dose

Radon will be released to the environment during all Project phases. During construction, the main source of radon to air will be during wellfield drilling from radium-bearing ore cuttings. During operation, radon from the ore body will be removed by the mining solution as it travels through the wellfield. The main source of radon to air will be from venting of the process water in the radon surge tank. During decommissioning radon will be released during wellfield restoration, and the main source of radon to air will also be from venting of the radon surge tank.

The radon dose was calculated separately from the dose from other radionuclides and was estimated outside of IMPACT. The atmospheric model used for the Project to estimate radon concentrations at various locations based on radon source emissions was CALPUFF, an advanced three-dimensional dispersion model (EIS Section 8).

The camp worker would be exposed to radon through inhalation while at the camp site, located southwest of the wellfield. The camp worker represents an adult who resides at the camp for 6 months of the year and away from the site for the remaining 6 months of the year. For exposure to radon, it has been conservatively assumed that the camp worker spends 100% of their time indoors when on site. The predicted radon concentrations at the camp site, from CALPUFF, are 2.1 Bq/m^3 during construction, 12.4 Bq/m^3 during operation, and 8.6 Bq/m^3 during decommissioning. These radon concentrations are incremental concentrations (excluding any background radon).

The dose from radon in air considers ingrowth of radon decay progeny (polonium-218, lead-214, bismuth-214) during dispersion of radon gas from the source to receptor. Ingrowth was quantified in terms of the radon progeny equilibrium ratio, according to the methods outlined in Health Canada's federal guidance on contaminated site radiological risk assessment in Canada, Part VI (Health Canada, 2010b). Radon dose is dependent on the radon equilibrium fraction as well as the exposure time for the receptor.

Consistent with recommendations in CSA N288.6-22 and Health Canada, the dose from radon in air was calculated according to the equation in Appendix A, Section 2.4.3, with input values shown in Table 4-11.

Indoor radon dose dominates over outdoor radon dose; and therefore, only indoor radon dose was quantified. However, the outdoor equilibrium fraction (F_{out}) was needed to estimate the indoor equilibrium fraction (F_{in}), which is needed to include short-lived progeny in the radon dose calculation.

The maximum predicted radon dose to the camp worker would be 0.13 mSv/yr during operation. A summary of the predicted radon dose to the camp worker during all Project phases is shown in Table 4-12.

Table 4-11: Summary of Input Parameters for Radon Dose Calculation

Parameter	Construction	Operation	Decommissioning	Source
Incremental C_{Rn} (at camp)	2.15 Bq/m^3	12.4 Bq/m^3	8.57 Bq/m^3	Atmospheric Model (EIS Section 7.2)
Distance from source to camp	403 m	981 m	981 m	From CALPUFF
Mean wind speed	204 m/min	204 m/min	204 m/min	From meteorological dataset
t (travel time to camp)	2.0 min	4.8 min	4.8 min	Calculated t = distance / wind speed
Exposure time	4,380 h/yr	4,380 h/yr	4,380 h/yr	Assumption based on camp worker residency of 0.5 of the year
F_{out}	0.04	0.10	0.10	Calculated
F_{in}	0.37	0.38	0.38	Calculated

Bq/m^3 = becquerels per cubic metre; F_{out} = outdoor equilibrium fraction; F_{in} = indoor equilibrium fraction; C_{Rn} = concentration of radon in air

Table 4-12: Predicted Radon Dose to Camp Worker during all Project Phases

Project Phase	Radon Dose at Camp (mSv/yr)
Construction	2.2E-02
Operation	1.3E-01
Decommissioning	9.2E-02

4.2.6 Uncertainty in Exposure Assessment

The exposure assessment followed CSA and Health Canada guidance. Key uncertainties in the human health exposure assumptions and how they are addressed in the HHRA are summarized in Table 4-13.

Concentrations of COPCs in environmental media including water, sediment, air, soil, and Traditional Food items were estimated based on the assumption that human and ecological receptors are exposed to the maximum exposure concentrations at their location for each model scenario and Project phase. The duration of this exposure was assumed to be sufficient for each receptor to be in equilibrium with their environment. This results in conservatively high predicted uptakes of COPCs by ecological receptors and exposures to human health receptors.

The assumptions to address uncertainties in the exposure assessment were anticipated to produce conservative exposure estimates for human health receptors. Therefore, the risk that the exposure assessment underestimated potential exposure of human health receptors to COPCs from the Project is low.

Table 4-13: Uncertainties in the Human Health Exposure Assessment

Area of Uncertainty	Description of Uncertainty	How Uncertainty has been Addressed
Receptor Selection	There are no permanent residents in the LSA or RSA, but the area is known to be used for harvesting including fishing, hunting, and gathering, and there are cabins in the LSA. There are uncertainties on how potential receptors would realistically use the LSA and RSA (i.e., locations and residency times).	• Based residency and location assumptions on current understanding of how people use the LSA and RSA. • Assumed reasonably conservative residency times for receptors that conservatively represent receptors with shorter residency times. • Located receptors in the LSA and RSA at locations known to have cabins and camps.
Traditional Foods Diet	Applied ERFN country foods study to the Traditional Diet for all average consumers of Traditional Foods. Applied Bobby John diet to the high consumer of Traditional Foods which includes a high proportion of fish and caribou in the diet	• Assumed all receptors consume Traditional Foods. Receptors included a high consumer and an average consumer of Traditional Foods. • Based the total food intake for male and female receptors on an adult male diet (N288.1-20 central tendency). • Used available information from Indigenous and Local Knowledge for the diet.
Selection of representative ecological receptors in the IMPACT model to represent Traditional Food components	Where possible, there is interest to simplify the environmental pathways model used to estimate potential human health risks without leading to an underestimate of potential risk.	• Selected representative foods from the Traditional Foods types known to be used by Indigenous and Local Communities. • Representative foods with linkages to the aquatic environment were preferred over terrestrial receptors from the same location because they have the potential to be more exposed to Project related COPCs through atmospheric and aquatic pathways.

4.3 Toxicity Assessment

4.3.1 Toxicity Reference Values

For assessment of non-radiological COPCs, a toxicity reference value (TRV) is used. A TRV is a toxicological index, associating specific health effects with a level of exposure to a chemical. TRVs may include slope factors and unit risks for carcinogens, and reference doses, tolerable daily intakes, or acceptable daily intakes for non-carcinogens.

No COPCs in air were identified for further evaluation of potential risks for human health; therefore, toxicity via inhalation was not included in the toxicity assessment. Separate toxicity benchmarks for direct contact effects from dermal exposure are not available. Although some of the COPCs present in soil may cause direct contact dermatitis, information is not available to suggest that such effects can occur at environmental levels (CSA, 2022). A summary of the TRVs used in the HHRA is shown in Table 4-14.

Chloride and sulphate were identified as COPCs; however, as discussed in Section 4.1.3, they were not evaluated further in the HHRA.

Arsenic, cadmium, chromium, cobalt, copper, molybdenum, selenium, uranium, and zinc were retained for further evaluation in the HHRA because effluent quality for these constituents were predicted to exceed water quality screening benchmarks (Section 3.1.1).

The relevant non-cancer TRVs are expressed as a quantity of a chemical per unit body weight per unit time (mg/kg/d) for oral exposure and have generally been derived for sensitive individuals in the public based on sensitive endpoints. Additionally, these factors typically involve the incorporation of uncertainty factors by regulatory agencies to account for uncertainties inherent in the underlying studies or their applicability for protection of members of the public. Carcinogenic effects TRVs are generally referred to as slope factors or unit risks and are used to estimate upper-bound lifetime probabilities of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The carcinogen slope factor or unit risk is, therefore, the lifetime cancer risk per unit of dose or concentration. The slope factor is expressed as risk per mg/kg/d, or $(mg/kg/d)^{-1}$, for oral exposure. Arsenic was the only Project-related COPC evaluated as a carcinogen.

Preference was given to toxicological benchmarks derived by Health Canada, the USEPA Integrated Risk Information System database, the Agency for Toxic Substances and Disease Registry (ATSDR) and the WHO. The supporting documentation for each toxicity benchmark was reviewed and professional judgment was used to evaluate the appropriateness of the benchmark value.

The human health TRVs were generally obtained from Health Canada's TRV Guidance (Health Canada, 2021b). Since Health Canada does not have a published TRV for cobalt, the cobalt TRV was obtained from the ATSDR (ATSDR, 2004).

For molybdenum, selenium and zinc, Health Canada has developed tolerable upper intake levels (ULs) for all of their defined age groups: infant, toddler, child, adolescent, and adult (Health Canada, 2021b). Given that the infant and adult life stages were assessed in the HHRA, the infant and adult ULs are shown in the table below.

Table 4-14: Human Health Oral Exposure Toxicity Reference Values

Constituent of Potential Concern	Benchmark Value	Unit	Reference
Arsenic (cancer)	1.8	$(mg/kg/d)^{-1}$	(Health Canada, 2021b)
Cadmium	0.0008	mg/kg/d	(Health Canada, 2021b)
Chromium	1.5	mg/kg/d	(Health Canada, 2021b)
Cobalt	0.01	mg/kg/d	(ATSDR, 2004)
Copper	0.426	mg/kg/d	(Health Canada, 2021b)
Molybdenum	0.023 (infant) 0.028 (adult)	mg/kg/d	(Health Canada, 2021b)
Selenium	0.0055 (infant) 0.0057 (adult)	mg/kg/d	(Health Canada, 2021b)
Uranium	0.0006	mg/kg/d	(Health Canada, 2021b)
Vanadium	0.0021	mg/kg/d	(MECP, 2011)
Zinc	0.49 (infant) 0.57 (adult)	mg/kg/d	(Health Canada, 2021b)

4.3.1.1 Arsenic

Arsenic is classified as a Group I carcinogen to humans (EC and HC, 1993). Health Canada recommends 1.8 $(mg/kg/d)^{-1}$ as the oral slope factor for arsenic (Health Canada, 2021b). It was originally developed by Health Canada when the agency was deriving a Guideline for Canadian Drinking Water Quality (Health Canada, 2006). The TRV is based on the risk of bladder, lung, and liver cancer in people exposed to arsenic in their drinking water (Chen et al., 1985; Morales et al., 2000; Wu et al., 1989).

4.3.1.2 Cadmium

Cadmium is not classified as a human carcinogen via the oral route of exposure. Health Canada provides a provisional oral tolerable daily intake (TDI) of 0.0008 mg/kg/d based on a meta-analysis of human epidemiological studies where the primary exposure route was via food (Health Canada, 2021b). A no-observed adverse effect level (NOAEL) of 1.2 µg/kg/d (corresponding with 5.24 µg Cd/g creatinine in urine) was identified (WHO, 2011). The critical endpoint was nephrotoxicity (renal tubular dysfunction). Uncertainty factors for toxicodynamic and toxicokinetic variation were incorporated into the model that calculated a lower bound TDI of 0.8 µg/kg/d (or 0.0008 mg/kg/d).

4.3.1.3 Chromium

Chromium is not classified as a human carcinogen via the oral route of exposure. Health Canada provides an oral TDI of 1.5 mg/kg/d for trivalent chromium based on a chronic dietary study in male and female BD rats administered chromic oxide (Cr_2O_3) in the diet at concentrations of 0%, 1% (360 g/kg-bw), 2% (720 g/kg-bw), or 5% (1800 g/kg-bw) for 5 days per week for a total of 600 feedings ((US EPA, 1998); based on (Ivankovic and Preussmann, 1975)). No adverse effects were observed at any dose level. As such, the highest dose level of 1800 g/kg-bw was selected as the point of departure. Uncertainty factors of 10 for interspecies variability, 10 for intraspecies variability, and 10 for database deficiencies were applied to derive the TDI of 1.5 mg/kg/d.

4.3.1.4 Cobalt

Cobalt is a trace element that is essential to human health (Health Canada, 2021b). Cobalt is not classified as a human carcinogen. Health Canada does not provide a threshold oral TRV for cobalt (Health Canada, 2021b). The listed TRV of 0.01 mg/kg/d is recommended by ATSDR (2004). The ATSDR TRV is an intermediate Minimal Risk Level, and is based on a study by Davis and Fields (Davis and Fields, 1958), in which human males ingested a 2% cobalt chloride solution (in water or milk) for up to 22 days. The critical endpoint was hematological effects (increased levels of erythrocytes). The ATSDR took the lowest observed adverse effect level (LOAEL) of 1 mg/kg/d and applied a total uncertainty factor of 100 to arrive at their intermediate minimal risk level. The ATSDR did not derive a chronic minimal risk level for cobalt due to a lack of relevant animal and human studies.

4.3.1.5 Copper

Copper is a trace element that is essential for human health (Health Canada, 2021b). Copper is not classified as a human carcinogen. Health Canada recommends 0.426 mg/kg/d as the threshold oral TRV for copper for all age groups. The TRV was originally developed by Health Canada when the agency was deriving a Guideline for Canadian Drinking Water Quality (Health Canada, 2019a). The TRV is based on a critical health effect of gastrointestinal toxicity and liver function (hepatoxicity) in human infants exposed to copper in drinking water (Olivares et al., 1998). The TRV is based directly (no uncertainty factors applied) on the upper bound of the 95th confidence interval for a NOAEL of 2 mg/L copper in drinking water (0.318 mg/kg/d).

4.3.1.6 Molybdenum

Molybdenum is considered to be an essential trace element for human health (Health Canada, 2021b). However, Health Canada recommends that potential health risks to human receptors be characterized if molybdenum is identified as a COPC (Health Canada, 2021b). The TRVs for essential trace elements are tolerable upper intake levels (ULs), which are considered to be the highest average daily nutrient intake levels that are likely to pose no risk of adverse health effects to almost all individuals in the general population. Health Canada recommends age-specific ULs for molybdenum that are based on a NOAEL value derived for adults (Health

Canada, 2010c; IOM, 2001) from sub-chronic developmental and reproductive effects on rats consuming molybdate in drinking water. An uncertainty factor of 30 was applied (10 for interspecies variability and 3 for intraspecies variability) to the NOAEL value of 0.9 mg/kg-d. The adult UL was weight adjusted to derive age-based TRVs. As with other essential trace elements, Health Canada recommends that adjustments for relative bioavailability of molybdenum may be necessary when considering oral exposures from different pathways (Health Canada, 2010c).

4.3.1.7 Selenium

Similar to molybdenum, selenium is also considered to be an essential trace element for human health (Health Canada, 2021b). Where selenium is identified as a COPC, age-based ULs are recommended. The ULs for selenium are based on the data from two epidemiological studies. The first study considered dietary intake by adults ((IOM, 2000); based on Yang and Zhou 1994) and the second study considered intake from breast milk by infants ((IOM, 2000); based on Shearer and Hadjimarkos 1975).

- The dietary study in adults identified a NOAEL of 800 µg/day based on mean selenium intake in adults associated with signs and symptoms of selenosis (hair and nail brittleness and loss). An uncertainty factor of 2 was incorporated into the derivation of the UL to account for the increased sensitivity of some individuals; furthermore, it is also noted that HC adjusted the IOM's original adult ULs to account for HC's adult age group. A UL of 0.0057 mg/kg/d was derived for adults.

- The breast milk study in infants aged up to six months considered concentrations ranging from 7 to 60 µg/L in unsupplemented women. The NOAEL of 60 µg/L adjusted for the estimated average intake of 0.78 L/d was used to derive the UL. Given that no evidence of infant or maternal toxicity was identified in the study, an uncertainty factor of 1 was applied. Considering the Health Canada (2010) age groups, age-based ULs were derived for older infants (0.006 mg/kg/d), children (0.0063 mg/kg/d) and adolescents (0.0062 mg/kg/d) based on the infant UL of 0.0055 mg/kg/d (Health Canada, 2010c).

4.3.1.8 Uranium

Health Canada recommends 6.0 x 10^{-4} mg/kg/d as the threshold oral TRV for uranium for non-radiological effects for all age groups (Health Canada, 2021b). Uranium (non-radiological) is not classified as a human carcinogen. The TRV was originally developed by Health Canada when the agency was deriving a Guideline for Canadian Drinking Water Quality and it has since been re-affirmed (Health Canada, 2019b). The TRV is based on the critical health effect of kidney toxicity in rats exposed to uranium in drinking water (Gilman et al., 1998). The TRV is based on a NOAEL of 0.06 mg/kg/d and a total uncertainty factor of 100.

4.3.1.9 Vanadium

Vanadium is present naturally in the diet of humans; an upper limit of 1.8 mg/d has been derived for adults between the ages of 18 and 50 years. Health Canada (2021b) has not derived nor adopted a TRV for vanadium. The listed TRV of 0.0021 mg/kg/d from MECP (2011) was adopted. MECP (2011) adopted its TRV from the California Office of Environmental Health Hazard Assessment (Cal OEHHA), which relied on the TRV of 0.0021 mg/kg/d to derive its action level of 15 µg/L for vanadium in drinking water. The TRV is based upon a developmental and reproductive rat study ((Cal OEHHA, 2000); based on Domingo et al. 1986) wherein no maternal toxicity was identified, but pups born to mothers administered all dose levels (5, 10 and 20 mg/kg of sodium metavanadate by oral gavage) prior to mating showed signs of developmental effects (low body weight and reduced pup length). The lowest dose level of 5 mg/kg was used to derive the point of departure of 2.1 mg/kg/d as the LOAEL. An uncertainty factor of 1000 was applied (10 for intraspecies variability, 10 for interspecies variability, and 10 for extrapolation from a LOAEL to a NOAEL).

4.3.1.10 Zinc

As described from molybdenum and selenium, zinc is an essential trace element for human health (Health Canada, 2021b). Where zinc is identified as a COPC, age-based ULs are recommended. The ULs for zinc are based on the data from two prospective epidemiological studies. The first study considered dietary supplementation by adult women ((IOM, 2001); based on Yadrick et al. 1989) and the second study considered intake from fortified formula by infants ((IOM, 2001); based on Walravens and Hambridge 1976).

- The dietary supplementation in adults identified a LOAEL of 60 mg/day based on mean zinc intake from food of 10 mg/day and supplementation of 50 mg/day as zinc gluconate. The LOAEL was associated with indications of copper deficiency (decrease in red blood cell (or erythrocyte) superoxide dismutase (ESOD) activity). An uncertainty factor of 1.5 was incorporated into the derivation of the UL to account for the increased sensitivity of some individuals and extrapolation from a LOAEL to a NOAEL; furthermore, it is also noted that HC adjusted the IOM's original adult ULs to account for HC's adult age group. A UL of 0.49 mg/kg/d was derived for adults.

- The formula study in infants aged up to six months considered concentrations of formula with 1.8 mg Zn/L, one group was given formula alone, and the other group was given formula with a 4 mg Zn/L supplement. No signs of copper deficiency or other indicators of adverse effect were identified in any exposure group. The NOAEL of 5.8 mg/L adjusted for the estimated average intake of 0.78 L/d was used to derive the UL. Given that no evidence of toxicity was identified in the study, an uncertainty factor of 1 was applied. Considering the HC (Health Canada, 2010c) age groups, age-based ULs were derived for older infants (0.48 mg/kg/d), children (0.51 mg/kg/d) and adolescents (0.54 mg/kg/d) based on the infant UL of 0.49 mg/kg/d.

4.3.2 Radiation Dose Limits and Targets

Potential effects from radiation were compared to an effective dose limit. The effective dose is defined as the sum of all tissue equivalent doses multiplied by the appropriate tissue weighting factors associated with each respective tissue (Health Canada, 2010b). The limit is incremental and is exclusive of natural background, such as natural levels of radon, and medical exposures.

The public dose limit and dose limit for a non-NEW for radiation protection is 1 mSv/yr, as described in the *Radiation Protection Regulations* under the *Nuclear Safety and Control Act*, and as recommended in CSA N288.6-22. A higher incremental dose than the effective dose limit is considered unacceptable.

Incremental dose from the Project can also be compared to a dose constraint. A dose constraint is a conservative value for the annual increment dose applied to a single operation that is considered protective without further demonstration in situations where multiple sources may contribute to incremental dose (Health Canada, 2011). Application of a dose constraint is meant to ensure that the combined doses from multiple sources do not exceed the dose limit of 1 mSv/yr. A dose constraint of 0.3 mSv/yr is used in the ERA, as recommended by Health Canada (Health Canada, 2011). The dose constraint represents a dose, lower than the dose limit that ensures that the combined dose from multiple sources does not result in exceedance of the dose limit. Exceedance of the dose constraint does not indicate that adverse effects would occur, but instead indicates that the assumptions used in the calculation of exposure estimates for the operation should be examined in more detail.

4.3.3 Uncertainties in the Toxicity Assessment

In general, TRVs are usually based on limited toxicological data. For this reason, a margin of safety is built into TRV estimates, by use of uncertainty factors or conservative confidence levels, and actual risks are lower than those estimated. In this risk assessment, TRVs recommended by Health Canada were used when available to reduce uncertainty that potential health risks for human receptors would be underestimated in the risk evaluation.

The two major areas of uncertainty introduced in this toxicity assessment are animal to human extrapolation for Health Canada's recommend TRV for uranium, and use of an intermediate-duration TRV from a regulatory agency other than Health Canada for cobalt. In both cases, uncertainty factors were applied in the derivation of the TRVs. For uranium, the chronic TRV was based on a no observed adverse effects level for rats and a total uncertainty factor of 100. For cobalt, the intermediate (sub-chronic) TRV was based on a LOAEL for humans and a total uncertainty factor of 100. As a result, overestimation of the potential for adverse effects on humans is more likely than underestimation for similar exposure scenarios.

4.4 Risk Characterization

4.4.1 Risk Estimation

The potential for adverse effects on human receptors was determined in the risk assessment through the risk characterization step, where risk estimates were calculated to determine the potential for effects on the human receptors identified. The risk estimate was determined by comparing the predicted exposures, in terms of doses, with exposures that are known to be protective based on effects data (i.e., TRVs or radiation dose limits).

The methods of non-radiological risk estimation used for the HHRA were:

- HQs for non-carcinogens; and
- ILCR for carcinogens.

Hazard quotients (HQs) were calculated in IMPACT as the ratio of the exposure concentration or intake rate divided by the benchmark value, as shown below:

$$HQ = \frac{Exposure\ (Dose)\ Estimate}{TRV}$$

The HQs were compared to benchmark values. Non-carcinogenic constituents are not expected to cause any adverse health effects at exposures below the TRV. The HQs can be compared to a benchmark value of one (1) if all exposure pathways (exposures from all pathways including background and store-bought foods) are accounted for.

To account for uncertainty in pathways beyond Project activities (i.e., exposure to background sources unrelated to the Project), it was determined that to be protective a benchmark HQ value of 0.2 per medium (e.g., water, soil, food, air) would be considered acceptable for the assessment. This approach is consistent with the approach taken by Health Canada in its guidance on human health preliminary quantitative risk assessment (Health Canada, 2021a).

For carcinogens (e.g., arsenic), the incremental risk (i.e., total risk minus background risk) of developing cancer over a lifetime was estimated by multiplying the predicted dose above background by the cancer slope factor, as shown below:

$$ILCR = \sum LADD_i \times SF \times ADAF_i$$

where,

ILCR	=	incremental lifetime cancer risk (unitless)
$LADD_i$	=	dose received during lifestage i averaged over a lifetime (mg/kg/d)
SF	=	adult cancer slope factor (per mg/kg/d)
$ADAF_i$	=	age-dependent adjustment factors for lifestage i

Health Canada recommends that for carcinogens where the mode of action is unknown or the burden of proof for a threshold mode of action is not met, that the assessment should follow the non-threshold approach (i.e., a linear dose-response relationship) (Health Canada, 2013). The Canadian drinking water guideline technical document for arsenic indicates that there is limited data on the mode of action for arsenic and that the use of a non-linear relationship may overestimate cancer risks of internal organs (Health Canada, 2006). Therefore, for this assessment, a linear approach for arsenic was used. Additionally, since the mode of action is unknown, and arsenic-specific data are not available on quantitative differences between early lifestages and adults, Health Canada's default age-dependent adjustment factors for all life stages were not used (ADAF = 1 for all life stages).

Incremental lifetime cancer risks were compared to de minimis risk levels that are considered essentially negligible compared to background cancer risks. Cancer risks that are considered acceptable can range from 1 in 10,000 to 1 in 1,000,000 in different jurisdictions. Health Canada considers an increase in lifetime cancer risk of 1 in 100,000 (or 0.00001) to be essentially negligible compared to the background cancer risk level in North America of approximately 5 in 10 (or 0.5) (Health Canada, 2021a).

Total radiation doses due to radionuclides in the uranium-238 decay series were predicted. Incremental radiation doses were compared to the regulatory public dose limit and dose limit for a non-NEW of 1 mSv/yr and a dose constraint of 0.3 mSv/yr, as described in Section 4.3.2, Radiation Dose Limits and Targets. Radon dose was also considered; and was also compared to the dose limit of 1 mSv/yr.

4.4.1.1 Non-carcinogen Risk

The HQs in Table 4-15 are presented as baseline HQs (based on existing risk prior to the Project), Project Total HQs (includes the Project risk in addition to the baseline risk), as well as Project incremental HQs (includes the Project risk only with baseline component removed). The HQs represent the maximum HQ over the Project phase for the COPCs of interest, which is a conservative representation as exposure varies within each Project phase. HQs were evaluated for the adult and the one-year-old; however, for assessment of non-carcinogens, the one-year-old is typically considered the most sensitive receptor (Health Canada 2010a).

For the Project incremental HQs, there are no exceedances of the HQ benchmark (HQ<0.2) for human receptors for non-carcinogens (cadmium, copper, chromium, cobalt, molybdenum, uranium, and zinc) during all phases of the Project, with the exception of selenium for the fisher/trapper at Russell Lake. The incremental Project HQ for the fisher/trapper from fish ingestion (northern pike and white sucker) was predicted to be 0.81. The Project incremental HQ represents an incremental HQ with existing baseline risk removed.

Since baseline risk includes all exposures not associated with the Project (including store-bought foods), it is also appropriate to discuss the Project total HQ (baseline plus Project) and compare against a HQ benchmark of 1. There are no exceedances of the HQ benchmark of 1 for human receptors for non-carcinogens (cadmium, copper, chromium, cobalt, molybdenum, uranium, vanadium, and zinc) during all phases of the Project, with the exception of selenium for the fisher/trapper at Russell Lake (Project total HQ = 1.35). The Project total HQs for the fisher/trapper for selenium are predicted to be equal to or greater than 1; and as previously indicated above, the Project incremental HQs for the fish ingestion pathway for selenium are predicted to be above 0.2. This indicates that the Project is expected to contribute to selenium in the environment and the food chain; however, conservatism in the assessment is discussed further.

The traditional foods diet for the fisher/trapper is conservative and is based on engagement with a local fisher/trapper. The diet of the fisher/trapper is representative of one person, who consumes a unique composition and quantity of traditional foods. Most people fishing, hunting, and trapping in the Project Area would consume traditional foods more consistent with the average traditional foods consumer diet which was developed from the ERFN country foods study (CanNorth, 2017). However, it is recognized that the ERFN considers the fisher/trapper's use of the area as representative of current and future land users and expects that their relationship to the Project Area will be continued and strengthened through generations of future use.

The ingestion rate for caribou based on engagement with a local fisher/trapper was 175 kg/yr of caribou (equivalent to approximately 2 to 3 servings per day). This ingestion rate is conservative compared to an annual caribou ingestion rate of 2.6 kg/yr (1 to 2 servings per month) from the ERFN's Country Food Study (CanNorth, 2017) and 54.4 kg/yr for the total game diet for a high traditional foods consumer in the Boreal Shield in the First Nations Food, Nutrition and Environment Study for Saskatchewan (Chan et al., 2018). Thus, the local fisher/trapper is relatively extreme with respect to local game consumption.

Additionally, the traditional foods diet for the fisher/trapper is conservative for fish as it assumes that all fish consumed in the diet is obtained from Russell Lake, whereas it is likely that someone would fish from many different lakes including those outside of the RSA. The annual fish consumption based on engagement with a local fisher/trapper was assumed to be 183 kg/yr (approximately 1 to 2 servings per day), which is conservative compared to an annual fish consumption of 27 kg/yr (2 servings per week) from the ERFN's Country Food Study (CanNorth, 2017) and 88 kg/yr (approximately 1 serving per day) for the high consumer for the Boreal Shield in the First Nations Food, Nutrition and Environment Study for Saskatchewan (Chan et al., 2018). Thus, the local fisher/trapper is relatively extreme with respect to local fish consumption. The Project incremental HQs are below 0.2 for all other pathways including consumption of terrestrial and riparian animals harvested in the Project area. The overall risk to the fisher/trapper from selenium is low.

The presence and concentrations of COPCs in the receiving environment would be monitored and the associated dose and risk estimates would be periodically reassessed in accordance with the processes outlined in the Environmental Protection Program.

The HQs for the future centuries (beyond the Project timeline) are presented in Table 4-16. During the future centuries a permanent resident is included on the former mine site instead of a camp worker. For the Project incremental HQs, there are no predicted exceedances of the HQ benchmark (HQ<0.2) for any human receptors for any non-carcinogens evaluated during the future centuries.

Table 4-15: Estimated Non-radiological Risk to Human Receptors – Project Phases

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
Camp Worker Adult (Whitefish Lake)		Average Baseline HQ									
	Cadmium	4.25E-04	9.44E-06	4.32E-05	2.94E-06	1.35E-05	0.00E+00	4.46E-05	4.39E-03	<u>2.56E-01</u>	2.61E-01
	Chromium	5.08E-06	4.62E-08	2.11E-06	2.72E-08	1.25E-06	0.00E+00	9.78E-06	3.72E-06	1.00E-05	3.20E-05
	Cobalt	1.48E-04	5.55E-07	2.54E-06	1.76E-07	8.04E-07	0.00E+00	6.25E-05	3.14E-03	1.64E-02	1.97E-02
	Copper	2.13E-05	7.15E-08	1.96E-06	3.02E-08	8.30E-07	0.00E+00	3.74E-04	5.13E-03	4.83E-02	5.38E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-07	8.40E-08	3.84E-07	0.00E+00	1.97E-07	9.24E-04	9.05E-02	9.15E-02
	Selenium	8.32E-05	3.93E-07	1.80E-06	7.59E-07	3.48E-06	0.00E+00	1.47E-02	3.85E-03	<u>2.96E-01</u>	3.14E-01
	Uranium	7.35E-04	1.33E-05	6.10E-04	6.71E-06	3.07E-04	0.00E+00	5.14E-04	2.27E-02	6.12E-02	8.62E-02
	Vanadium	1.01E-03	4.80E-05	2.20E-03	3.71E-05	1.70E-03	0.00E+00	3.39E-03	1.71E-03	1.72E-01	1.82E-01
	Zinc	1.75E-05	1.95E-07	8.92E-06	1.21E-07	5.56E-06	0.00E+00	1.23E-03	9.38E-03	<u>2.12E-01</u>	2.23E-01
		Project Total HQ - Project Phases									
	Cadmium	5.70E-04	9.44E-06	4.32E-05	3.64E-06	1.67E-05	0.00E+00	6.26E-05	4.39E-03	<u>2.56E-01</u>	2.61E-01
	Chromium	6.13E-06	4.62E-08	2.11E-06	3.13E-08	1.43E-06	0.00E+00	1.23E-05	3.72E-06	1.09E-05	3.66E-05
	Cobalt	1.68E-04	5.56E-07	2.54E-06	1.94E-07	8.88E-07	0.00E+00	7.34E-05	3.15E-03	1.64E-02	1.98E-02
	Copper	2.48E-05	7.22E-08	1.98E-06	3.40E-08	9.34E-07	0.00E+00	4.52E-04	5.15E-03	4.83E-02	5.40E-02
	Molybdenum	6.41E-03	8.59E-08	3.93E-07	7.17E-06	3.28E-05	0.00E+00	2.84E-05	9.24E-04	9.20E-02	9.94E-02
	Selenium	5.98E-04	3.94E-07	1.80E-06	3.73E-06	1.71E-05	0.00E+00	9.45E-02	3.85E-03	<u>3.07E-01</u>	4.06E-01
	Uranium	7.39E-03	3.60E-05	1.65E-03	4.51E-05	2.06E-03	0.00E+00	5.59E-03	5.04E-02	6.54E-02	1.33E-01
	Vanadium	2.79E-03	4.80E-05	2.20E-03	8.03E-05	3.68E-03	0.00E+00	7.57E-03	1.72E-03	1.76E-01	1.94E-01
	Zinc	2.22E-05	1.95E-07	8.93E-06	1.44E-07	6.59E-06	0.00E+00	1.61E-03	9.38E-03	<u>2.13E-01</u>	2.24E-01
		Project Incremental HQ - Project Phases									
	Cadmium	1.45E-04	1.42E-09	6.48E-09	6.95E-07	3.18E-06	0.00E+00	1.80E-05	2.07E-06	1.53E-04	3.22E-04
	Chromium	1.05E-06	4.44E-12	2.03E-10	4.05E-09	1.85E-07	0.00E+00	2.48E-06	4.42E-09	8.57E-07	4.58E-06
	Cobalt	1.99E-05	5.98E-10	2.74E-09	1.85E-08	8.46E-08	0.00E+00	1.09E-05	1.72E-06	3.71E-05	6.98E-05
	Copper	3.45E-06	6.38E-10	1.75E-08	3.78E-09	1.04E-07	0.00E+00	7.83E-05	1.94E-05	8.46E-05	1.86E-04
	Molybdenum	6.35E-03	6.60E-11	3.02E-10	7.08E-06	3.24E-05	0.00E+00	2.82E-05	3.31E-07	1.47E-03	7.89E-03
	Selenium	5.15E-04	4.18E-10	1.91E-09	2.98E-06	1.36E-05	0.00E+00	7.98E-02	2.42E-06	1.12E-02	9.15E-02
	Uranium	6.66E-03	2.26E-05	1.04E-03	3.84E-05	1.76E-03	0.00E+00	5.08E-03	2.77E-02	4.17E-03	4.65E-02

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Vanadium	1.77E-03	1.45E-08	6.61E-07	4.32E-05	1.98E-03	0.00E+00	4.18E-03	5.34E-06	3.64E-03	1.16E-02
	Zinc	4.64E-06	1.67E-10	7.64E-09	2.27E-08	1.04E-06	0.00E+00	3.88E-04	3.28E-06	1.77E-04	5.74E-04
Rec F/H Adult (McGowan Lake)		Average Baseline HQ									
	Cadmium	4.25E-04	9.44E-06	4.32E-06	2.94E-06	1.35E-06	0.00E+00	8.92E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.08E-06	4.62E-08	2.11E-07	2.72E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.48E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.30E-08	0.00E+00	7.48E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.84E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.32E-05	3.93E-07	1.80E-07	7.59E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.35E-04	1.33E-05	6.10E-05	6.71E-06	3.07E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.01E-03	4.80E-05	2.20E-04	3.71E-05	1.70E-04	0.00E+00	6.78E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.75E-05	1.95E-07	8.92E-07	1.21E-07	5.56E-07	0.00E+00	2.45E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Project Phases									
	Cadmium	4.78E-04	9.44E-06	4.32E-06	3.22E-06	1.47E-06	0.00E+00	1.25E-04	8.79E-03	2.48E-01	2.58E-01
	Chromium	5.50E-06	4.62E-08	2.11E-07	2.89E-08	1.32E-07	0.00E+00	2.45E-05	7.44E-06	2.19E-05	5.98E-05
	Cobalt	1.56E-04	5.55E-07	2.54E-07	1.84E-07	8.40E-08	0.00E+00	1.47E-04	6.29E-03	1.77E-02	2.43E-02
	Copper	2.26E-05	7.16E-08	1.97E-07	3.19E-08	8.75E-08	0.00E+00	9.05E-04	1.03E-02	6.00E-02	7.12E-02
	Molybdenum	2.52E-03	8.59E-08	3.93E-08	3.13E-06	1.43E-06	0.00E+00	5.68E-05	1.85E-03	8.91E-02	9.36E-02
	Selenium	2.56E-04	3.94E-07	1.80E-07	1.90E-06	8.67E-07	0.00E+00	1.89E-01	7.70E-03	3.12E-01	5.09E-01
	Uranium	2.98E-03	1.68E-05	7.68E-05	2.14E-05	9.78E-05	0.00E+00	1.12E-02	1.01E-01	6.70E-02	1.82E-01
	Vanadium	1.49E-03	4.80E-05	2.20E-04	4.81E-05	2.20E-04	0.00E+00	1.51E-02	3.44E-03	1.79E-01	1.99E-01
	Zinc	1.93E-05	1.95E-07	8.93E-07	1.30E-07	5.97E-07	0.00E+00	3.23E-03	1.88E-02	2.34E-01	2.56E-01
		Project Incremental HQ - Project Phases									
	Cadmium	5.28E-05	1.97E-10	9.00E-11	2.75E-07	1.26E-07	0.00E+00	3.60E-05	4.14E-06	3.08E-04	4.01E-04
	Chromium	4.16E-07	6.86E-13	3.14E-12	1.64E-09	7.53E-09	0.00E+00	4.96E-06	8.84E-09	1.72E-06	7.12E-06
	Cobalt	7.28E-06	8.29E-11	3.80E-11	8.01E-09	3.66E-09	0.00E+00	2.18E-05	3.44E-06	7.40E-05	1.07E-04
	Copper	1.25E-06	8.90E-11	2.44E-10	1.63E-09	4.48E-09	0.00E+00	1.57E-04	3.88E-05	1.69E-04	3.66E-04
	Molybdenum	2.47E-03	6.62E-12	3.03E-12	3.05E-06	1.40E-06	0.00E+00	5.64E-05	6.63E-07	2.93E-03	5.46E-03
	Selenium	1.73E-04	5.85E-11	2.68E-11	1.14E-06	5.20E-07	0.00E+00	1.60E-01	4.83E-06	2.24E-02	1.82E-01

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Uranium	2.24E-03	3.45E-06	1.58E-05	1.46E-05	6.70E-05	0.00E+00	1.02E-02	5.54E-02	8.36E-03	7.63E-02
	Vanadium	4.72E-04	2.01E-09	9.18E-09	1.10E-05	5.03E-05	0.00E+00	8.36E-03	1.07E-05	7.29E-03	1.62E-02
	Zinc	1.81E-06	2.32E-11	1.06E-10	9.00E-09	4.12E-08	0.00E+00	7.76E-04	6.57E-06	3.54E-04	1.14E-03
Rec F/H One-year-old (McGowan Lake)		**Average Baseline HQ**									
	Cadmium	4.75E-04	6.17E-04	7.39E-06	1.92E-04	2.30E-06	0.00E+00	8.45E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.67E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.85E-05	1.72E-05	1.17E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.37E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.00E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.63E-05	2.66E-05	3.19E-07	5.14E-05	6.16E-07	0.00E+00	2.88E-02	1.87E-02	7.51E-01	7.98E-01
	Uranium	8.21E-04	8.71E-04	1.04E-04	4.38E-04	5.25E-05	0.00E+00	9.73E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.13E-03	3.13E-03	3.76E-04	2.42E-03	2.91E-04	0.00E+00	6.42E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.23E-06	1.11E-06	0.00E+00	2.70E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Project Phases									
	Cadmium	5.34E-04	6.17E-04	7.39E-06	2.10E-04	2.52E-06	0.00E+00	1.19E-04	1.97E-02	6.29E-01	6.50E-01
	Chromium	6.14E-06	3.02E-06	3.62E-07	1.89E-06	2.26E-07	0.00E+00	2.32E-05	1.72E-05	1.29E-05	6.49E-05
	Cobalt	1.74E-04	3.63E-05	4.35E-07	1.20E-05	1.44E-07	0.00E+00	1.39E-04	1.46E-02	3.78E-02	5.28E-02
	Copper	2.52E-05	4.68E-06	3.36E-07	2.08E-06	1.50E-07	0.00E+00	8.57E-04	2.38E-02	1.01E-01	1.26E-01
	Molybdenum	3.43E-03	6.83E-06	8.18E-08	2.49E-04	2.99E-06	0.00E+00	6.55E-05	5.20E-03	2.75E-01	2.84E-01
	Selenium	2.96E-04	2.66E-05	3.19E-07	1.28E-04	1.54E-06	0.00E+00	1.86E-01	1.87E-02	7.66E-01	9.70E-01
	Uranium	3.32E-03	1.10E-03	1.31E-04	1.40E-03	1.67E-04	0.00E+00	1.06E-02	2.14E-01	1.57E-01	3.88E-01
	Vanadium	1.66E-03	3.13E-03	3.76E-04	3.14E-03	3.77E-04	0.00E+00	1.43E-02	6.22E-03	4.22E-01	4.51E-01
	Zinc	2.51E-05	1.48E-05	1.78E-06	9.91E-06	1.19E-06	0.00E+00	3.56E-03	5.01E-02	5.64E-01	6.17E-01
		Project Incremental HQ - Project Phases									
	Cadmium	5.89E-05	1.29E-08	1.55E-10	1.80E-05	2.16E-07	0.00E+00	3.41E-05	8.55E-06	2.13E-04	3.33E-04
	Chromium	4.64E-07	4.50E-11	5.37E-12	1.07E-07	1.29E-08	0.00E+00	4.70E-06	1.15E-08	1.14E-06	6.44E-06
	Cobalt	8.13E-06	5.42E-09	6.50E-11	5.23E-07	6.27E-09	0.00E+00	2.07E-05	7.64E-06	4.22E-05	7.92E-05
	Copper	1.40E-06	5.81E-09	4.18E-10	1.07E-07	7.67E-09	0.00E+00	1.48E-04	9.07E-05	9.83E-05	3.39E-04
	Molybdenum	3.35E-03	5.27E-10	6.31E-12	2.43E-04	2.91E-06	0.00E+00	6.51E-05	1.80E-06	2.03E-03	5.70E-03

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Selenium	2.00E-04	3.96E-09	4.74E-11	7.69E-05	9.22E-07	0.00E+00	1.57E-01	1.14E-05	1.48E-02	1.72E-01
	Uranium	2.50E-03	2.25E-04	2.70E-05	9.57E-04	1.15E-04	0.00E+00	9.62E-03	1.10E-01	5.28E-03	1.29E-01
	Vanadium	5.27E-04	1.31E-07	1.57E-08	7.18E-04	8.61E-05	0.00E+00	7.91E-03	1.37E-05	4.03E-03	1.33E-02
	Zinc	2.35E-06	1.77E-09	2.12E-10	6.84E-07	8.20E-08	0.00E+00	8.54E-04	1.78E-05	2.07E-04	1.08E-03
Rec F/H Adult (Russell Lake)		Average Baseline HQ									
	Cadmium	4.25E-04	9.44E-06	4.32E-06	2.94E-06	1.35E-06	0.00E+00	8.92E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.08E-06	4.62E-08	2.11E-07	2.72E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.48E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.30E-08	0.00E+00	7.48E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.84E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.32E-05	3.93E-07	1.80E-07	7.59E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.35E-04	1.33E-05	6.10E-05	6.71E-06	3.07E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.01E-03	4.80E-05	2.20E-04	3.71E-05	1.70E-04	0.00E+00	6.78E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.75E-05	1.95E-07	8.92E-07	1.21E-07	5.56E-07	0.00E+00	2.45E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Project Phases									
	Cadmium	4.68E-04	9.44E-06	4.32E-06	3.15E-06	1.44E-06	0.00E+00	1.15E-04	8.78E-03	2.48E-01	2.58E-01
	Chromium	5.42E-06	4.62E-08	2.11E-07	2.84E-08	1.30E-07	0.00E+00	2.32E-05	7.44E-06	2.15E-05	5.80E-05
	Cobalt	1.54E-04	5.55E-07	2.54E-07	1.82E-07	8.31E-08	0.00E+00	1.41E-04	6.29E-03	1.77E-02	2.43E-02
	Copper	2.23E-05	7.16E-08	1.97E-07	3.15E-08	8.64E-08	0.00E+00	8.66E-04	1.03E-02	5.99E-02	7.11E-02
	Molybdenum	1.91E-03	8.58E-08	3.93E-08	2.40E-06	1.10E-06	0.00E+00	4.28E-05	1.85E-03	8.84E-02	9.22E-02
	Selenium	2.07E-04	3.93E-07	1.80E-07	1.59E-06	7.27E-07	0.00E+00	1.47E-01	7.70E-03	3.06E-01	4.60E-01
	Uranium	2.35E-03	1.42E-05	6.52E-05	1.74E-05	7.97E-05	0.00E+00	8.35E-03	6.03E-02	6.36E-02	1.35E-01
	Vanadium	1.38E-03	4.80E-05	2.20E-04	4.41E-05	2.02E-04	0.00E+00	1.24E-02	3.43E-03	1.76E-01	1.94E-01
	Zinc	1.90E-05	1.95E-07	8.92E-07	1.28E-07	5.86E-07	0.00E+00	3.02E-03	1.88E-02	2.34E-01	2.56E-01
		Project Incremental HQ - Project Phases									
	Cadmium	4.28E-05	5.09E-11	2.32E-11	2.03E-07	9.30E-08	0.00E+00	2.62E-05	1.07E-06	2.29E-04	2.99E-04
	Chromium	3.42E-07	1.78E-13	8.10E-13	1.22E-09	5.60E-09	0.00E+00	3.64E-06	2.30E-09	1.30E-06	5.29E-06
	Cobalt	5.45E-06	2.13E-11	9.75E-12	6.09E-09	2.79E-09	0.00E+00	1.64E-05	8.85E-07	5.35E-05	7.63E-05
	Copper	9.39E-07	2.29E-11	6.29E-11	1.24E-09	3.41E-09	0.00E+00	1.18E-04	9.99E-06	9.25E-05	2.21E-04
	Molybdenum	1.85E-03	1.32E-12	6.04E-13	2.31E-06	1.06E-06	0.00E+00	4.24E-05	1.33E-07	2.22E-03	4.12E-03

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Selenium	1.24E-04	1.50E-11	6.88E-12	8.29E-07	3.80E-07	0.00E+00	1.17E-01	1.24E-06	1.65E-02	1.34E-01
	Uranium	1.61E-03	9.20E-07	4.21E-06	1.07E-05	4.90E-05	0.00E+00	7.33E-03	1.48E-02	4.92E-03	2.87E-02
	Vanadium	3.63E-04	5.17E-10	2.36E-09	6.98E-06	3.20E-05	0.00E+00	5.62E-03	2.75E-06	4.91E-03	1.09E-02
	Zinc	1.49E-06	5.97E-12	2.74E-11	6.64E-09	3.04E-08	0.00E+00	5.64E-04	1.69E-06	2.59E-04	8.26E-04
		Average Baseline HQ									
	Cadmium	4.75E-04	6.17E-04	7.39E-06	1.92E-04	2.30E-06	0.00E+00	8.45E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.67E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.85E-05	1.72E-05	1.17E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.37E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.00E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.63E-05	2.66E-05	3.19E-07	5.14E-05	6.16E-07	0.00E+00	2.88E-02	1.87E-02	7.51E-01	7.98E-01
	Uranium	8.21E-04	8.71E-04	1.04E-04	4.38E-04	5.25E-05	0.00E+00	9.73E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.13E-03	3.13E-03	3.76E-04	2.42E-03	2.91E-04	0.00E+00	6.42E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.23E-06	1.11E-06	0.00E+00	2.70E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Project Phases									
	Cadmium	5.22E-04	6.17E-04	7.39E-06	2.06E-04	2.46E-06	0.00E+00	1.09E-04	1.97E-02	6.29E-01	6.50E-01
Rec F/H One-year-old (Russell Lake)	Chromium	6.06E-06	3.02E-06	3.62E-07	1.86E-06	2.23E-07	0.00E+00	2.20E-05	1.72E-05	1.26E-05	6.33E-05
	Cobalt	1.72E-04	3.63E-05	4.35E-07	1.19E-05	1.42E-07	0.00E+00	1.34E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.49E-05	4.68E-06	3.36E-07	2.06E-06	1.48E-07	0.00E+00	8.20E-04	2.38E-02	1.01E-01	1.25E-01
	Molybdenum	2.59E-03	6.83E-06	8.18E-08	1.91E-04	2.29E-06	0.00E+00	4.93E-05	5.20E-03	2.75E-01	2.83E-01
	Selenium	2.40E-04	2.66E-05	3.19E-07	1.08E-04	1.29E-06	0.00E+00	1.44E-01	1.87E-02	7.62E-01	9.25E-01
	Uranium	2.62E-03	9.31E-04	1.12E-04	1.14E-03	1.36E-04	0.00E+00	7.91E-03	1.34E-01	1.55E-01	3.01E-01
	Vanadium	1.54E-03	3.13E-03	3.76E-04	2.88E-03	3.45E-04	0.00E+00	1.17E-02	6.21E-03	4.21E-01	4.47E-01
	Zinc	2.47E-05	1.48E-05	1.78E-06	9.73E-06	1.17E-06	0.00E+00	3.32E-03	5.01E-02	5.64E-01	6.17E-01
		Project Incremental HQ - Project Phases									
	Cadmium	4.78E-05	3.32E-09	3.96E-11	1.33E-05	1.59E-07	0.00E+00	2.48E-05	2.20E-06	1.58E-04	2.46E-04
	Chromium	3.81E-07	1.18E-11	1.39E-12	7.99E-08	9.58E-09	0.00E+00	3.44E-06	3.00E-09	8.57E-07	4.77E-06
	Cobalt	6.08E-06	1.39E-09	1.67E-11	3.98E-07	4.77E-09	0.00E+00	1.55E-05	1.96E-06	3.06E-05	5.46E-05
	Copper	1.05E-06	1.50E-09	1.08E-10	8.10E-08	5.83E-09	0.00E+00	1.11E-04	2.33E-05	5.58E-05	1.92E-04
	Molybdenum	2.52E-03	1.06E-10	1.26E-12	1.84E-04	2.21E-06	0.00E+00	4.89E-05	3.61E-07	1.54E-03	4.29E-03

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
Seasonal Resident (Russell Lake)	Selenium	1.44E-04	1.02E-09	1.22E-11	5.62E-05	6.73E-07	0.00E+00	1.15E-01	2.93E-06	1.09E-02	1.26E-01
	Uranium	1.80E-03	6.01E-05	7.21E-06	6.99E-04	8.38E-05	0.00E+00	6.94E-03	2.94E-02	3.10E-03	4.21E-02
	Vanadium	4.05E-04	3.38E-08	4.05E-09	4.56E-04	5.47E-05	0.00E+00	5.32E-03	3.54E-06	2.70E-03	8.94E-03
	Zinc	1.94E-06	4.55E-10	5.45E-11	5.05E-07	6.05E-08	0.00E+00	6.21E-04	4.58E-06	1.52E-04	7.80E-04
		Average Baseline HQ									
	Cadmium	4.25E-04	9.44E-06	4.32E-06	2.94E-06	1.35E-06	0.00E+00	8.92E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.08E-06	4.62E-08	2.11E-07	2.72E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.48E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.30E-08	0.00E+00	7.48E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.84E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.32E-05	3.93E-07	1.80E-07	7.59E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.35E-04	1.33E-05	6.10E-05	6.71E-06	3.07E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.01E-03	4.80E-05	2.20E-04	3.71E-05	1.70E-04	0.00E+00	6.78E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.75E-05	1.95E-07	8.92E-07	1.21E-07	5.56E-07	0.00E+00	2.45E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Project Phases									
	Cadmium	4.68E-04	9.44E-06	4.32E-06	3.15E-06	1.44E-06	0.00E+00	9.78E-05	8.78E-03	2.48E-01	2.58E-01
	Chromium	5.42E-06	4.62E-08	2.11E-07	2.84E-08	1.30E-07	0.00E+00	2.08E-05	7.43E-06	2.06E-05	5.47E-05
	Cobalt	1.54E-04	5.55E-07	2.54E-07	1.82E-07	8.31E-08	0.00E+00	1.30E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.23E-05	7.16E-08	1.97E-07	3.15E-08	8.64E-08	0.00E+00	7.81E-04	1.03E-02	5.98E-02	7.09E-02
	Molybdenum	1.91E-03	8.58E-08	3.93E-08	2.40E-06	1.10E-06	0.00E+00	1.31E-05	1.85E-03	8.69E-02	9.06E-02
	Selenium	2.07E-04	3.93E-07	1.80E-07	1.59E-06	7.27E-07	0.00E+00	6.39E-02	7.70E-03	2.94E-01	3.66E-01
	Uranium	2.35E-03	1.42E-05	6.52E-05	1.74E-05	7.97E-05	0.00E+00	3.20E-03	4.99E-02	6.09E-02	1.17E-01
	Vanadium	1.38E-03	4.80E-05	2.20E-04	4.41E-05	2.02E-04	0.00E+00	9.08E-03	3.43E-03	1.73E-01	1.88E-01
	Zinc	1.90E-05	1.95E-07	8.92E-07	1.28E-07	5.86E-07	0.00E+00	2.65E-03	1.88E-02	2.34E-01	2.55E-01
		Project Incremental HQ - Project Phases									
	Cadmium	4.28E-05	5.09E-11	2.32E-11	2.03E-07	9.30E-08	0.00E+00	8.62E-06	3.21E-07	7.37E-05	1.26E-04
	Chromium	3.42E-07	1.78E-13	8.10E-13	1.22E-09	5.60E-09	0.00E+00	1.26E-06	6.97E-10	4.24E-07	2.03E-06
	Cobalt	5.45E-06	2.13E-11	9.75E-12	6.09E-09	2.79E-09	0.00E+00	4.55E-06	2.66E-07	1.49E-05	2.51E-05
	Copper	9.39E-07	2.29E-11	6.29E-11	1.24E-09	3.41E-09	0.00E+00	3.26E-05	3.00E-06	2.73E-05	6.39E-05

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Molybdenum	1.85E-03	1.32E-12	6.04E-13	2.31E-06	1.06E-06	0.00E+00	1.27E-05	3.99E-08	6.64E-04	2.53E-03
	Selenium	1.24E-04	1.50E-11	6.88E-12	8.29E-07	3.80E-07	0.00E+00	3.45E-02	3.73E-07	5.25E-03	3.99E-02
	Uranium	1.61E-03	9.20E-07	4.21E-06	1.07E-05	4.90E-05	0.00E+00	2.17E-03	4.45E-03	2.22E-03	1.05E-02
	Vanadium	3.63E-04	5.17E-10	2.36E-09	6.98E-06	3.20E-05	0.00E+00	2.30E-03	8.33E-07	1.89E-03	4.59E-03
	Zinc	1.49E-06	5.97E-12	2.74E-11	6.64E-09	3.04E-08	0.00E+00	1.99E-04	5.07E-07	1.00E-04	3.01E-04
Seasonal Resident One-year-old (Russell Lake)		**Average Baseline HQ**									
	Cadmium	4.75E-04	6.17E-04	7.39E-06	1.92E-04	2.30E-06	0.00E+00	8.45E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.67E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.85E-05	1.72E-05	1.17E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.37E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.00E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.63E-05	2.66E-05	3.19E-07	5.14E-05	6.16E-07	0.00E+00	2.88E-02	1.87E-02	7.51E-01	7.98E-01
	Uranium	8.21E-04	8.71E-04	1.04E-04	4.38E-04	5.25E-05	0.00E+00	9.73E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.13E-03	3.13E-03	3.76E-04	2.42E-03	2.91E-04	0.00E+00	6.42E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.23E-06	1.11E-06	0.00E+00	2.70E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Project Phases									
	Cadmium	5.22E-04	6.17E-04	7.39E-06	2.06E-04	2.46E-06	0.00E+00	9.26E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	6.06E-06	3.02E-06	3.62E-07	1.86E-06	2.23E-07	0.00E+00	1.97E-05	1.72E-05	1.20E-05	6.04E-05
	Cobalt	1.72E-04	3.63E-05	4.35E-07	1.19E-05	1.42E-07	0.00E+00	1.23E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.49E-05	4.68E-06	3.36E-07	2.06E-06	1.48E-07	0.00E+00	7.40E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	2.59E-03	6.83E-06	8.18E-08	1.91E-04	2.29E-06	0.00E+00	1.51E-05	5.20E-03	2.74E-01	2.82E-01
	Selenium	2.40E-04	2.66E-05	3.19E-07	1.08E-04	1.29E-06	0.00E+00	6.27E-02	1.87E-02	7.54E-01	8.36E-01
	Uranium	2.62E-03	9.31E-04	1.12E-04	1.14E-03	1.36E-04	0.00E+00	3.03E-03	1.13E-01	1.53E-01	2.74E-01
	Vanadium	1.54E-03	3.13E-03	3.76E-04	2.88E-03	3.45E-04	0.00E+00	8.60E-03	6.21E-03	4.19E-01	4.42E-01
	Zinc	2.47E-05	1.48E-05	1.78E-06	9.73E-06	1.17E-06	0.00E+00	2.92E-03	5.01E-02	5.63E-01	6.17E-01
		Project Incremental HQ - Project Phases									
	Cadmium	4.78E-05	3.32E-09	3.96E-11	1.33E-05	1.59E-07	0.00E+00	8.17E-06	6.59E-07	4.84E-05	1.18E-04
	Chromium	3.81E-07	1.18E-11	1.39E-12	7.99E-08	9.58E-09	0.00E+00	1.19E-06	8.93E-10	2.69E-07	1.93E-06
	Cobalt	6.08E-06	1.39E-09	1.67E-11	3.98E-07	4.77E-09	0.00E+00	4.31E-06	5.89E-07	8.26E-06	1.96E-05

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Copper	1.05E-06	1.50E-09	1.08E-10	8.10E-08	5.83E-09	0.00E+00	3.09E-05	7.00E-06	1.60E-05	5.50E-05
	Molybdenum	2.52E-03	1.06E-10	1.26E-12	1.84E-04	2.21E-06	0.00E+00	1.47E-05	1.08E-07	4.46E-04	3.16E-03
	Selenium	1.44E-04	1.02E-09	1.22E-11	5.62E-05	6.73E-07	0.00E+00	3.39E-02	8.77E-07	3.36E-03	3.75E-02
	Uranium	1.80E-03	6.01E-05	7.21E-06	6.99E-04	8.38E-05	0.00E+00	2.06E-03	8.80E-03	1.34E-03	1.48E-02
	Vanadium	4.05E-04	3.38E-08	4.05E-09	4.56E-04	5.47E-05	0.00E+00	2.18E-03	1.05E-06	1.04E-03	4.14E-03
	Zinc	1.94E-06	4.55E-10	5.45E-11	5.05E-07	6.05E-08	0.00E+00	2.19E-04	1.37E-06	6.00E-05	2.83E-04
		Average Baseline HQ									
	Cadmium	4.25E-04	9.44E-06	4.32E-06	2.94E-06	1.35E-06	0.00E+00	6.14E-04	0.00E+00	2.01E-01	2.02E-01
	Chromium	5.08E-06	4.62E-08	2.11E-07	2.72E-08	1.25E-07	0.00E+00	1.35E-04	0.00E+00	5.51E-04	6.91E-04
	Cobalt	1.48E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	8.60E-04	0.00E+00	7.79E-03	8.80E-03
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.30E-08	0.00E+00	5.15E-03	0.00E+00	2.80E-02	3.32E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.84E-08	0.00E+00	2.71E-06	0.00E+00	4.58E-02	4.59E-02
	Selenium	8.32E-05	3.93E-07	1.80E-07	7.59E-07	3.48E-07	0.00E+00	2.02E-01	0.00E+00	2.77E-01	4.79E-01
	Uranium	7.35E-04	1.33E-05	6.10E-05	6.71E-06	3.07E-05	0.00E+00	7.07E-03	0.00E+00	3.64E-02	4.44E-02
	Vanadium	1.01E-03	4.80E-05	2.20E-04	3.71E-05	1.70E-04	0.00E+00	4.67E-02	0.00E+00	3.67E-01	4.16E-01
	Zinc	1.75E-05	1.95E-07	8.92E-07	1.21E-07	5.56E-07	0.00E+00	1.69E-02	0.00E+00	5.40E-01	5.57E-01
		Project Total HQ - Project Phases									
Fisher/Trapper (Russell Lake)	Cadmium	4.88E-04	9.44E-06	4.32E-06	3.28E-06	1.50E-06	0.00E+00	7.94E-04	0.00E+00	2.02E-01	2.03E-01
	Chromium	5.57E-06	4.62E-08	2.11E-07	2.93E-08	1.34E-07	0.00E+00	1.60E-04	0.00E+00	5.58E-04	7.24E-04
	Cobalt	1.58E-04	5.55E-07	2.54E-07	1.86E-07	8.50E-08	0.00E+00	9.73E-04	0.00E+00	7.80E-03	8.94E-03
	Copper	2.30E-05	7.16E-08	1.97E-07	3.23E-08	8.87E-08	0.00E+00	5.96E-03	0.00E+00	2.82E-02	3.42E-02
	Molybdenum	3.14E-03	8.59E-08	3.93E-08	3.94E-06	1.80E-06	0.00E+00	2.94E-04	0.00E+00	4.70E-02	5.05E-02
	Selenium	2.92E-04	3.93E-07	1.80E-07	2.14E-06	9.80E-07	0.00E+00	1.01E+00	0.00E+00	3.36E-01	**1.35E+00**
	Uranium	3.44E-03	1.49E-05	6.80E-05	2.45E-05	1.12E-04	0.00E+00	5.75E-02	0.00E+00	1.62E-01	2.23E-01
	Vanadium	1.52E-03	4.80E-05	2.20E-04	4.87E-05	2.23E-04	0.00E+00	8.53E-02	0.00E+00	4.07E-01	4.94E-01
	Zinc	1.97E-05	1.95E-07	8.93E-07	1.32E-07	6.06E-07	0.00E+00	2.08E-02	0.00E+00	5.42E-01	5.63E-01
		Project Incremental HQ - Project Phases									
	Cadmium	6.30E-05	8.46E-11	3.87E-11	3.39E-07	1.55E-07	0.00E+00	1.80E-04	0.00E+00	7.17E-04	9.60E-04
	Chromium	4.92E-07	2.98E-13	1.35E-12	2.04E-09	9.33E-09	0.00E+00	2.50E-05	0.00E+00	6.74E-06	3.23E-05

Human Receptor	COPC	HQs during Project Phases									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Cobalt	9.49E-06	3.55E-11	1.63E-11	1.01E-08	4.64E-09	0.00E+00	1.13E-04	0.00E+00	1.37E-05	1.36E-04
	Copper	1.63E-06	3.81E-11	1.05E-10	2.06E-09	5.67E-09	0.00E+00	8.09E-04	0.00E+00	1.48E-04	9.59E-04
	Molybdenum	3.08E-03	2.20E-12	1.01E-12	3.86E-06	1.76E-06	0.00E+00	2.92E-04	0.00E+00	1.21E-03	4.59E-03
	Selenium	2.09E-04	2.51E-11	1.15E-11	1.38E-06	6.33E-07	0.00E+00	<u>8.07E-01</u>	0.00E+00	5.87E-02	8.66E-01
	Uranium	2.70E-03	1.53E-06	7.02E-06	1.78E-05	8.16E-05	0.00E+00	5.04E-02	0.00E+00	1.25E-01	1.79E-01
	Vanadium	5.01E-04	8.62E-10	3.94E-09	1.16E-05	5.32E-05	0.00E+00	3.87E-02	0.00E+00	3.95E-02	7.88E-02
	Zinc	2.13E-06	9.96E-12	4.56E-11	1.11E-08	5.06E-08	0.00E+00	3.88E-03	0.00E+00	1.87E-03	5.75E-03

<u>Underlined values</u> indicate exceedance of the HQ of 0.2 for a given exposure pathway; **Bolded** values indicate exceedance of the HQ of 1 for all exposure pathways.
HQ = hazard quotient; COPC = constituent of potential concern.

Table 4-16: Estimated Non-radiological Risk to Human Receptors – Future Centuries

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
Permanent Resident Adult (Whitefish Lake)		Baseline HQ									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.94E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.09E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.49E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.31E-08	0.00E+00	7.49E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.85E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.34E-05	3.93E-07	1.80E-07	7.61E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.37E-04	1.33E-05	6.10E-05	6.72E-06	3.08E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.72E-05	1.70E-04	0.00E+00	6.81E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.76E-05	1.95E-07	8.92E-07	1.22E-07	5.56E-07	0.00E+00	2.46E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.28E-04	9.44E-06	4.32E-06	2.96E-06	1.36E-06	0.00E+00	8.99E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.16E-06	4.62E-08	2.11E-07	2.76E-08	1.26E-07	0.00E+00	1.98E-05	7.43E-06	2.03E-05	5.32E-05
	Cobalt	1.56E-04	5.56E-07	2.54E-07	1.85E-07	8.47E-08	0.00E+00	1.32E-04	6.30E-03	1.77E-02	2.43E-02
	Copper	2.16E-05	7.16E-08	1.97E-07	3.06E-08	8.42E-08	0.00E+00	7.59E-04	1.03E-02	5.98E-02	7.09E-02
	Molybdenum	6.12E-05	8.58E-08	3.93E-08	9.16E-08	4.19E-08	0.00E+00	4.29E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	1.11E-04	3.93E-07	1.80E-07	1.01E-06	4.64E-07	0.00E+00	3.82E-02	7.70E-03	2.91E-01	3.37E-01
	Uranium	9.01E-04	1.59E-05	7.27E-05	8.22E-06	3.76E-05	0.00E+00	1.26E-03	6.15E-02	5.88E-02	1.23E-01
	Vanadium	1.03E-03	4.80E-05	2.20E-04	3.76E-05	1.72E-04	0.00E+00	6.87E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.91E-05	1.95E-07	8.93E-07	1.32E-07	6.04E-07	0.00E+00	2.67E-03	1.88E-02	2.34E-01	2.55E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	2.47E-06	1.57E-10	7.19E-11	1.71E-08	7.81E-09	0.00E+00	5.17E-07	2.86E-07	5.25E-06	8.54E-06
	Chromium	6.59E-08	0.00E+00	0.00E+00	3.53E-10	1.62E-09	0.00E+00	2.54E-07	0.00E+00	1.05E-07	4.27E-07
	Cobalt	7.89E-06	5.50E-10	2.52E-10	9.33E-09	4.27E-09	0.00E+00	6.64E-06	1.29E-05	1.80E-05	4.55E-05
	Copper	2.84E-07	4.03E-11	1.11E-10	4.02E-10	1.10E-09	0.00E+00	9.94E-06	1.09E-05	7.76E-06	2.89E-05
	Molybdenum	5.07E-06	0.00E+00	0.00E+00	7.59E-09	3.48E-09	0.00E+00	3.56E-08	0.00E+00	1.66E-06	6.78E-06

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Selenium	2.77E-05	4.12E-12	1.89E-12	2.53E-07	1.16E-07	0.00E+00	8.71E-03	1.69E-07	1.31E-03	1.00E-02
	Uranium	1.64E-04	2.56E-06	1.17E-05	1.50E-06	6.87E-06	0.00E+00	2.30E-04	1.60E-02	1.72E-04	1.66E-02
	Vanadium	9.19E-06	4.00E-09	1.83E-08	3.35E-07	1.54E-06	0.00E+00	6.14E-05	3.08E-07	5.90E-05	1.32E-04
	Zinc	1.52E-06	1.86E-11	8.53E-11	1.05E-08	4.82E-08	0.00E+00	2.13E-04	3.19E-06	9.73E-05	3.15E-04
Permanent Resident One-year-old (Whitefish Lake)		Baseline HQ									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.46E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.68E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.86E-05	1.72E-05	1.17E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.38E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.01E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.65E-05	2.66E-05	3.19E-07	5.15E-05	6.17E-07	0.00E+00	2.89E-02	1.87E-02	7.51E-01	7.99E-01
	Uranium	8.23E-04	8.71E-04	1.04E-04	4.39E-04	5.26E-05	0.00E+00	9.75E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.43E-03	2.92E-04	0.00E+00	6.45E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.24E-06	1.11E-06	0.00E+00	2.71E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.78E-04	6.17E-04	7.39E-06	1.94E-04	2.32E-06	0.00E+00	8.51E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.76E-06	3.02E-06	3.62E-07	1.80E-06	2.16E-07	0.00E+00	1.88E-05	1.72E-05	1.18E-05	5.90E-05
	Cobalt	1.75E-04	3.63E-05	4.35E-07	1.21E-05	1.45E-07	0.00E+00	1.25E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.42E-05	4.68E-06	3.36E-07	2.00E-06	1.44E-07	0.00E+00	7.18E-04	2.38E-02	1.01E-01	1.25E-01
	Molybdenum	8.32E-05	6.83E-06	8.18E-08	7.29E-06	8.73E-08	0.00E+00	4.95E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	1.29E-04	2.66E-05	3.19E-07	6.86E-05	8.22E-07	0.00E+00	3.74E-02	1.87E-02	7.52E-01	8.08E-01
	Uranium	1.01E-03	1.04E-03	1.24E-04	5.37E-04	6.44E-05	0.00E+00	1.19E-03	1.42E-01	1.52E-01	2.98E-01
	Vanadium	1.15E-03	3.13E-03	3.76E-04	2.45E-03	2.94E-04	0.00E+00	6.51E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.48E-05	1.48E-05	1.78E-06	1.00E-05	1.20E-06	0.00E+00	2.94E-03	5.01E-02	5.63E-01	6.17E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	2.75E-06	1.03E-08	1.23E-10	1.12E-06	1.34E-08	0.00E+00	4.90E-07	6.48E-07	3.64E-06	8.67E-06
	Chromium	7.36E-08	0.00E+00	0.00E+00	2.31E-08	2.76E-09	0.00E+00	2.40E-07	0.00E+00	6.99E-08	4.10E-07
	Cobalt	8.81E-06	3.59E-08	4.30E-10	6.10E-07	7.31E-09	0.00E+00	6.29E-06	3.03E-05	1.06E-05	5.67E-05

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Copper	3.17E-07	2.63E-09	1.89E-10	2.62E-08	1.89E-09	0.00E+00	9.42E-06	2.56E-05	4.80E-06	4.02E-05
	Molybdenum	6.90E-06	0.00E+00	0.00E+00	6.04E-07	7.24E-09	0.00E+00	4.10E-08	0.00E+00	1.16E-06	8.71E-06
	Selenium	3.21E-05	2.78E-10	3.33E-12	1.71E-05	2.05E-07	0.00E+00	8.55E-03	4.10E-07	8.92E-04	9.49E-03
	Uranium	1.84E-04	1.67E-04	2.00E-05	9.80E-05	1.17E-05	0.00E+00	2.18E-04	3.77E-02	1.20E-04	3.85E-02
	Vanadium	1.03E-05	2.61E-07	3.13E-08	2.19E-05	2.63E-06	0.00E+00	5.81E-05	7.25E-07	3.29E-05	1.27E-04
	Zinc	1.97E-06	1.42E-09	1.70E-10	8.00E-07	9.58E-08	0.00E+00	2.34E-04	8.70E-06	5.74E-05	3.03E-04
Rec F/H Adult (McGowan Lake)		**Baseline HQ**									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.94E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.09E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.49E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.31E-08	0.00E+00	7.49E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.85E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.34E-05	3.93E-07	1.80E-07	7.61E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.37E-04	1.33E-05	6.10E-05	6.72E-06	3.08E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.72E-05	1.70E-04	0.00E+00	6.81E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.76E-05	1.95E-07	8.92E-07	1.22E-07	5.56E-07	0.00E+00	2.46E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.97E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.10E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.98E-05	7.43E-06	2.03E-05	5.30E-05
	Cobalt	1.50E-04	5.55E-07	2.54E-07	1.78E-07	8.13E-08	0.00E+00	1.30E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.14E-05	7.15E-08	1.96E-07	3.03E-08	8.33E-08	0.00E+00	7.56E-04	1.03E-02	5.98E-02	7.09E-02
	Molybdenum	5.73E-05	8.58E-08	3.93E-08	8.57E-08	3.92E-08	0.00E+00	4.20E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.89E-05	3.93E-07	1.80E-07	8.11E-07	3.71E-07	0.00E+00	3.53E-02	7.70E-03	2.90E-01	3.33E-01
	Uranium	7.70E-04	1.35E-05	6.19E-05	7.02E-06	3.21E-05	0.00E+00	1.18E-03	4.76E-02	5.87E-02	1.08E-01
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.73E-05	1.71E-04	0.00E+00	6.84E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.79E-05	1.95E-07	8.92E-07	1.24E-07	5.66E-07	0.00E+00	2.60E-03	1.88E-02	2.34E-01	2.55E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	5.08E-07	1.09E-11	5.00E-12	3.52E-09	1.61E-09	0.00E+00	3.55E-07	3.17E-08	3.80E-06	4.70E-06

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Chromium	1.39E-08	0.00E+00	0.00E+00	7.45E-11	3.41E-10	0.00E+00	1.78E-07	0.00E+00	7.72E-08	2.70E-07
	Cobalt	1.77E-06	3.81E-11	1.75E-11	2.10E-09	9.61E-10	0.00E+00	4.98E-06	1.40E-06	1.68E-05	2.49E-05
	Copper	6.35E-08	2.81E-12	7.72E-12	9.00E-11	2.47E-10	0.00E+00	7.43E-06	1.18E-06	6.22E-06	1.49E-05
	Molybdenum	1.14E-06	0.00E+00	0.00E+00	1.70E-09	7.78E-10	0.00E+00	2.66E-08	0.00E+00	1.53E-06	2.70E-06
	Selenium	5.52E-06	2.84E-13	1.28E-13	5.03E-08	2.30E-08	0.00E+00	5.81E-03	1.82E-08	9.02E-04	6.72E-03
	Uranium	3.28E-05	1.94E-07	8.90E-07	2.99E-07	1.37E-06	0.00E+00	1.53E-04	2.09E-03	7.56E-05	2.36E-03
	Vanadium	1.21E-06	2.80E-10	1.27E-09	4.42E-08	2.02E-07	0.00E+00	2.70E-05	3.35E-08	2.73E-05	5.57E-05
	Zinc	3.13E-07	1.29E-12	5.97E-12	2.17E-09	9.92E-09	0.00E+00	1.46E-04	3.45E-07	6.69E-05	2.14E-04
Rec F/H One-year-old (McGowan Lake)		**Baseline HQ**									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.46E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.68E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.86E-05	1.72E-05	1.18E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.38E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.01E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.65E-05	2.66E-05	3.19E-07	5.15E-05	6.17E-07	0.00E+00	2.89E-02	1.87E-02	7.51E-01	7.99E-01
	Uranium	8.23E-04	8.71E-04	1.04E-04	4.39E-04	5.26E-05	0.00E+00	9.75E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.43E-03	2.92E-04	0.00E+00	6.45E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.24E-06	1.11E-06	0.00E+00	2.71E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.50E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.70E-06	3.02E-06	3.62E-07	1.79E-06	2.14E-07	0.00E+00	1.87E-05	1.72E-05	1.18E-05	5.88E-05
	Cobalt	1.68E-04	3.63E-05	4.35E-07	1.16E-05	1.39E-07	0.00E+00	1.23E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.39E-05	4.67E-06	3.36E-07	1.98E-06	1.43E-07	0.00E+00	7.16E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.78E-05	6.83E-06	8.18E-08	6.82E-06	8.17E-08	0.00E+00	4.84E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	1.03E-04	2.66E-05	3.19E-07	5.49E-05	6.58E-07	0.00E+00	3.46E-02	1.87E-02	7.51E-01	8.05E-01
	Uranium	8.59E-04	8.84E-04	1.06E-04	4.59E-04	5.50E-05	0.00E+00	1.12E-03	1.09E-01	1.52E-01	2.64E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.44E-03	2.92E-04	0.00E+00	6.48E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.32E-05	1.48E-05	1.78E-06	9.40E-06	1.13E-06	0.00E+00	2.87E-03	5.01E-02	5.63E-01	6.16E-01

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		Project Incremental HQ - Future Centuries									
	Cadmium	5.67E-07	7.57E-10	8.64E-12	2.30E-07	2.75E-09	0.00E+00	3.37E-07	7.08E-08	2.68E-06	3.89E-06
	Chromium	1.55E-08	0.00E+00	0.00E+00	4.87E-09	5.83E-10	0.00E+00	1.69E-07	0.00E+00	5.12E-08	2.41E-07
	Cobalt	1.98E-06	2.49E-09	2.99E-11	1.37E-07	1.64E-09	0.00E+00	4.72E-06	3.29E-06	9.69E-06	1.98E-05
	Copper	7.09E-08	1.83E-10	1.32E-11	5.88E-09	4.23E-10	0.00E+00	7.03E-06	2.77E-06	3.81E-06	1.37E-05
	Molybdenum	1.54E-06	0.00E+00	0.00E+00	1.35E-07	1.62E-09	0.00E+00	3.06E-08	0.00E+00	1.07E-06	2.78E-06
	Selenium	6.39E-06	1.82E-11	2.27E-13	3.41E-06	4.09E-08	0.00E+00	5.70E-03	4.28E-08	6.10E-04	6.32E-03
	Uranium	3.66E-05	1.27E-05	1.52E-06	1.95E-05	2.34E-06	0.00E+00	1.45E-04	4.91E-03	5.50E-05	5.19E-03
	Vanadium	1.35E-06	1.82E-08	2.18E-09	2.89E-06	3.46E-07	0.00E+00	2.55E-05	7.87E-08	1.52E-05	4.54E-05
	Zinc	4.07E-07	9.91E-11	1.18E-11	1.65E-07	1.97E-08	0.00E+00	1.61E-04	9.42E-07	3.95E-05	2.02E-04
Rec F/H Adult (Russell Lake)		Baseline HQ									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.94E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.09E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.49E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.31E-08	0.00E+00	7.49E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.85E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.34E-05	3.93E-07	1.80E-07	7.61E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.37E-04	1.33E-05	6.10E-05	6.72E-06	3.08E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.72E-05	1.70E-04	0.00E+00	6.81E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.76E-05	1.95E-07	8.92E-07	1.22E-07	5.56E-07	0.00E+00	2.46E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.96E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.10E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.97E-05	7.43E-06	2.03E-05	5.29E-05
	Cobalt	1.50E-04	5.55E-07	2.54E-07	1.77E-07	8.11E-08	0.00E+00	1.29E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.14E-05	7.15E-08	1.96E-07	3.03E-08	8.32E-08	0.00E+00	7.54E-04	1.03E-02	5.98E-02	7.09E-02
	Molybdenum	5.70E-05	8.58E-08	3.93E-08	8.53E-08	3.90E-08	0.00E+00	4.14E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.75E-05	3.93E-07	1.80E-07	7.98E-07	3.65E-07	0.00E+00	3.37E-02	7.70E-03	2.90E-01	3.31E-01
	Uranium	7.61E-04	1.34E-05	6.12E-05	6.94E-06	3.18E-05	0.00E+00	1.14E-03	4.61E-02	5.87E-02	1.07E-01

Human Receptor	COPC	Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		HQ during Future Centuries									
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.73E-05	1.71E-04	0.00E+00	6.83E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.78E-05	1.95E-07	8.92E-07	1.23E-07	5.64E-07	0.00E+00	2.57E-03	1.88E-02	2.34E-01	2.55E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	3.77E-07	2.73E-12	9.09E-13	2.61E-09	1.19E-09	0.00E+00	2.64E-07	8.38E-09	2.85E-06	3.50E-06
	Chromium	1.04E-08	0.00E+00	0.00E+00	5.57E-11	2.55E-10	0.00E+00	1.33E-07	0.00E+00	5.85E-08	2.03E-07
	Cobalt	1.35E-06	9.78E-12	4.46E-12	1.60E-09	7.32E-10	0.00E+00	3.80E-06	3.59E-07	1.26E-05	1.81E-05
	Copper	4.84E-08	7.18E-13	1.99E-12	6.85E-11	1.88E-10	0.00E+00	5.66E-06	3.04E-07	4.08E-06	1.01E-05
	Molybdenum	8.64E-07	0.00E+00	0.00E+00	1.29E-09	5.92E-10	0.00E+00	2.02E-08	0.00E+00	1.17E-06	2.06E-06
	Selenium	4.05E-06	8.53E-14	2.84E-14	3.70E-08	1.69E-08	0.00E+00	4.28E-03	4.66E-09	6.71E-04	4.95E-03
	Uranium	2.41E-05	5.19E-08	2.37E-07	2.20E-07	1.00E-06	0.00E+00	1.12E-04	5.58E-04	5.06E-05	7.46E-04
	Vanadium	7.74E-07	7.28E-11	3.20E-10	2.83E-08	1.29E-07	0.00E+00	1.72E-05	8.61E-09	1.82E-05	3.64E-05
	Zinc	2.32E-07	3.27E-13	1.53E-12	1.61E-09	7.36E-09	0.00E+00	1.08E-04	8.75E-08	5.07E-05	1.59E-04
Rec F/H One-year-old (Russell Lake)		Baseline HQ									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.46E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.68E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.86E-05	1.72E-05	1.17E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.38E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.01E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.65E-05	2.66E-05	3.19E-07	5.15E-05	6.17E-07	0.00E+00	2.89E-02	1.87E-02	7.51E-01	7.99E-01
	Uranium	8.23E-04	8.71E-04	1.04E-04	4.39E-04	5.26E-05	0.00E+00	9.75E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.43E-03	2.92E-04	0.00E+00	6.45E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.24E-06	1.11E-06	0.00E+00	2.71E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.49E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.69E-06	3.02E-06	3.62E-07	1.78E-06	2.14E-07	0.00E+00	1.87E-05	1.72E-05	1.18E-05	5.87E-05
	Cobalt	1.67E-04	3.63E-05	4.35E-07	1.16E-05	1.39E-07	0.00E+00	1.22E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.39E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.14E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.75E-05	6.83E-06	8.18E-08	6.79E-06	8.13E-08	0.00E+00	4.77E-07	5.20E-03	2.73E-01	2.79E-01

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Selenium	1.01E-04	2.66E-05	3.19E-07	5.40E-05	6.47E-07	0.00E+00	3.31E-02	1.87E-02	7.51E-01	8.03E-01
	Uranium	8.50E-04	8.74E-04	1.05E-04	4.53E-04	5.43E-05	0.00E+00	1.08E-03	1.05E-01	1.52E-01	2.61E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.43E-03	2.92E-04	0.00E+00	6.47E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.31E-05	1.48E-05	1.78E-06	9.36E-06	1.12E-06	0.00E+00	2.83E-03	5.01E-02	5.63E-01	6.16E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	4.21E-07	1.75E-10	2.27E-12	1.71E-07	2.04E-09	0.00E+00	2.50E-07	1.86E-08	2.03E-06	2.89E-06
	Chromium	1.16E-08	0.00E+00	0.00E+00	3.64E-09	4.36E-10	0.00E+00	1.26E-07	0.00E+00	3.87E-08	1.81E-07
	Cobalt	1.51E-06	6.37E-10	7.67E-12	1.05E-07	1.25E-09	0.00E+00	3.60E-06	8.43E-07	7.26E-06	1.33E-05
	Copper	5.40E-08	4.68E-11	3.38E-12	4.48E-09	3.22E-10	0.00E+00	5.36E-06	7.13E-07	2.56E-06	8.69E-06
	Molybdenum	1.18E-06	0.00E+00	0.00E+00	1.03E-07	1.23E-09	0.00E+00	2.33E-08	0.00E+00	8.05E-07	2.11E-06
	Selenium	4.69E-06	3.64E-12	5.68E-14	2.50E-06	3.00E-08	0.00E+00	4.20E-03	1.12E-08	4.52E-04	4.66E-03
	Uranium	2.69E-05	3.39E-06	4.06E-07	1.43E-05	1.72E-06	0.00E+00	1.06E-04	1.31E-03	3.75E-05	1.50E-03
	Vanadium	8.65E-07	4.66E-09	5.53E-10	1.85E-06	2.21E-07	0.00E+00	1.63E-05	2.05E-08	1.01E-05	2.94E-05
	Zinc	3.02E-07	2.55E-11	2.96E-12	1.22E-07	1.47E-08	0.00E+00	1.19E-04	2.38E-07	2.99E-05	1.50E-04
Seasonal Resident Adult (Russell Lake)		**Baseline HQ**									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.94E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.09E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.27E-05
	Cobalt	1.49E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	1.25E-04	6.29E-03	1.77E-02	2.42E-02
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.31E-08	0.00E+00	7.49E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.85E-08	0.00E+00	3.94E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.34E-05	3.93E-07	1.80E-07	7.61E-07	3.48E-07	0.00E+00	2.94E-02	7.70E-03	2.89E-01	3.26E-01
	Uranium	7.37E-04	1.33E-05	6.10E-05	6.72E-06	3.08E-05	0.00E+00	1.03E-03	4.55E-02	5.86E-02	1.06E-01
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.72E-05	1.70E-04	0.00E+00	6.81E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.76E-05	1.95E-07	8.92E-07	1.22E-07	5.56E-07	0.00E+00	2.46E-03	1.88E-02	2.34E-01	2.55E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	8.94E-05	8.78E-03	2.48E-01	2.57E-01
	Chromium	5.10E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.96E-05	7.43E-06	2.02E-05	5.28E-05
	Cobalt	1.50E-04	5.55E-07	2.54E-07	1.77E-07	8.11E-08	0.00E+00	1.26E-04	6.29E-03	1.77E-02	2.42E-02

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
	Copper	2.14E-05	7.15E-08	1.96E-07	3.03E-08	8.32E-08	0.00E+00	7.50E-04	1.03E-02	5.98E-02	7.08E-02
	Molybdenum	5.70E-05	8.58E-08	3.93E-08	8.53E-08	3.90E-08	0.00E+00	4.00E-07	1.85E-03	8.62E-02	8.81E-02
	Selenium	8.75E-05	3.93E-07	1.80E-07	7.98E-07	3.65E-07	0.00E+00	3.07E-02	7.70E-03	2.89E-01	3.28E-01
	Uranium	7.61E-04	1.34E-05	6.12E-05	6.94E-06	3.18E-05	0.00E+00	1.06E-03	4.57E-02	5.87E-02	1.06E-01
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.73E-05	1.71E-04	0.00E+00	6.82E-03	3.43E-03	1.72E-01	1.83E-01
	Zinc	1.78E-05	1.95E-07	8.92E-07	1.23E-07	5.64E-07	0.00E+00	2.49E-03	1.88E-02	2.34E-01	2.55E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	3.77E-07	2.73E-12	9.09E-13	2.61E-09	1.19E-09	0.00E+00	7.91E-08	2.79E-09	9.09E-07	1.37E-06
	Chromium	1.04E-08	0.00E+00	0.00E+00	5.57E-11	2.55E-10	0.00E+00	4.00E-08	0.00E+00	1.90E-08	6.98E-08
	Cobalt	1.35E-06	9.78E-12	4.46E-12	1.60E-09	7.32E-10	0.00E+00	1.14E-06	1.08E-07	3.73E-06	6.33E-06
	Copper	4.84E-08	7.18E-13	1.99E-12	6.85E-11	1.88E-10	0.00E+00	1.70E-06	9.13E-08	1.23E-06	3.07E-06
	Molybdenum	8.64E-07	0.00E+00	0.00E+00	1.29E-09	5.92E-10	0.00E+00	6.06E-09	0.00E+00	3.50E-07	1.22E-06
	Selenium	4.05E-06	8.53E-14	2.84E-14	3.70E-08	1.69E-08	0.00E+00	1.28E-03	1.40E-09	2.14E-04	1.50E-03
	Uranium	2.41E-05	5.19E-08	2.37E-07	2.20E-07	1.00E-06	0.00E+00	3.36E-05	1.67E-04	1.57E-05	2.42E-04
	Vanadium	7.74E-07	7.28E-11	3.20E-10	2.83E-08	1.29E-07	0.00E+00	5.17E-06	2.56E-09	6.32E-06	1.24E-05
	Zinc	2.32E-07	3.27E-13	1.53E-12	1.61E-09	7.36E-09	0.00E+00	3.25E-05	2.61E-08	1.69E-05	4.97E-05
Seasonal Resident One-year-old (Russell Lake)		**Baseline HQ**									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.46E-05	1.97E-02	6.29E-01	6.50E-01
	Chromium	5.68E-06	3.02E-06	3.62E-07	1.78E-06	2.13E-07	0.00E+00	1.86E-05	1.72E-05	1.17E-05	5.85E-05
	Cobalt	1.66E-04	3.63E-05	4.35E-07	1.15E-05	1.38E-07	0.00E+00	1.18E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.38E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.09E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.63E-05	6.83E-06	8.18E-08	6.68E-06	8.01E-08	0.00E+00	4.54E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	9.65E-05	2.66E-05	3.19E-07	5.15E-05	6.17E-07	0.00E+00	2.89E-02	1.87E-02	7.51E-01	7.99E-01
	Uranium	8.23E-04	8.71E-04	1.04E-04	4.39E-04	5.26E-05	0.00E+00	9.75E-04	1.04E-01	1.52E-01	2.59E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.43E-03	2.92E-04	0.00E+00	6.45E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.28E-05	1.48E-05	1.78E-06	9.24E-06	1.11E-06	0.00E+00	2.71E-03	5.01E-02	5.63E-01	6.16E-01
		Project Total HQ - Future Centuries									
	Cadmium	4.76E-04	6.17E-04	7.39E-06	1.93E-04	2.31E-06	0.00E+00	8.47E-05	1.97E-02	6.29E-01	6.50E-01

Human Receptor	COPC	Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		HQ during Future Centuries									
	Chromium	5.69E-06	3.02E-06	3.62E-07	1.78E-06	2.14E-07	0.00E+00	1.86E-05	1.72E-05	1.18E-05	5.86E-05
	Cobalt	1.67E-04	3.63E-05	4.35E-07	1.16E-05	1.39E-07	0.00E+00	1.19E-04	1.46E-02	3.78E-02	5.27E-02
	Copper	2.39E-05	4.67E-06	3.36E-07	1.98E-06	1.42E-07	0.00E+00	7.11E-04	2.37E-02	1.01E-01	1.25E-01
	Molybdenum	7.75E-05	6.83E-06	8.18E-08	6.79E-06	8.13E-08	0.00E+00	4.61E-07	5.20E-03	2.73E-01	2.79E-01
	Selenium	1.01E-04	2.66E-05	3.19E-07	5.40E-05	6.47E-07	0.00E+00	3.02E-02	1.87E-02	7.51E-01	8.00E-01
	Uranium	8.50E-04	8.74E-04	1.05E-04	4.53E-04	5.43E-05	0.00E+00	1.01E-03	1.05E-01	1.52E-01	2.60E-01
	Vanadium	1.14E-03	3.13E-03	3.76E-04	2.43E-03	2.92E-04	0.00E+00	6.46E-03	6.21E-03	4.18E-01	4.38E-01
	Zinc	2.31E-05	1.48E-05	1.78E-06	9.36E-06	1.12E-06	0.00E+00	2.74E-03	5.01E-02	5.63E-01	6.16E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	4.21E-07	1.75E-10	2.27E-12	1.71E-07	2.04E-09	0.00E+00	7.49E-08	5.59E-09	5.96E-07	1.27E-06
	Chromium	1.16E-08	0.00E+00	0.00E+00	3.64E-09	4.36E-10	0.00E+00	3.79E-08	0.00E+00	1.21E-08	6.57E-08
	Cobalt	1.51E-06	6.37E-10	7.67E-12	1.05E-07	1.25E-09	0.00E+00	1.08E-06	2.52E-07	2.08E-06	5.03E-06
	Copper	5.40E-08	4.68E-11	3.38E-12	4.48E-09	3.22E-10	0.00E+00	1.61E-06	2.14E-07	7.38E-07	2.62E-06
	Molybdenum	1.18E-06	0.00E+00	0.00E+00	1.03E-07	1.23E-09	0.00E+00	6.99E-09	0.00E+00	2.38E-07	1.52E-06
	Selenium	4.69E-06	3.64E-12	5.68E-14	2.50E-06	3.00E-08	0.00E+00	1.26E-03	1.86E-09	1.39E-04	1.41E-03
	Uranium	2.69E-05	3.39E-06	4.06E-07	1.43E-05	1.72E-06	0.00E+00	3.19E-05	3.93E-04	1.10E-05	4.83E-04
	Vanadium	8.65E-07	4.66E-09	5.53E-10	1.85E-06	2.21E-07	0.00E+00	4.90E-06	6.05E-09	3.55E-06	1.14E-05
	Zinc	3.02E-07	2.55E-11	2.96E-12	1.22E-07	1.47E-08	0.00E+00	3.58E-05	7.08E-08	1.04E-05	4.67E-05
Fisher/Trapper Adult (Russell Lake)		**Baseline HQ**									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	6.15E-04	0.00E+00	2.01E-01	2.02E-01
	Chromium	5.09E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.35E-04	0.00E+00	5.51E-04	6.92E-04
	Cobalt	1.49E-04	5.55E-07	2.54E-07	1.76E-07	8.04E-08	0.00E+00	8.61E-04	0.00E+00	7.79E-03	8.80E-03
	Copper	2.13E-05	7.15E-08	1.96E-07	3.02E-08	8.31E-08	0.00E+00	5.15E-03	0.00E+00	2.80E-02	3.32E-02
	Molybdenum	5.61E-05	8.58E-08	3.93E-08	8.40E-08	3.85E-08	0.00E+00	2.71E-06	0.00E+00	4.58E-02	4.59E-02
	Selenium	8.34E-05	3.93E-07	1.80E-07	7.61E-07	3.48E-07	0.00E+00	2.03E-01	0.00E+00	2.77E-01	4.80E-01
	Uranium	7.37E-04	1.33E-05	6.10E-05	6.72E-06	3.08E-05	0.00E+00	7.09E-03	0.00E+00	3.64E-02	4.44E-02
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.72E-05	1.70E-04	0.00E+00	4.69E-02	0.00E+00	3.68E-01	4.16E-01
	Zinc	1.76E-05	1.95E-07	8.92E-07	1.22E-07	5.56E-07	0.00E+00	1.69E-02	0.00E+00	5.41E-01	5.57E-01

Human Receptor	COPC	HQ during Future Centuries									
		Water (internal)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by COPC
		Project Total HQ - Future Centuries									
	Cadmium	4.26E-04	9.44E-06	4.32E-06	2.95E-06	1.35E-06	0.00E+00	6.17E-04	0.00E+00	2.01E-01	2.02E-01
	Chromium	5.11E-06	4.62E-08	2.11E-07	2.73E-08	1.25E-07	0.00E+00	1.36E-04	0.00E+00	5.51E-04	6.93E-04
	Cobalt	1.51E-04	5.55E-07	2.54E-07	1.78E-07	8.16E-08	0.00E+00	8.87E-04	0.00E+00	7.79E-03	8.83E-03
	Copper	2.14E-05	7.15E-08	1.96E-07	3.04E-08	8.34E-08	0.00E+00	5.19E-03	0.00E+00	2.80E-02	3.32E-02
	Molybdenum	5.76E-05	8.58E-08	3.93E-08	8.62E-08	3.94E-08	0.00E+00	2.85E-06	0.00E+00	4.58E-02	4.59E-02
	Selenium	9.02E-05	3.93E-07	1.80E-07	8.22E-07	3.76E-07	0.00E+00	2.32E-01	0.00E+00	2.79E-01	5.12E-01
	Uranium	7.77E-04	1.34E-05	6.14E-05	7.09E-06	3.24E-05	0.00E+00	7.86E-03	0.00E+00	3.65E-02	4.53E-02
	Vanadium	1.02E-03	4.80E-05	2.20E-04	3.73E-05	1.71E-04	0.00E+00	4.70E-02	0.00E+00	3.68E-01	4.16E-01
	Zinc	1.80E-05	1.95E-07	8.92E-07	1.24E-07	5.69E-07	0.00E+00	1.77E-02	0.00E+00	5.41E-01	5.59E-01
		Project Incremental HQ - Future Centuries									
	Cadmium	6.28E-07	4.55E-12	1.82E-12	4.35E-09	1.99E-09	0.00E+00	1.82E-06	0.00E+00	8.06E-06	1.05E-05
	Chromium	1.73E-08	0.00E+00	0.00E+00	9.28E-11	4.25E-10	0.00E+00	9.19E-07	0.00E+00	2.51E-07	1.19E-06
	Cobalt	2.26E-06	1.63E-11	7.45E-12	2.67E-09	1.22E-09	0.00E+00	2.61E-05	0.00E+00	2.61E-06	3.10E-05
	Copper	8.06E-08	1.20E-12	3.31E-12	1.14E-10	3.14E-10	0.00E+00	3.89E-05	0.00E+00	2.52E-06	4.15E-05
	Molybdenum	1.44E-06	0.00E+00	0.00E+00	2.16E-09	9.87E-10	0.00E+00	1.39E-07	0.00E+00	6.59E-07	2.24E-06
	Selenium	6.76E-06	1.14E-13	5.68E-14	6.16E-08	2.82E-08	0.00E+00	2.94E-02	0.00E+00	2.30E-03	3.17E-02
	Uranium	4.01E-05	8.65E-08	3.96E-07	3.66E-07	1.67E-06	0.00E+00	7.72E-04	0.00E+00	9.41E-05	9.09E-04
	Vanadium	1.29E-06	1.20E-10	5.38E-10	4.71E-08	2.16E-07	0.00E+00	1.19E-04	0.00E+00	1.50E-04	2.70E-04
	Zinc	3.87E-07	5.40E-13	2.56E-12	2.68E-09	1.23E-08	0.00E+00	7.46E-04	0.00E+00	3.13E-04	1.06E-03

Underlined values indicate exceedance of the HQ of 0.2 for a given exposure pathway; **Bolded** values indicate exceedance of the HQ of 1 for all exposure pathways.
HQ = hazard quotient; COPC = constituent of potential concern.

4.4.1.2 Carcinogen Risk

The arsenic ILCR was not predicted to exceed the negligible cancer risk level of 1 in 100,000 for the camp worker, recreational fisher/hunter, and seasonal resident at any locations during the Project phases, as shown in Table 4-17. The recreational fisher/hunter, and seasonal resident were assessed as composite receptors throughout all life stages. The arsenic ILCR is essentially equal to the negligible cancer risk level of 1 in 100,000 for the adult fisher/trapper at Russell Lake during the Project phases. In the future centuries, a permanent resident was assessed instead of a camp worker – the cancer risk was not predicted to exceed the negligible cancer risk level for any of the receptors assessed in the future centuries (Table 4-17).

The main ingestion exposure pathway for arsenic for all human receptors was consumption of local terrestrial animals including muskrat, goose, mallard, moose, moose organs, and caribou, as well as locally caught fish represented in the HHRA by northern pike and white sucker.

The main contribution to the arsenic cancer risk for the fisher/trapper at Russell Lake is from ingestion of caribou. The predicted tissue concentration of arsenic in caribou in the Russell Lake area was 0.07 mg/kg fw, (see Appendix B) compared to a measured average value in barren-ground caribou of 0.02 mg/kg fw or maximum of 0.04 mg/kg fw from the Eastern Athabasca Regional Monitoring Program from 2011 to 2017 (CanNorth, 2018).

The diet assumptions for the fisher/trapper are conservative and are based on engagement with a local fisher/trapper. The diet of the fisher/trapper is representative of one person, who consumes a unique composition and quantity of traditional foods (e.g., ingestion rate of 175 kg/yr of caribou, equivalent to approximately 2 to 3 servings per day). Most people fishing, hunting, and trapping in the LSA and RSA would consume traditional foods more consistent with the average traditional foods consumer diet which was developed from the ERFN country foods study. In comparison, the ERFN country foods study (Table 4-4) indicates a caribou ingestion rate of 2.6 kg/yr (1 to 2 servings per month) and a total game ingestion rate of 21.3 kg/yr. The First Nations Food, Nutrition and Environment Study for Saskatchewan (Chan et al., 2018) indicates a total game ingestion rate of 54.4 kg/yr for the high consumer for the boreal shield. Overall, other local fisher/trappers may prefer consumption of moose over caribou.

The potential for arsenic to represent health risks for consumers of Traditional Foods was assessed for the Eastern Athabasca Region and for the Boreal Shield region of Saskatchewan by CanNorth (2018) and Chan et al. (2018), respectively. The Eastern Athabasca Region HHRA used a high consumer of traditional foods with a caribou ingestion rate of approximately 132 kg/yr (from the Hatchet Lake Dietary Survey [(CanNorth, 2000)]) and concluded that arsenic did not pose a significant risk to consumers of Traditional Foods.

Table 4-17: Estimated Incremental Lifetime Cancer Risk from Arsenic to Human Receptors

Human Receptor	Project Phases Cancer Risk (per 100,000)	Future Centuries Cancer Risk (per 100,000)
Camp Worker	0.1	N/A
Recreational Fisher/Hunter (LA-1)	0.4	0.1
Recreational Fisher/Hunter (Russell Lake)	0.3	0.04
Seasonal Resident (Russell Lake)	0.1	0.01
Fisher/Trapper (Russell Lake)	1.2	0.2
Permanent Resident	N/A	0.1

4.4.1.3 Radiological Risk

The incremental radiation dose to all human receptors in the Project area, LSA, or RSA during all phases of the Project was predicted to be below the dose limit of 1 mSv/yr, as shown in Table 4-18. If a dose constraint of 0.3 mSv/yr is applied, the predicted radiation dose to all human receptors during all phases of the Project was predicted to remain below the dose constraint. Therefore, it is unlikely that there would be significant adverse effects on human receptors as a result of radionuclide releases from the Project.

The predicted highest dose during the Project phases would be to the fisher/trapper at Russell Lake (0.06 mSv/yr for the adult, as shown in Table 4-19). The main contributor to total dose would be from Po-210 due to ingestion of fish from Russell Lake (inlet) and ingestion of animals (mallard and woodland caribou) harvested in the area around Russell Lake who eat from the aquatic environment. The mallard consumes benthic invertebrates and aquatic plants (macrophytes). The woodland caribou consumes aquatic plants (macrophytes) as the aquatic component of its diet.

During the future centuries, the predicted highest dose would be 0.04 mSv/yr to the permanent resident (one-year old) at Whitefish Lake, as shown in Table 4-18.

Overall, since the radiation dose estimates were below the dose limit, no discernable health effects would be anticipated due to exposure of these receptors to radioactive releases from the Project. The presence and concentrations of radionuclides in the receiving environment would be monitored and the associated radiation dose estimates would be periodically reassessed in accordance with the processes outlined in the Environmental Protection Program.

Table 4-18: Summary of All Radiation Doses to Human Receptors during Project Phases

Human Receptor	Location	Maximum Total Incremental Dose (mSv/yr)	% of Dose Limit	% of Dose Constraint
Camp Worker (Adult)	Whitefish Lake	0.03	3%	8%
Recreational Fisher/Hunter (Adult)	McGowan Lake	0.04	4%	12%
Recreational Fisher/Hunter (One-year-old)	McGowan Lake	0.05	5%	16%
Recreational Fisher/Hunter (Adult)	Russell Lake	0.02	2%	8%
Recreational Fisher/Hunter (One-year-old)	Russell Lake	0.03	3%	10%
Seasonal Resident (Adult)	Russell Lake	0.01	1%	4%
Seasonal Resident (One-year-old)	Russell Lake	0.02	2%	6%
Fisher/Trapper (Adult)	Russell Lake	0.06	6%	19%

Note: The dose limit and dose limit for a non-NEW is 1 mSv/yr and the dose constraint is 0.3 mSv/yr. The camp worker is not assessed in the future centuries.

Table 4-19: Summary of Radiation Dose to Limiting Human Receptor – Project Phases

Maximum Incremental Dose (mSv/yr)	Receptor	Location	Largest Contributor to Dose
0.06	Fisher/Trapper	Russell Lake	Po-210 Aquatic Animals

Table 4-20: Summary of All Radiation Doses to Human Receptors during Future Centuries

Human Receptor	Location	Maximum Total Incremental Dose (mSv/yr)	% of Dose Limit	% of Dose Constraint
Permanent Resident (Adult)	Whitefish Lake	0.03	3%	9%
Permanent Resident (One-year-old)	Whitefish Lake	0.04	4%	12%
Recreational Fisher/Hunter (Adult)	McGowan Lake	0.01	1%	3%
Recreational Fisher/Hunter (One-year-old)	McGowan Lake	0.01	1%	5%
Recreational Fisher/Hunter (Adult)	Russell Lake	0.01	1%	2%

Human Receptor	Location	Maximum Total Incremental Dose (mSv/yr)	% of Dose Limit	% of Dose Constraint
Recreational Fisher/Hunter (One-year-old)	Russell Lake	0.01	1%	3%
Seasonal Resident (Adult)	Russell Lake	0.002	0%	1%
Seasonal Resident (One-year-old)	Russell Lake	0.003	0%	1%
Fisher/Trapper (Adult)	Russell Lake	0.01	1%	4%

Note: The public dose limit is 1 mSv/yr and the dose constraint is 0.3 mSv/yr. The camp worker is not assessed in the future centuries.

4.4.1.4 Radon Risk

The maximum incremental radon dose to the camp worker was estimated to be 0.13 mSv/yr during operation. The assessment is conservative in that it assumes that the camp worker spends 100% of the time indoors.

The total incremental dose to the camp worker from all radionuclides in the U-238 decay chain including radon would be 0.16 mSv/year, which is below the dose limit for a non-NEW of 1 mSv/yr (Table 4-21). The estimate of total dose including radon is conservative based on the following assumptions:

- the camp worker spends 100% of their time indoors when on site for exposure to radon (Section 4.2.5.3).
- receptors are exposed to the maximum exposure concentrations at their location for each model scenario and Project phase (Section 4.2.6).
- For radionuclides in the U-238 decay chain (other than radon), the camp worker is also exposed to radionuclides through ingestion (water and food) pathways resulting in a conservative dose when also factoring in the dose from radon indoors.

Table 4-21: Total Radiation Dose to Camp Worker from all Radionuclides including Radon Progeny – Project Phases

Human Receptor	Location	Maximum Total Incremental Dose - U-238 decay chain (mSv/yr)	Maximum Radon Dose (mSv/yr)	Maximum Total Dose (mSv/yr)	% of Dose Limit for non-NEW
Camp Worker (Adult)	Whitefish Lake	0.03	0.13	0.16	16%

4.4.2 Uncertainties in the Risk Characterization

The problem formulation and toxicity and exposure information are combined in the risk characterization step to estimate the potential for human health effects. The uncertainties associated with each of the previous steps of the HHRA are discussed in Section 4.1.6, Uncertainty in Problem Formulation, Section 4.2.6, Uncertainty in Exposure Assessment, and Section 4.3.3, Uncertainty in the Toxicity Assessment. In each step of the HHRA, conservative assumptions were used to address uncertainties. The use of this approach is far more likely to overestimate potential risk than to underestimate risk.

5.0 Ecological Risk Assessment

5.1 Problem Formulation

The problem formulation includes identification of ecological receptors (i.e., VCs) and their characteristics, selection of COPCs (radiological and non-radiological) and other stressors, identification of assessment and measurement endpoints and exposure pathways, and an overall conceptual model for the EcoRA.

5.1.1 Receptor Selection

It is generally an impractical task to assess the effect of radiological and non-radiological emissions on all the species within a natural ecosystem, and specifically within the ecosystem around the Project. Therefore, a representative group of organisms were selected for dose and risk analysis. The organisms were selected as ecological receptors because they are known to exist at the site and in the local study area, are representative of major taxonomic groups or exposure pathways, are listed federally and/or provincially, and/or have a special importance or value to people or other ecological factors.

A preliminary list of ecological receptors for the Project was compiled from the species identified in the Aquatic Baseline Report (Ecometrix, 2020) and Terrestrial Environment, Wildlife and Vegetation Baseline Inventory Report (Omnia, 2020). Species were included in the preliminary list if they were quantified and/or incidentally observed through respective survey methods, except for birds, where only the ten most abundant song birds and area waterfowl, or sensitive bird species are included in the preliminary list.

A representative subset of organisms was selected from each major plant or animal group to be carried forward as ecological receptors. Several factors were considered in the selection process, following the criteria provided in Table 7.1 of CSA N288.6 (2022):

- Availability of chemical analyses for radiological and non-radiological parameters for the species. For example, the southern red-backed vole was selected on this basis;
- Abundance of the species in the study area relative to other species;
- Value or importance to Indigenous communities, based on information from Denison's meeting notes with a local fisher/trapper Mr. Bobby John (KPI Program, 2019);
- Classification as threatened or species of special concern identified by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and listed under the federal Species at Risk Act (SARA) (e.g., woodland caribou);
- Representing a potential exposure pathway to COPCs through releases to the environment; and,

- Availability of scientific information for the receptor that can be used in risk analysis. For example, amphibian and reptiles are relatively less characterized. Therefore, frogs were not included on the ecological receptor list on the basis of limited scientific information for risk assessment. However, the assessment of a fish receptor is considered to be protective of the most sensitive life stage of frogs, which is the tadpole.

The major plant and animal groups were defined based on taxonomy and ecology, so as to represent the different possible pathways of exposure to COPCs. The organisms selected to represent each major group were either individual species of vertebrate organisms, or generic types of plants or invertebrates such as aquatic macrophytes or zooplankton.

Table 5-1 below summarizes the selected ecological receptors for the Denison Project, and the key information used in the selection process. A finalized summary table of all ecological receptors selected for the EcoRA can be found in Table 5-3.

5.1.1.1 Consideration of Species at Risk

Species at Risk (SAR) often lack the information needed for risk assessment, because they are difficult to study. However, some SAR can be represented by other more common species that have similar diets and exposure pathways. For example, the olive-sided flycatcher (SAR) was selected to represent other aerial insectivores, which include the SAR common nighthawk and barn swallow.

Table 5-2 lists the SAR or species of conservation concern that may potentially interact with the Project, which are listed by COSEWIC or under SARA, or ranked “imperiled” or “vulnerable” by the Saskatchewan Conservation Data Centre (SKCDC). The SKCDC rankings are intended to provide support in conservation planning and monitoring of SAR, but protection of species on the list is not regulated. Surrogate species selected to represent each listed species are also provided in Table 5-2.

Table 5-1: List of Ecological Receptors for Wheeler River Project

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1	2	3	4	5	
	Major Plant/Animal Group	Facility or Stakeholder Importance*	Ecological Significance**	Socio-Economic Significance***	Exposed to and/or Sensitive to Stressor	
Terrestrial Invertebrates						
Terrestrial Invertebrates (general category)	Terrestrial Invertebrates	Habitat identified in the baseline study.	Food source for other receptors	Not identified	Exposed to atmospheric release through soil	**Selected as VC: 1,2,5**
Aquatic Invertebrates						
Zooplankton (general category)	Zooplankton	Present in lakes / potential discharge locations	Food source for other receptors	Not identified	Exposed to aquatic release through water	**Selected as VC: 1,2,5**
Benthic invertebrates (general category)	Benthic invertebrates	Taxonomy was classified in most lakes surveyed in the studied area. Whole body tissue was collected and analyzed for metal and radionuclides.	Food source for other receptors	Not identified	Exposed to aquatic release through water and sediment.	**Selected as VC: 1,2,5**
Aquatic Plants						
Macrophyte (e.g., *Carex sp.*) (general category)	Aquatic Macrophyte	Present in most surface water bodies.	Food source for other receptors. Provides spawning substrate for some fish species (e.g. Northern Pike)	Provides habitat and food for traditional food fish and animals	Exposed to aquatic release through water and sediment.	**Selected as VC: 1,2,3,4,5**
Phytoplankton (general category)	Phytoplankton	Present in lakes / potential discharge locations	Food source for other receptors	Provides food for traditional food fish	Exposed to aquatic release through water.	**Selected as VC: 1,2,3,4,5**
Terrestrial Plants						
Lichen	Lichen	Observed in the study area. Sampled and analyzed for metals and radionuclides in terrestrial baseline studies.	Primary food source for woodland caribou. Some lichen species are provincially rare.	Provides food for caribou, a species of socio-economic significance.	Exposed to atmospheric release through soil	**Selected as VC: 1,2,3,4,5**
Blueberry (*Vaccinium myrtilloides*)	Shrub	Observed in the study area. Fruit, leaves and stems collected and analyzed for metals and radionuclides.	Food source for other receptors.	Regional traditional food item.	Exposed to atmospheric release through soil	**Selected as VC: 1,2,3,4,5**

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1	2	3	4	5	
	Major Plant/Animal Group	Facility or Stakeholder Importance*	Ecological Significance**	Socio-Economic Significance***	Exposed to and/or Sensitive to Stressor	
Labrador tea (*Rhododendron groenlandicum*)	Shrub	Observed in the study area.	Food source for other receptors. Surrogate for leafy plants used in the human diet and rare species observed in the area such as Alaskan clubmoss (ranked S2) and three-seeded sedge (ranked S3).	Harvested regionally for medicinal use (tea)	Exposed to atmospheric release through soil	**Selected as VC: 1,2,3,4,5**
Browse	Shrub	Observed in the study area.	Food source for other receptors.	Not identified	Exposed to atmospheric release through soil	Not selected as a VC, but it is a component of the food web.
Terrestrial Mammals						
Woodland caribou (*Rangifer tarandus caribou*)	Terrestrial herbivore	Observed in the study area.	Threatened status under COSEWIC and SARA for broader regional study area	Harvested regionally as a traditional food item and for fur.	Exposed to atmospheric and aquatic releases through consumption of food (plants and lichens), water and soil.	**Selected as VC: 1,2,3,4,5**
Snowshoe hare (*Lepus americanus*)	Terrestrial herbivore	Observed in the study area.	Food source for other receptors.	Regional traditional food item. Harvested regionally for fur.	Exposed to atmospheric and aquatic releases through food (upland plants), water and soil.	**Selected as VC: 1,2,3,4,5**
Moose (*Alces americanus*)	Terrestrial herbivore	Observed in the study area.	Food source for other receptors.	Regional traditional food item.	Exposed to atmospheric and aquatic releases through food (upland and aquatic plants), water and soil.	**Selected as VC: 1,2,3,4,5**
Red-backed vole (*Myodes gapperi*)	Terrestrial omnivore	Observed in the study area. 124 specimens were analyzed for metals and radionuclides. Surrogate for other small mammals such as dusky shrews, meadow vole.	Food source for other receptors.	Food source for other species. Regional traditional food items and/or traditionally harvested for fur.	Exposed to atmospheric and aquatic releases through food (plants, insects and invertebrates), water and soil	**Selected as VC: 1,2,3,4,5**
Meadow vole (*Microtus pennsylvanicus*)	Terrestrial herbivore	Observed in the study area.	Food source for other receptors.	Traditionally harvested for fur.	Exposed to atmospheric release through food (plants) and soil	Not Selected. Assessment of Red-backed vole is expected to be protective of this species.
Red squirrel	Terrestrial omnivore	Observed in the study area.	Food source for other receptors	Trapped for fur/meat and hunted by indigenous people	Exposed to atmospheric release through food (plants) and soil	

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1	2	3	4	5	
	Major Plant/Animal Group	Facility or Stakeholder Importance*	Ecological Significance**	Socio-Economic Significance***	Exposed to and/or Sensitive to Stressor	
Dusky Shrews (*Sorex monticolus*)	Terrestrial omnivore	Observed in the study area.	Food source for other receptors	Not identified	Exposed to atmospheric release through food (plants) and soil	
Black bear (*Ursus americanus*)	Terrestrial omnivore	Observed in the study area.	Top Omnivore	Regional traditional food item. Harvested regionally for fur.	Exposed to atmospheric and aquatic releases through food (berries, nuts, small mammals, fish, birds), water, sediment and soil.	**Selected as VC: 1,2,3,4,5**
Canada Lynx (*Lynx canadensis*)	Terrestrial carnivore	Observed in the study area.	Top carnivore. Surrogate for other carnivores such as wolf, marten, fisher, and ermine.	Harvested regionally for fur. Small lynx is also consumed as traditional food item.	Exposed to atmospheric and aquatic releases through food (small mammals), water and soil	**Selected as VC: 1,2,3,4,5**
American marten (*Martes americana*)	Terrestrial carnivore	Observed in the study area.	Small mammal, carnivore.	Regional traditional food item. Harvested regionally for fur.	Exposed to atmospheric release through food (small mammals) and soil	Not selected. Assessment of the Canada Lynx is expected to be protective of this species.
Fisher (*Pekania pennanti*)	Terrestrial carnivore	Observed in the study area.	Small mammal, carnivore.	Trapped for fur/meat.	Exposed to atmospheric release through food (small mammals) and soil	
Red fox	Terrestrial carnivore	Observed in the study area.	Small mammal, carnivore.	Trapped for fur/meat and hunted by indigenous people	Exposed to atmospheric release through food (small mammals) and soil	
Ermine (*Mustela erminea*)	Terrestrial carnivore	Observed in the study area.	Small mammal, carnivore.	Trapped for fur/meat.	Exposed to atmospheric release through food (small mammals) and soil	
Grey wolf (*Canis lupus*)	Terrestrial carnivore	Observed in the study area.	Large mammal, top carnivore.	Trapped for fur/meat.	Exposed to atmospheric release through food (small mammals) and soil	
Riparian Mammals						
Muskrat (*Ondatra zibethicus*)	Riparian herbivore	Observed in the study area.	Surrogate for other riparian herbivores such as the beaver.	Regional traditional food item. Harvested regionally for fur.	Exposed to aquatic release through food (aquatic vegetation), water and sediment	**Selected as VC: 1,2,3,4,5**
North American beaver (*Castor canadensis*)	Riparian herbivore	Observed in the study area.	Food source for other receptors	Trapped for fur/meat and hunted by indigenous people	Exposed to aquatic release through food (aquatic vegetation), water and sediment	Not selected. Assessment of the Muskrat is expected to be protective of this species.

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1	2	3	4	5	
	Major Plant/Animal Group	Facility or Stakeholder Importance*	Ecological Significance**	Socio-Economic Significance***	Exposed to and/or Sensitive to Stressor	
American Mink (*Neovison vison*)	Riparian carnivore	Observed in the study area.	Surrogate for other riparian carnivores such as river otter.	Harvested regionally for fur.	Exposed to atmospheric and aquatic releases through food (small mammals, fish, amphibians, insects), water, sediment, and soil.	**Selected as VC: 1,2,3,4,5**
River otter (*Lontra canadensis*)	Riparian carnivore	Observed in the study area.	Small riparian carnivore. SKCDC status S3.	Trapped for fur/meat and hunted by indigenous people	Exposed to atmospheric and aquatic releases through food (small mammals, fish, amphibians, insects), water, sediment, and soil.	Not selected. Assessment of the American Mink is expected to be protective of this species.
Terrestrial Birds***						
Olive-sided flycatcher (*Contopus cooperi*)	Aerial insectivore	Observed in the study area.	Special concern (COSEWIC) and threatened status (SARA). Surrogate for other small birds and at-risk species, such as barn swallow and common nighthawk.	Not identified	Exposed to atmospheric and aquatic releases through food (flying insects) and water.	**Selected as VC: 1,2,4,5**
Barn swallow (*Hirundo rustica*)	Aerial insectivore	Observed in the study area.	SB, S5M, threatened (COSEWIC)	Not identified	Exposed to atmospheric and aquatic releases through food (flying insects) and water.	Not selected. Assessment of the Olive-sided flycatcher is expected to be protective of this species.
Common Nighthawk (*Chordeiles minor*)	Aerial Insectivore	Observed in the study area.	S4B, S4M, COSEWIC Special Concern, SARA Status Threatened.	Not identified	Exposed to atmospheric and aquatic releases through food (flying insects) and water.	
Bald Eagle (*Haliaeetus leucocephalus*)	Terrestrial carnivore	Observed in the study area.	Surrogate of other raptors	Not identified	Exposed to atmospheric and aquatic releases through food (fish and small mammals), water, sediment, and soil.	**Selected as VC: 1,2, 5**
American Robin (*Turdus migratorius*)	Ground feeding omnivore	Observed in the study area.	Surrogate for other insectivores and ground-feeding birds, such as dark-eyed junco, Hermit thrush, and yellow-rumped warbler.	Not identified	Exposed to atmospheric and aquatic releases through food (seeds, fruits, terrestrial invertebrates), water and soil.	**Selected as VC: 1,2,5**

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1 Major Plant/Animal Group	2 Facility or Stakeholder Importance*	3 Ecological Significance**	4 Socio-Economic Significance***	5 Exposed to and/or Sensitive to Stressor	
Dark-eyed junco (*Junco hyemalis*)	Ground feeding omnivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	Not selected. Assessment of the American Robin is expected to be protective of this species.
Chipping sparrow (*Spizella passerina*)	Ground feeding omnivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Yellow-rumped warbler (*Setophaga coronata*)	Tree/shrub feeding insectivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Fox sparrow (*Passerella iliaca*)	Ground feeding omnivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Gray jay (*Perisoreus canadensis*)	Ground feeding omnivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Hermit thrush (*Catharus guttatus*)	Ground feeding omnivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Lincoln's sparrow (*Melospiza lincolnii*)	Ground feeding omnivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Ruby-crowned kinglet (*Regulus calendula*)	Tree/shrub feeding insectivore	Observed in the study area.	Breeds within the study area.	Not identified	Exposed to atmospheric release through food (terrestrial invertebrates) and soil	
Canada Goose (*Branta canadensis*)	Ground feeding herbivore	Observed in the study area.	Breeds within the study area.	Regional traditional food item.	Exposed to atmospheric and aquatic releases through food (grass, sedges, berries, seeds), water and soil.	**Selected as VC: 1,2,3,4,5**
Riparian Birds******						

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1 Major Plant/Animal Group	2 Facility or Stakeholder Importance*	3 Ecological Significance**	4 Socio-Economic Significance***	5 Exposed to and/or Sensitive to Stressor	
Lesser Scaup (*Aythya affinis*)	Riparian omnivore	Observed in the study area.	Surrogate for other omnivore ducks and gulls (e.g. bufflehead, mew gull, herring gull, bonaparte's gull, and horned grebe).	Not identified	Exposed to aquatic release through water, food (invertebrates) and sediment.	**Selected as VC: 1,2,5**
Ring-necked duck (*Aythya collaris*)	Riparian omnivore	Observed in the study area.	Food source for other receptors.	Not identified.	Exposed to aquatic release through water, food (invertebrates) and sediment.	Not selected. Assessment of the a Lesser Scaup is expected to be protective of this species.
Bufflehead (*Bucephala albeola*)	Diving bird, riparian omnivore	Observed in the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through water, food and sediment.	
Herring Gull (*Larus argentatus*)	Gull (riparian omnivore)	Observed in the study area.	S5B, S5M, not threatened. Breeds in the study area.	Hunted by indigenous people.	Exposed to aquatic release through water and food (fish and aquatic invertebrates)	
Bonaparte's Gull (*Chroicocephalus philadelphia*)	Gull (riparian omnivore)	Observed in the study area.	S4B, S4M, not threatened.	Not identified.	Exposed to aquatic release through water and food (fish and aquatic invertebrates)	
Common Tern (*Sterna hirundo*)	Riparian omnivore	Observed in the study area.	S5B, S5M, Not at risk	Not identified.	Exposed to aquatic release through water and aquatic food (fish) and invertebrates.	
Horned Grebe (*Podiceps auritus*)	Diving bird, riparian omnivore	Incidental observation in the study area.	S5B, S5M, COSEWIC Special Concern, SARA Special Concern	Not identified.	Exposed to aquatic release through water, food and sediment.	
Mew Gull (Larus canus)	Gull (riparian omnivore)	Observed in the study area.	S4B, S4M, Not threatened. Breeds in the study area.	Hunted by indigenous people.	Exposed to aquatic release through water, food and sediment.	
Mallard (*Anas platyrhynchos*)	Riparian herbivore	Observed in the study area.	Surrogate for other herbivore duck species (e.g. ring-necked duck).	Regional traditional food item.	Exposed to aquatic release through water, food (aquatic plants and invertebrates) and sediment	**Selected as VC: 1,2,3,4,5**
Common loon (*Gavia immer*)	Piscivore	Observed in the study area.	Surrogate for other fish-eating birds (e.g. common tern, common merganser, and osprey).	Regional traditional food item.	Exposed to aquatic release through water and aquatic food (fish)	**Selected as VC: 1,2,3,4,5**

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1	2	3	4	5	
	Major Plant/Animal Group	Facility or Stakeholder Importance*	Ecological Significance**	Socio-Economic Significance***	Exposed to and/or Sensitive to Stressor	
Common merganser (*Mergus merganser*)	Piscivore	Observed in the study area.	Prey on other receptors.	Not identified.	Exposed to aquatic release through water and aquatic food (fish)	Not selected. Assessment of a Loon is expected to be protective of this species.
Osprey (*Pandion haliaetus*)	Piscivore	Observed in the study area (including the nest).	S2B, S2M, not threatened.	Not identified	Exposed to atmospheric and aquatic releases through food (fish and small mammals), water, sediment, and soil.	
Fish****						
Northern Pike (*Esox lucius*)	Pelagic predator fish (Piscivore)	Present in most area lakes and surrounding surface water bodies. Spawning habitat has also been identified within the study area. Fish flesh and bone were analyzed for metal and radionuclides. Age determination has also been done.	Food source for other receptors. Surrogate for all predator fish.	Regional traditional food item. Recreational and commercial fishing documented at Russell Lake.	Exposed to aquatic release through food (fish and other aquatic biota) and water.	**Selected as VC: 1,2,3,4,5**
Lake Trout (*Salvelinus namaycush*)	Pelagic predator fish	Observed in McGowan Lake and Russell Lake. Spawning habitat was observed in the study area.	Food source for other receptors.	Regional traditional food item. Recreational and commercial fishing documented at Russell Lake.	Exposed to aquatic release through food (fish and other aquatic biota) and water.	Not selected. Assessment of the Northern Pike is expected to be protective of this species.
Walleye (*Sander vitreus*)	Pelagic predator fish	Present in most area lakes and streams within the study area. Spawning habitat has also been identified within the study area.	Food source for other receptors.	Regional traditional food item. Commercial fishing is documented at Russell Lake.	Exposed to aquatic release through food (fish and other aquatic biota) and water.	
Yellow Perch (*Perca flavescens*)	Pelagic predator fish	Observed in McGowan Lake and the regional study area.	Food source for other receptors.	Regional traditional food item.	Exposed to aquatic release through food (fish and other aquatic biota) and water.	
White Sucker (*Catostomus commersoni*)	Benthic forage fish	Present in most area lakes and surrounding surface water bodies. Spawning habitat has also been identified within the study area. Fish flesh and bone were analyzed for metal and radionuclides. Age determination has also been done.	Food source for other receptors. Surrogate for all foraging fish.	Regional traditional food item. Recreational and commercial fishing documented at Russell Lake.	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	**Selected as VC: 1,2,3,4,5**
Lake Whitefish (*Coregonus clupeaformis*)	Benthopelagic fish	Present in most area lakes and surrounding surface water bodies.	Food source for other receptors.	Regional traditional food item. Commercial fishing is documented at Russell Lake.	Exposed to aquatic release through food (aquatic	Not selected. Assessment of the White Sucker is

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1 Major Plant/Animal Group	2 Facility or Stakeholder Importance*	3 Ecological Significance**	4 Socio-Economic Significance***	5 Exposed to and/or Sensitive to Stressor	
					invertebrates and aquatic plants).	expected to be protective of this species.
Slimy Sculpin (representative small fish)	Benthopelagic forage fish	Observed in the Icelander River and other streams within the study area.	Food source for other receptors.	Not identified.	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	
Arctic Grayling (*Thymallus arcticus*)	Benthopelagic forage fish	Observed in the Icelander River and other streams within the study area.	Food source for other receptors.	Regional traditional food item.	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	
Longnose Sucker (*Catostumus catostumus*)	Benthic forage fish	Observed in McGowan Lake, Icelander River and other streams within the study area.	Food source for other receptors.	Regional traditional food item.	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	
Lake Chub (*Couesius plumbeus*)	Benthopelagic forage fish	Observed in Icelander River and other streams within the study area. Spawning habitat has also been identified within the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	
Spottail Shiner (*Notropis hudsonius*)	Benthopelagic forage fish	Present in most area lakes and other surface water bodies in the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	
Ninespine Stickleback (*Pungitius pungitius*)	Benthopelagic forage fish	Observed in the Whitefish Lake, south basin (LA-5), and streams within the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through food (aquatic invertebrates and aquatic plants).	
Burbot (*Lota lota*)	Benthic predator fish	Observed in Russell Lake and other streams within the study area.	Food source for other receptors.	Regional traditional food item.	Exposed to aquatic release through food (fish and other aquatic biota) and water.	
Amphibians and Reptiles						
Northern Leopard frog (*Lithobates pipiens*)	Frog	Present in the study area.	Listed as a species of concern under SARA and COSEWIC, and is provincially ranked S3 (vulnerable/rare to uncommon)	Not identified	Exposed to aquatic release through surface water, sediment, and prey.	Not selected. A fish model will be used to represent the early sensitive life stages of amphibians (egg and tadpole).
Canadian toad (*Anaxyrus hemiphrys*)	Toad	Present in the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through surface water, sediment, and prey.	

Representative Species	Selection Criteria					Selection Rationale and Applicable Criteria[1,2,3]
	1	2	3	4	5	
	Major Plant/Animal Group	Facility or Stakeholder Importance*	Ecological Significance**	Socio-Economic Significance***	Exposed to and/or Sensitive to Stressor	
Wood Frogs (*Lithobates sylvaticus*)	Frog	Present in the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through surface water, sediment, and prey.	
Boreal chorus frogs (*Pseudacris maculata*)	Frog	Present in the study area.	Food source for other receptors.	Not identified	Exposed to aquatic release through surface water, sediment, and prey.	

Notes:
* Information from EcoMetrix (2020) and Omnia (2020).
** Information from EcoMetrix (2020) and Omnia (2020).
***FNFNES (First Nations Food, Nutrition and Environment Study), Hatchet Lake and Uranium City food study results were used to identify VECs that are part of the human traditional/subsistence diet and characterize regional socio-economic significance. Partial information is also from the meeting notes Denison provided with local trapper/fisher Mr. Bobby John.
**** Amphibian species such as wood frogs and boreal chorus frogs were not specified on the list on the basis of limited scientific information for amphibian risk assessment. Amphibian species will be assessed qualitatively in the EcoRA.
***** As there are many birds observed in the study area (36 song birds and 20 water fowls), only the ten most abundant breeding songbirds and aerial waterfowls, as well as all sensitive bird species are included in this table.
Species names that are highlighted and underlined are sensitive or threatened species at risk observed at the Wheeler River Project.
SKCDC: Saskatchewan Conservation Data Center.
COSWIC: Committee on the Status of Endangered Wildlife in Canada.
No observation of bat is documented in the terrestrial baseline report (Omnia, 2019).

References:
1. Omnia Ecological Services (Omnia). 2020. Denison Mines Corporation Wheeler River Project - Terrestrial Environment Wildlife and Vegetation Baseline Inventory.
2. Denison Mines Corp (Denison). 2019. Wheeler River Project Provincial Technical Proposal and Federal Project Description. May.
3. Denison Mines Corp (Denison). 2019. Denison Mines Wheeler River Project Key Person Interview with Bobby John - Meeting Notes. October.

Table 5-2: Species at Risk for the Wheeler River Project and Associated Surrogates

Common Name	Scientific Name	Feeding Behaviour	SKCDC Status	COSEWIC Status	SARA Status	Field Observations	Surrogate species, if not selected as a VC
Mammals							
Woodland Caribou	*Rangifer tarandus caribou*	Terrestrial herbivore	S3	Threatened	Threatened	Only observed in the Regional Study Area	Selected
River Otter	*Lontra canadensis*	Riparian carnivore	S3	N/A	N/A	Eleven observations.	American Mink
Wolverine	*Gulo gulo*	Terrestrial carnivore	S2	Special Concern	Special Concern	Not observed	Canada Lynx
Birds							
Osprey	*Pandion haliaetus*	Piscivore	S2B, S2M	N/A	N/A	8 pairs observed.	Common Loon
Common Nighthawk	*Chordeiles minor*	Aerial insectivore	S4B, S4M	Special Concern	Threatened	Incidentally observed.	Olive-sided Flycatcher
Olive-sided Flycatcher	*Contopus cooperi*	Aerial insectivore	S4B, S4M	Threatened	Threatened	8 pairs observed.	Selected
Barn Swallow	*Hirundo rustica*	Aerial insectivore	S5B, S5M	Threatened	Threatened	4 pairs observed.	Olive-sided Flycatcher
Horned Grebe	*Podiceps auritus*	Aquatic invertebrates/ piscivore	S5B, S5M	Special Concern	Special Concern	One incidental observation.	Lesser Scaup
Short-eared Owl	*Asio flammeus*	Terrestrial carnivore	S3B, S2N	Threatened	Special Concern	Not observed	Bald Eagle
Yellow Rail	*Coturnicops noveboracensis*	Aquatic invertebrates	S3B	Special Concern	Special Concern	Not observed	Lesser Scaup
Rusty Blackbird	*Euphagus carolinus*	Aerial insectivore	S3B, SUN	Special Concern	Special Concern	Not observed	Olive-sided Flycatcher

Notes:
Modified from Table 3-1 (Omnia, 2020)
'N/A' denotes species status not assessed.
SKCDC Rankings:
2: Imperiled/Very rare

3: Vulnerable/Rare to uncommon
4: Apparently secure
5: Secure/Common
M: for a migratory species, rank applies to the transient (migrant) population
B: for a migratory species, applies to the breeding population in the province
N: for a migratory species, applies to the non-breeding population in the province
U: status is uncertain in Saskatchewan because of limited or conflicting information (unrankable)

Table 5-3: List of Ecological Receptors for Wheeler River Project

Category	Representative Species
Terrestrial Invertebrates	Terrestrial Invertebrates
Terrestrial Plants	Lichen
	Blueberry (*Vaccinium myrtilloides*)
	Labrador tea (*Rhododendron groenlandicum*)
Aquatic Invertebrates	Zooplankton (general category)
	Benthic invertebrates
Aquatic Plants	Macrophyte (*e.g., Carex sp.)*
	Phytoplankton
Fish	Northern Pike *(Esox lucius*)
	White Sucker (*Catostomus commersoni*)
Terrestrial Mammals	Woodland caribou (*Rangifer tarandus caribou*)
	Snowshoe hare (*Lepus americanus*)
	Moose (*Alces americanus*)
	Red-backed vole (*Myodes gapperi*)
	Black bear (*Ursus americanus*)
	Canada Lynx (*Lynx canadensis*)
Riparian Mammals	Muskrat (*ondatra zibethicus*)
	American Mink (*Neovision vision*)
Terrestrial Birds	Olive-sided flycatcher (*Contopus cooperi*)
	Bald Eagle (*Haliaeetus leucocephalus*)
	American Robin (*Turdus migratorius*)
	Canada Goose (*Branda canadensis*)
Riparian Birds	Lesser Scaup (*Aythya affinis*)
	Mallard (*Anas platyrhynchos*)
	Common loon (*Gavia immer*)

5.1.2 Receptor Characterization

The following section provides a brief summary of the ecological receptors selected for the EcoRA. For additional information regarding ecological characteristics relevant to receptor exposures, refer to Appendix C of this report.

5.1.2.1 Terrestrial Invertebrates

Soil invertebrates such as earthworms, grubs, arthropods, etc. are important components of terrestrial ecosystems. Invertebrates provide a food source to mammals and birds and the community can reflect the health of the environment.

5.1.2.2 Terrestrial Plants

Lichens are a complex life form that is a symbiotic partnership of two separate organisms, a fungus and an alga. The dominant partner is the fungus, which gives the lichen the majority of its characteristics. The alga can be either a green alga or a blue-green alga, also known as cyanobacteria. Lichen are important indicator species of environmental conditions, as they can absorb atmospheric pollutants, including heavy metals (USFS, 2021).

Blueberries and Labrador Tea are important terrestrial plant species consumed by humans for food or for medicinal purposes (CanNorth, 2017). Berries are also an important food source for many terrestrial bird and mammal species, offering a reliable source of carbohydrates, vitamins and antioxidants.

5.1.2.3 Aquatic Invertebrates

Aquatic invertebrates are an important food item for many species of fish and waterfowl. Benthic invertebrates are often found living on or within sediment. Benthic invertebrates can be used to provide an indication of habitat quality in aquatic environments.

Zooplankton are aquatic microorganisms that include crustaceans, rotifers, insect larvae and aquatic mites. The zooplankton community is composed of both primary consumers, which eat free-floating algae, and secondary consumers, which feed on other zooplankton and microorganisms. Zooplankton are particularly sensitive to changes in the aquatic environment. The effects of environmental disturbances can be perceived through changes in species composition, abundance and body size (US EPA, 2021a).

5.1.2.4 Aquatic Plants

Macrophytes are aquatic plants that grow within or in close proximity to water. They may be emergent (i.e., portions of the plant exist above the water surface), fully submerged or floating. Examples of macrophytes include cattails, hydrilla, water hyacinth and duckweed. Macrophytes provide habitat for fish and other aquatic organisms. They also produce oxygen and are an important food source for fish and wildlife. Macrophytes are an important indicator species, as they tend to quickly respond to changing environmental conditions (US EPA, 2021b).

Phytoplankton are free-floating algae that inhabit the upper sunlit layers of most freshwater and marine environments. They are often associated with freshwater water quality characteristics such as colour and clarity. Phytoplankton are primary producers, and convert solar energy into biologically-useable energy through photosynthesis. They are an important food source for higher organisms, including zooplankton and small fish. Phytoplankton can be used to assess an ecosystem's environmental condition by examining their abundance and community richness (US EPA, 2021c).

5.1.2.5 Fish

The Northern Pike (*Esox lucius*) is a cool-water fish, and tends to live in slower-moving, heavily vegetated rivers or lake bays. Spawning occurs in the spring, immediately following the seasonal ice melt. Northern pike are opportunistic feeders, targeting smaller fish, crayfish, frogs, mice, muskrats and young waterfowl for food. In many regions across Canada, northern pike are considered an important commercial and sport fish species (DFO, 2018).

The White Sucker (*Catostomus commersoni*) is a bottom-feeding, freshwater fish common to North America. They tend to live in shallow lakes and rivers, where they feed on benthic invertebrates, clams, insect larvae and fish eggs. They are an important prey species of northern pike (DFO, 2016).

5.1.2.6 Terrestrial Mammals

The Woodland Caribou (*Rangifer tarandus caribou*) is a herbivorous mammal found in Canada's boreal and open taiga forests. They consume plant materials for sustenance, including tree and ground lichens in winter, and lichens, grasses, sedges, forbs, horsetails and shrub leaves in summer. Woodland caribou are threatened by habitat degradation and fragmentation, and have been classified as "threatened" under the federal *Species at Risk Act, 2002* (NRC, 2021).

The Snowshoe Hare (*Lepus americanus*) is a herbivorous mammal found in coniferous and boreal forests throughout Canada and the United States. They often forage through brush, consuming plant materials such as grasses, flowers, and new growth from trees. Snowshoe hares breed rapidly, and thus maintain a relatively stable population throughout their range. They are an important prey item for larger carnivorous birds and mammals, such as the bald eagle and lynx (NWF, 2021a).

Moose (*Alces americanus*) are the largest members of the deer family, and are common in forested regions across Canada and the United States. In the winter, moose will eat various shrubs and pinecones for sustenance. In summer, moose feed on aquatic plants (macrophytes) both on and below the water's surface. Moose are potentially threatened by habitat degradation and fragmentation, but are not a federally-recognized species at risk (NCC, 2022).

The Red-backed Vole (*Myodes gapperi*) is a small, herbivorous mammal common across forested areas of Canada and the United States. They often consume vegetation, seeds, nuts and fungi, but will occasionally prey on soil invertebrates depending on food availability. They are an important prey item for larger carnivorous birds and mammals (BC Conservation Data Centre, 1993).

The Black Bear (*Ursus americanus*) is a large, omnivorous mammal, and can be found across almost the entirety of the North American continent. They can survive in a variety of habitat types, including both coniferous and deciduous forests and mountainous terrain. Their diet typically consists of plant materials (roots, berries, grass, succulents), fish, invertebrates, and meat, often of young deer, elk or moose (NWF, 2021b).

The Canada Lynx (*Lynx canadensis*) is a medium-sized carnivorous mammal found across Canada's boreal forests. The snowshoe hare composes the majority of the lynx's diet, particularly during the winter months. In summer, lynx will supplement their diet by preying on other small mammals and birds, such as grouse, voles, mice and squirrels. Lynx are resilient and well-adapted to living in areas close to human settlements (CWF, 2022).

5.1.2.7 Riparian Mammals

The Muskrat (*Ondatra zibethicus*) is a semi-aquatic herbivorous mammal well adapted to swimming. Muskrats can occur in high densities in suitable areas with appropriate food and shelter (i.e., cattail marshes). Muskrats are an important prey species of predatory birds and mammals (US EPA, 1993).

The American Mink (*Neovision vision*) is the most abundant carnivorous mammal in North America. They are mostly nocturnal hunters and are opportunistic feeders, preferring small mammals as their main prey, including muskrat. They are often found near aquatic habitats such as streams, rivers and lakes (US EPA, 1993).

5.1.2.8 Terrestrial Birds

The Bald Eagle (*Haliaeetus leucocephalus*) is a carnivorous terrestrial bird of prey. They are primarily carrion feeders, and will consume dead or dying prey species. Bald eagles are opportunistic feeders, scavenging different foods based on their availability and hunting easily-captured prey, such as fish, mammals, and other birds. Bald eagles generally are restricted to coastal areas, lakes, and rivers, although some may winter in areas not associated with water (US EPA, 1993).

The American Robin (*Turdus migratorius*) is a common, medium-sized terrestrial bird. They often consume worms, insects and fruit. They are found living in a variety of habitats, including woodlands, swamps, suburbs, and parks (US EPA, 1993).

The Olive-sided Flycatcher (*Contopus cooperi*) is a medium-sized songbird and aerial insectivore, consuming flying insects over both land and water. It is a migratory species, with approximately half of its breeding range across most of forested Canada, and the remainder in the western and northeastern United States. Olive-sided Flycatcher is a designated threatened species, largely due to its susceptibility to habitat loss, a decline in prey species (insects) from pesticide use, and climate change (COSEWIC, 2018).

The Canada Goose (*Branda canadensis*) is a common herbivorous bird, native to both Arctic and temperate regions of North America. They are a migratory bird species, and tend to overwinter in the United States. They often consume grass, seeds, berries and other terrestrial and aquatic plant materials as food. Canada geese tend to build their nests near water, and prefer secluded areas. They are highly adapted to living near humans and can be often found in parks and greenspaces in urban and suburban areas (ECCC, 2018).

5.1.2.9 Riparian Birds

The Mallard (*Anas platyrhynchos*) is an omnivorous waterfowl species, and primarily feeds on aquatic vegetation, seeds, acorns and grains, and occasionally on fish and other aquatic organisms. While common across North America, populations have experienced a marked declined in the last few decades, primarily due to habitat degradation and drought (US EPA, 1993).

The Lesser Scaup (*Aythya affinis*) is one of the most abundant North American ducks. Lesser scaup are found on larger lakes and bays during the fall and winter but are more common on smaller bodies of water (e.g., ponds) during the spring. Most populations of lesser scaup primarily consume aquatic invertebrates, but are known to consume aquatic plant materials (often seeds) as food availability changes seasonally (US EPA, 1993).

The Common Loon (*Gavia immer*) is a riparian bird that primarily feeds on fish and aquatic invertebrates, and to a lesser extent aquatic vegetation. They are well adapted to swimming and diving to catch and consume prey. Populations of common loon are generally considered to be stable across North America. They require clean and largely undisturbed freshwater lakes for their survival, and thus are potentially susceptible to pollution and human disturbances. Adult loons are occasionally preyed upon by larger raptors such as the bald eagle and osprey. Their eggs and chicks are an important food source for a variety of other birds, mammals and some predatory fish (NWF, 2021c).

5.1.3 Assessment and Measurement Endpoints

Assessment endpoints for the EcoRA are explicit expressions of the environmental values that are to be protected (FCSAP, 2012). Assessment endpoints for the EcoRA should include the ecological receptor and the attribute of the ecological receptor that is to be protected (e.g., abundance, viability of the population) (FCSAP, 2012). The EcoRA assessment endpoints to be evaluated are presented in Table 5-4.

Measurement endpoints for the EcoRA are conceptually related to assessment endpoints and are defined as the specific measures that would be used to judge potential for effect on the attribute of an assessment endpoint (e.g., if we predict an effect on organism growth or reproduction, we can infer a potential for effect on abundance). Measurement endpoints for the EcoRA may include endpoints such as survival, growth, or reproduction. Measurement endpoints for the EcoRA are the foundation for the lines of evidence that are used to estimate risks to ecological receptors (FCSAP, 2012).

In this EcoRA, the assessment endpoints are at the population or community level; however, for species at risk, the assessment endpoint is at the individual level. While exposure and risk estimates always pertain to individuals, for most receptors, when effects on individuals are predicted from constituent levels in a certain location, further discussion of population or community effects (or lack thereof) is appropriate. For species at risk, it is considered that effects on even a single individual represent an effect on the population.

Table 5-4: Assessment Endpoints, Measurement Endpoints, and Lines of Evidence

Ecological Receptor	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Measurement Endpoints and their Interpretation
Fish	Population	Maintenance of fish populations as a source of food for piscivorous fish and wildlife.	Viability of fish populations.	Water chemistry	COPC concentrations in water. Compare to toxicological reference values (low-effect threshold concentrations) for effect on survival, growth, or reproduction.
				Radiological dose	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Aquatic Vegetation	Population	Maintenance of aquatic plant populations as a source of food and cover for wildlife.	Viability of aquatic plant populations.	Water chemistry	COPC concentrations in water. Compare to toxicological reference values (low-effect threshold concentrations) for aquatic plants for effect on survival, growth, or reproduction.
				Radiological dose	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.

Ecological Receptor	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Measurement Endpoints and their Interpretation
Zooplankton	Community	Maintenance of a diverse zooplankton community as a source of food for fish.	Density, richness, and diversity of zooplankton community.	Water chemistry	COPC concentrations in water. Compare to toxicological reference values (low-effect threshold concentrations) for zooplankton for effect on survival, growth, or reproduction.
				Radiological dose	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Benthic Invertebrates	Community	Maintenance of a diverse benthic invertebrate community as a source of food for fish and wildlife.	Richness, diversity, abundance of benthic invertebrates.	Water chemistry	Compare COPC concentrations to water quality guidelines.
				Sediment chemistry	Compare COPC concentrations to sediment quality guidelines.
				Radiological dose	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.

Ecological Receptor	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Measurement Endpoints and their Interpretation
Riparian Birds	Population	Maintenance of riparian bird populations.	Viability of riparian bird populations.	Radiological and toxicological doses	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Riparian Mammals	Population	Maintenance of riparian mammal populations.	Viability of riparian mammal populations.	Radiological and toxicological doses	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Invertebrates	Population	Maintenance of terrestrial invertebrate population as a source of food for wildlife.	Viability of terrestrial invertebrate populations.	Soil chemistry	COPC concentrations in soil. Compare COPC concentrations to soil quality guidelines.
				Radiological dose	Compare estimated doses to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Plants	Population	Maintenance of terrestrial plant	Viability of terrestrial plant populations.	Soil chemistry	COPC concentrations in soil. Compare COPC concentrations to soil quality guidelines.

Ecological Receptor	Level of Protection	Protection Goal	Assessment Endpoint	Lines of Evidence	
				Line of Evidence	Measurement Endpoints and their Interpretation
		population as a source of food for wildlife.		Radiological dose	Compare estimated doses to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Birds	Population	Maintenance of terrestrial bird populations.	Viability of terrestrial bird populations.	Radiological and toxicological doses	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.
Terrestrial Mammals	Population	Maintenance of terrestrial mammal populations.	Viability of terrestrial mammal populations.	Radiological and toxicological doses	Compare estimated doses of COPCs to growth, survival, and reproduction benchmark values (low-effect threshold doses) relevant to the assessment endpoint.

Note:
For species at risk, protection is at the individual level, recognizing that effects on even a few individuals represent an effect on the population.
COPC = constituent of potential concern

5.1.4 Selection of Chemical, Radiological, and Other Stressors

The selection of COPCs retained for the EcoRA is presented in Section 3.0 of this report. Chloride and sulphate were identified as COPCs in the aquatic environment, but not in the terrestrial environment. The selection of chemical stressors to evaluate in the EcoRA followed a tiered screening approach to reduce the risk of overlooking any COPCs relevant to ecological health. The selection of COPCs in water was based on the assumption that the main source of aquatic release to Whitefish Lake Middle part will be from the effluent monitoring and release ponds during operation and decommissioning phases. The list of water COPCs is composed of constituents expected to potentially be operational issues or to result in changes to water quality in Whitefish Lake (LA-5) and the downstream environment.

The screening involved a conservative process of comparing the expected treated effluent quality against the selected water quality guidelines protective of ecological health (refer to Table 3-1 in Section 3.0).

No formal screening was conducted for radionuclides. However, since radiation dose to ecological receptors is of public and regulatory interest, the radionuclides in the uranium-238 decay series are carried forward as COPCs for further assessment.

No specific COPCs were identified in air; however, to be sure that exposures were not underestimated in the multi-media pathways analysis, evaluation of potential ecological risk via indirect exposures such as air to soil deposition, soil contact and exposure through the food chain was included for all COPCs identified in water. Exposure to constituents that may deposit from air to surface water was not considered, as that pathway is considered negligible according to CSA N288.1-20.

5.1.5 Selection of Exposure Pathways

Exposure pathways consider the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or for radionuclides, may exert effects from outside the body. Exposures to environmental media may be direct (i.e., by contact) or indirect (i.e., via constituent transport through the food chain).

For each type of ecological receptor, Table 5-5 summarizes the relevant exposure pathways to various environmental media including air, surface water, soil, and sediment. Direct contact or uptake exposure pathways associated with groundwater are assumed to be incomplete, as it is assumed that groundwater is inaccessible to ecological receptors, or negligible relative to other pathways.

Airborne COPCs partition to soil and plants. For most COPCs, ingestion pathways dominate over inhalation and air immersion. The latter pathways are considered minor pathways in the EcoRA, but inhalation was included in the IMPACT model and is thus included in Table 5-5.

For fish, aquatic plants, and aquatic invertebrates, contact with water and constituent uptake from water via bioaccumulation represents the main exposure pathway. Direct contact or uptake from sediment are also considered for benthic invertebrates and bottom-feeding fish. Individual food chain transport pathways are not calculated by the IMPACT model for aquatic organisms because exposures for aquatic receptors are determined using bioaccumulation factors (BAFs) based on surface water concentrations; these BAFs represent all operable exposure pathways. The CSA N288.6-22 recommends the use of BAFs for the estimation of COPC concentrations in plant, invertebrate, and fish tissues based on concentrations in ambient media.

For soil invertebrates and terrestrial plants, the main exposure pathway is through contact with soil and constituent uptake from soil via bioaccumulation. Earthworms and plant roots may have the potential to be exposed to groundwater when groundwater levels are high; however, both earthworms and plants would only be exposed to groundwater occasionally as they do not reside in the saturated zone. Therefore, direct contact with groundwater (for soil invertebrates) and uptake of groundwater (for terrestrial plants) are not quantified in IMPACT.

The dominant exposure pathways for birds and mammals are expected to include uptake of constituents via the ingestion of water, direct contact with or incidental ingestion of soil and/or sediment, and ingestion of food/prey. Direct contact with surface water is also considered to be a complete exposure pathway for riparian mammals and birds.

Table 5-5: Complete Exposure Pathways for All Selected Ecological Receptors to be Assessed using the IMPACT Model

Category	Ecological Receptor	Exposure Pathways	Environmental Media
Terrestrial invertebrates	Terrestrial invertebrates	Direct contact	In Soil
Aquatic invertebrates	Benthic invertebrates	Uptake	In water On sediment
Zooplankton	Zooplankton	Direct contact	In water
Terrestrial plants	Lichen	Direct contact	Air
	Blueberry	Direct contact	In soil
	Labrador tea	Direct contact	In soil
Aquatic plants	Macrophytes	Direct contact	In water On sediment
	Phytoplankton	Direct contact	In water
Fish	Northern pike	Direct contact	In water
	White sucker	Direct contact	In water On sediment
Terrestrial mammals	Woodland caribou	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil

Category	Ecological Receptor	Exposure Pathways	Environmental Media
			Sediment Browse Lichen Macrophytes
	Snowshoe hare	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Browse Blueberries
	Moose	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Sediment Browse Macrophytes
	Red-backed vole	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Browse Blueberries
	Black bear	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Blueberries Fish (Northern pike)
	Canada lynx	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Snowshoe hare Red-backed Vole Canada Goose
Riparian mammals	Muskrat	Direct contact	In water On sediment

Category	Ecological Receptor	Exposure Pathways	Environmental Media
		Inhalation	Air
		Ingestion	Water Sediment Benthic invertebrates Macrophytes
	American mink	Direct contact	In water On soil On sediment
		Inhalation	Air
		Ingestion	Water Soil Sediment Benthic invertebrates Muskrat Fish (Northern pike) Mallard
Terrestrial birds	Olive-sided flycatcher	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Benthic invertebrates Soil invertebrates
	Bald eagle	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Fish (Northern pike) Mallard
	American robin	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Soil invertebrates Blueberries
	Canada goose	Direct contact	On soil
		Inhalation	Air
		Ingestion	Water Soil Browse

Category	Ecological Receptor	Exposure Pathways	Environmental Media
Riparian birds	Lesser scaup	Direct contact	In water On sediment
		Inhalation	Air
		Ingestion	Water Sediment Benthic invertebrates Macrophytes
	Mallard	Direct contact	In water On sediment
		Inhalation	Air
		Ingestion	Water Sediment Benthic invertebrates Macrophytes
	Common loon	Direct contact	In water
		Inhalation	Air
		Ingestion	Water Benthic invertebrates Fish (Northern pike)

5.1.6 Ecological Health Conceptual Model

The ecological conceptual site model (CSM) illustrates how receptors are exposed to COPCs. It identifies the source of constituents, constituent transport mechanisms, environmental media, and the exposure pathways to be considered in the assessment for each receptor. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body.

The conceptual site model for the EcoRA is illustrated below in Figure 5-1.

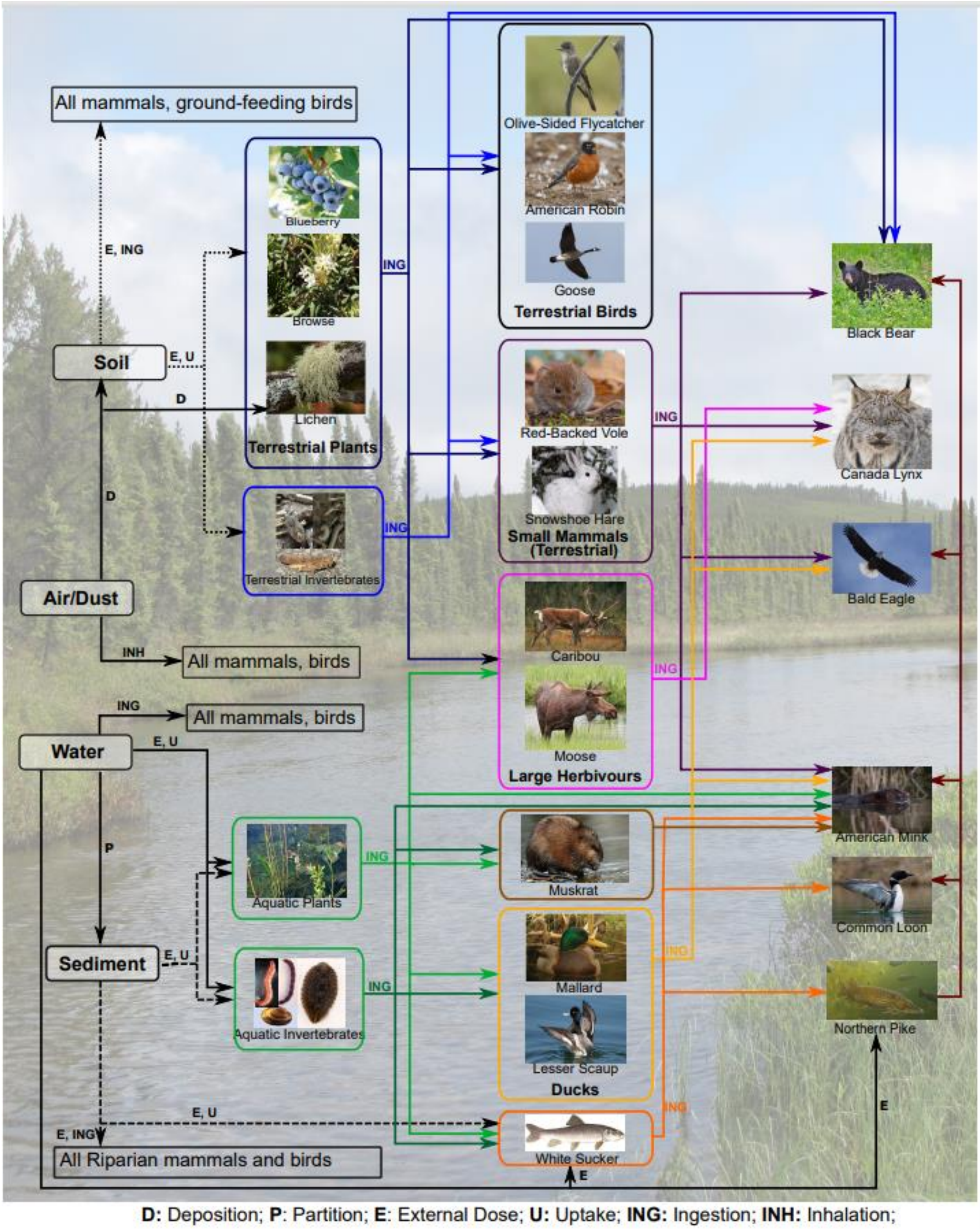


Figure 5-1: Ecological CSM for the Wheeler River Project

5.2 Exposure Assessment

The exposure assessment includes identification of exposure locations and exposure factors for each receptor, explanation of dispersion models, and presentation of exposure concentrations and doses (radiological and non-radiological). Uncertainties are discussed. This section presents the information used in the IMPACT model at a high-level; however, the details of the model will be included in Appendix A to the ERA.

5.2.1 Exposure Locations

The conceptual model assumes that all terrestrial and aquatic receptors are present at Whitefish Lake (LA-5 North), McGowan Lake (LA-1) and the inlet to Russell Lake (Figure 5-2). All terrestrial and aquatic receptors were also assumed to be at Kratchkowsky Lake, which was chosen as a reference location. Separate exposure values were estimated for each receptor in the locations where they were assumed to be present.

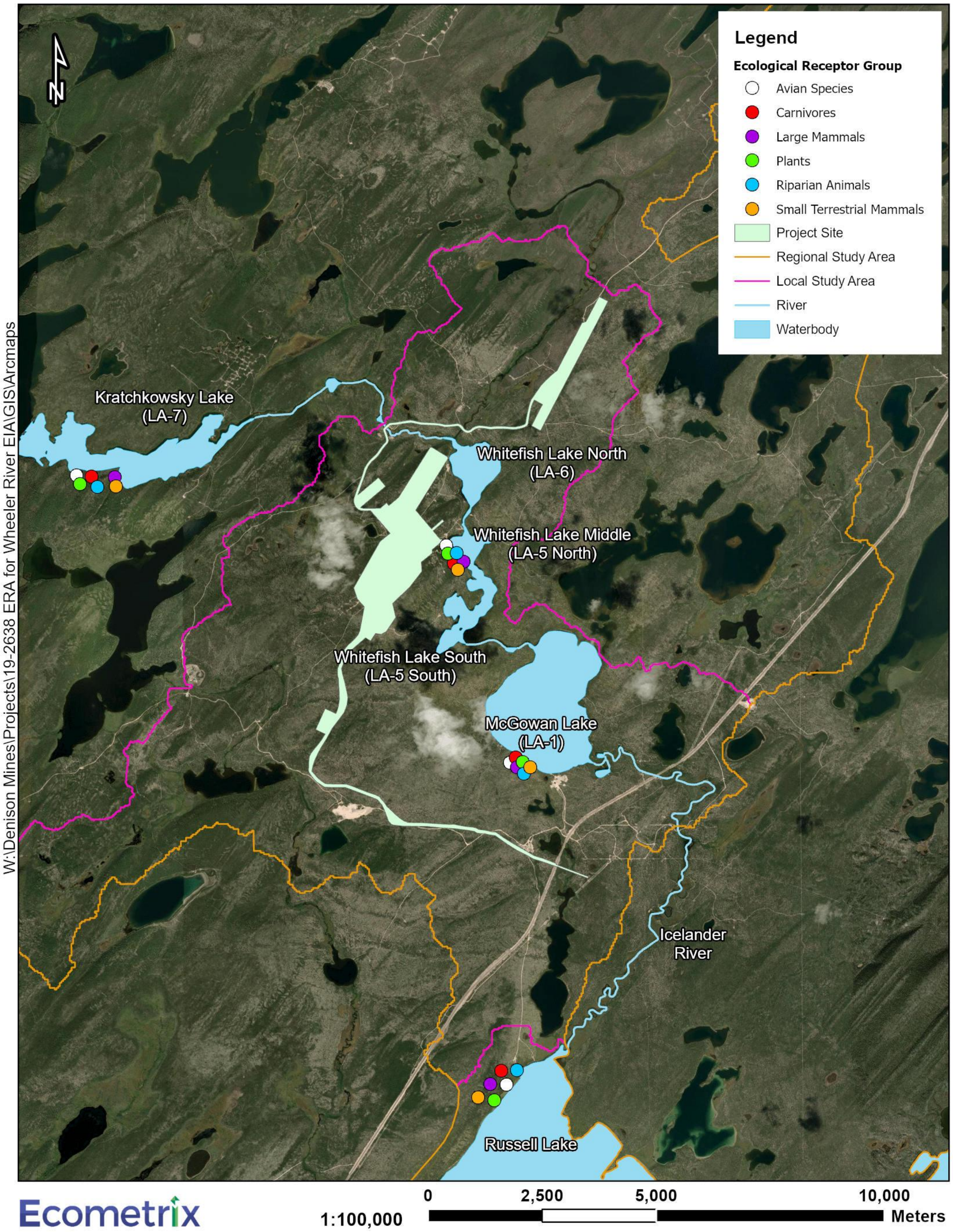


Figure 5-2: Locations of Ecological Receptors Assessed in the Ecological Risk Assessment

5.2.2 Exposure Averaging

Most ecological receptors were assessed assuming 100% residency at the exposure point location. This was the case for aquatic biota, immobile terrestrial biota such as plants and soil invertebrates, and mobile terrestrial mammals and birds that have small home ranges. This assumption was also applied to migratory ecological receptors, such as waterfowl and passerine birds, that spend part of the year away from the LSA and RSA, or ecological receptors that have a small home range while nesting or rearing young. For instance, mallards are not present in the LSA and RSA for over half the year due to migration, but have a small home range during the nesting and rearing season. Therefore, it was conservatively assumed that the mallard has a 100% residency factor on one lake where the young are hatched and reared. Similarly, moose have large annual home ranges but generally remain within small seasonal home ranges of 5 km^2 to 10 km^2 during the summer and winter. For modelling purposes, these animals were associated with one location.

Animals with large home ranges (i.e., greater than 10 km^2), such as the woodland caribou, black bear and bald eagle, interact with several different exposed polygon locations for feeding and water intake. All other receptors have relatively small home ranges (i.e., less than 10 km^2) and were assumed to reside in the same polygon year-round. For modelling purposes, the large home range animals were associated with a central location but with residency factors applied to other adjacent locations depending on the size of their home range. In some cases, a portion of their time in the LSA or RSA may be attributed to time spent at unexposed (reference) locations. For example, due to its large home range of 314 km^2, the bald eagle located near Whitefish Lake was assumed to spend 12.2% of its time at exposed locations and 87.8% of its time at unexposed locations. Further details are provided in Appendix A. The residency assumptions for ecological receptors with large home ranges are summarized in Table 5-6.

Table 5-6: Residency Factors for Terrestrial Ecological Receptors with Potentially Larger Home Ranges

Ecological Receptors	Home Polygon	Waterbody Surface Area (ha)	Total Waterbody Surface Area (ha)	Residency Factor	Water and Feed Source Polygon
Woodland Caribou	LA-7 South	323	323	1	LA-7 South
	LA-5	59	1111	0.06	LA-5
		149		0.13	LA-1
		512		0.46	Russell Lake
		392		0.35	Unexposed Locations
Moose	LA-7 South	-	-	1	LA-7 South
	LA-5	-	-	1	LA-5
	LA-1	-	-	1	LA-1
	Russell Lake	-	-	1	Russell Lake
Black Bear	LA-7 South	323	323	1	LA-7 South
	LA-5	59	1111	0.06	LA-5
		149		0.13	LA-1

Ecological Receptors	Home Polygon	Waterbody Surface Area (ha)	Total Waterbody Surface Area (ha)	Residency Factor	Water and Feed Source Polygon
		512		0.46	Russell Lake
		392		0.35	Unexposed Locations
Mink	LA-7 South	-	-	1	LA-7 South
	LA-5			1	LA-5
	LA-1	-	-	1	LA-1
	Russell Lake	-	-	1	Russell Lake
Bald Eagle	LA-7 South	323	323	1	LA-7 South
	LA-5	59	5872	0.010	LA-5
		149		0.025	LA-1
		512		0.087	Russell Lake
		5153		0.878	Unexposed Locations

5.2.3 Exposure and Dose Calculations

Exposure and dose calculations for ecological receptors were completed using IMPACT version 5.6.0. IMPACT is consistent with the COPC transport equations outlined in CSA N288.1-20 and with the methods of biota dose calculation outlined in CSA N288.6-22 for both non-radiological and radiological COPCs. The equations are presented in Appendix A.

Assessment of radiation exposures to ecological receptors is commonly based on estimation of the effects of the project or site. Assessments consider the radiation dose received from external exposure to radiation as well as the dose received from inhalation and ingestion of radionuclides. The radionuclide intake by ecological receptors from various pathways is converted into a dose that is presented in milligrays per day (mGy/d). The dose for each radionuclide is comprised of an internal dose component, and an external dose component, which is driven by water and sediment.

Assessment of non-radiological exposures to ecological receptors considers the dose received from ingestion of COPCs. This is presented as a dose in mg/kg/d for each pathway. Inhalation for non-radionuclides is not included as no non-radiological air COPCs were identified for further assessment. Additionally, this is consistent with guidance in CSA N288.6-22 which indicates that inhalation exposure is usually minor compared to soil and food ingestion.

The inputs and assumptions used in the IMPACT model for the Project, including receptor characteristics, exposure pathways, and the derivation and identification of site-specific information used in the model are provided in Appendix A. Relevant to the exposure and dose calculations, the IMPACT model report:

- describes the model structure for ecological receptor assessment, specific assumptions made for the Project, and the generic equations used to calculate the transfer of constituents between environmental media and the receptors; and
- presents the development of input parameters and describes the approach used for calibration and validation based on regional monitoring data.

5.2.4 Exposure Factors

Exposure estimates rely on several COPC- and biota-specific exposure factors for the dose calculations. These parameters include body weights and intake rates as well as occupancy factors (OFs), DCFs, BAFs, and transfer factors (TFs).

5.2.4.1 Body Weights and Intake Rates for Ecological Receptors

The body weight and intake rates are required for the calculation of exposure to birds and mammals (Table 5-7). Body weights and intake rates were obtained, in order of preference, from CSA N288.1-20, the US Environmental Protection Agency (USEPA) *Wildlife Exposure Factors Handbook* (US EPA, 1993), and the Federal Contaminated Sites Action Plan *Module 3: Standardization of Wildlife Receptor Characteristics* (FCSAP, 2012). For species not represented in the above sources, additional sources as identified in Table 5-7 were consulted to identify representative body weights, and then feed intake rates were calculated using allometric equations from the USEPA (1993).

Water intake and inhalation rates were determined using allometric equations from the USEPA (1993) for birds and mammals. The incidental ingestion of soil and/or sediment was estimated from feed intake. Incidental ingestion varied from 2% to 10.4% of food intake as dry weight, depending on the biota (Beyer et al., 1994). However, no incidental soil or sediment ingestion was assumed for the common loon, which feeds from the water column.

Table 5-7: Bird and Mammal Body Weights and Intake Rates

Receptor	Body Weight		Total Feed Intake				Dietary Components	Feed Type Fraction		Feed Intake Rate		Dry Weight Fraction [g]	IMPACT Intake Group	Feed Intake by Group		Intake of Soil [m]	Intake of Sediment [m]	Intake of Soil & Sediment [j]	Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment Intake [k]	Water Intake [l]	Inhalation Rate	
	kg	Source	kg dw/d	Source	kg fw/d	Source		fw	dw	kg dw/d	kg fw/d	unitless		kg dw/d	kg fw/d	%	%	%		kg dw/d	L/d	m^3/d	source
Woodland Caribou	180.0	e	3.817	l	11.327	-	Browse	0.50	0.30	1.133	5.664	0.20	Terrestrial Plants	2.968	7.929	5.3	1.5	6.8	Bison	0.260	10.602	34.774	l
							Lichen	0.20	0.48	1.835	2.265	0.81											
							Macrophytes	0.30	0.22	0.850	3.398	0.25	Aquatic Plants	0.850	3.398								
Snowshoe Hare	1.8	c	0.110	c	0.475	-	Browse	0.90	0.78	0.086	0.428	0.20	Terrestrial Plants	0.110	0.475	3.7	0	3.7	Average of small mammals	0.004	0.168	0.900	c,l
							Berries (Blueberry)	0.10	0.22	0.024	0.048	0.52											
Moose	400.0	b	8.000	b	38.095	-	Browse	0.80	0.76	6.095	30.476	0.20	Terrestrial Plants	6.095	30.476	1.5	0.5	2.0	Moose	0.160	21.751	65.869	l
							Macrophytes	0.20	0.24	1.905	7.619	0.25	Aquatic Plants	1.905	7.619								
Southern Red-Backed Vole	0.03	a, i	0.004	-	0.012	a, i	Berries (Blueberry)	0.60	0.79	0.004	0.007	0.52	Terrestrial Plants	0.004	0.012	2.4	0	2.4	Meadow vole	0.0001	0.005	0.048	a
							Browse	0.40	0.21	0.001	0.005	0.20											
Black Bear	102.5	f	3.075	b	7.053	-	Berries (Blueberry)	0.70	0.83	2.546	4.937	0.52	Terrestrial Plants	2.546	4.937	2.9	0	2.9	Average of large mammals	0.090	6.387	22.162	l
							Fish (Northern Pike)	0.30	0.17	0.529	2.116	0.25	Aquatic Animals	0.529	2.116								
Canada Lynx	14.0	n	0.601	l	2.038	-	Showshoe hare	0.80	0.81	0.489	1.630	0.30	Terrestrial Animals	0.601	2.038	2.8	0	2.8	Red fox	0.017	1.065	4.508	l
							Small Mammals (represented by Vole)	0.15	0.14	0.082	0.306	0.27											
							Terrestrial Birds (Goose)	0.05	0.05	0.031	0.102	0.30											
Muskrat	1.2	a	0.088	-	0.352	a	Macrophytes	0.80	0.80	0.070	0.282	0.25	Aquatic Plants	0.070	0.282	0	3.3	3.3	Mallard	0.003	0.114	0.590	a
							Benthic Invertebrates	0.20	0.20	0.018	0.070	0.25	Aquatic Animals	0.018	0.070								
Mink	1.0	a	0.045	-	0.161	a	Fish (Northern Pike)	0.30	0.27	0.012	0.048	0.25	Aquatic Animals	0.018	0.072	2.6	0.4	3.1	Average of mallard and Lynx	0.001	0.101	0.440	a
							Benthic Invertebrates	0.15	0.14	0.006	0.024	0.25											
							Small Mammals (Muskrat)	0.45	0.49	0.022	0.072	0.30	Terrestrial Animals	0.026	0.088								
							Birds (Mallard)	0.10	0.11	0.005	0.016	0.30											
Canada Goose	3.7	c	0.023	-	0.115	a	Browse	1.00	1.00	0.023	0.115	0.20	Terrestrial Plants	0.023	0.115	8.2	0	8.2	Canada goose	0.002	0.142	0.082	c
Olive-Sided Flycatcher	0.03	d	0.008	-			Soil Invertebrates (Earthworms)	0.90	0.86	0.007	0.039	0.17	Terrestrial Plants	0.007	0.039	8.9	1.5	10.4	American woodcock	0.001	0.006	0.058	l
							Benthic Invertebrates	0.10	0.14	0.001	0.004	0.25	Aquatic Animals	0.001	0.004								
Bald Eagle	5.8	a		-	0.691	a	Fish (Northern Pike)	0.80	0.77	0.138	0.553	0.25	Aquatic Animals	0.138	0.553	9.3	0	9.3	Wild turkey	0.051	0.191	1.310	a
							Riparian birds (Mallard)	0.20	0.23	0.041	0.138	0.30	Terrestrial Animals	0.041	0.138								
American Robin	0.1	a			0.202	a, h	Fruit (Berries)	0.60	0.82	0.062	0.121	0.52	Terrestrial Plants	0.076	0.202	10.4	0	10.4	American woodcock	0.008	0.013	0.142	l
							Soil Invertebrates (Earthworms)	0.40	0.18	0.014	0.081	0.17											
Lesser Scaup	0.8	a	0.063	a			Benthic Invertebrates	0.90	0.90	0.056	0.226	0.25	Aquatic Animals	0.056	0.226	0	3.3	3.3	Mallard	0.002	0.051	0.350	a
							Macrophytes	0.10	0.10	0.006	0.025	0.25	Aquatic Plants	0.006	0.250								
Mallard	1.1	c	0.060	c	0.240	-	Macrophytes	0.25	0.25	0.015	0.060	0.25	Aquatic Plants	0.015	0.060	0	3.3	3.3	Mallard	0.002	0.064	0.020	c
							Benthic Invertebrates	0.75	0.75	0.045	0.180	0.25	Aquatic Animals	0.045	0.180								
Common Loon	5.3	b	0.159	b	0.636	-	Fish (Northern Pike)	0.90	0.90	0.143	0.572	0.25	Aquatic Animals	0.159	0.636	0	0	0	negligible	0	0.180	1.477	l
							Benthic Invertebrates	0.10	0.10	0.016	0.064	0.25											

Notes:

[a] USEPA (1993). Body weights, ingestion rates and inhalation rates of adults or all groups (adults and juveniles) are an average of the listed values. If only a range is given, the upper limit of the range is used. Values for the southern red-backed vole was based on the meadow vole

[b] FCSAP Ecological Risk Assessment Guidance, Module 3: Standardization of Wildlife Receptor Characteristics (March 2012)

[c] CSA Standard N288.1-20 (March 2020), Clause 7.7.4.2, and Table A.5d

[d] Environment Canada. 2015. Recovery Strategy for Olive-sided Flycatcher (*Contopus cooperi*) in Canada; average for adult male/female weight range of 31 to 34 g.

[e] COSEWIC Assessment and Update Status Report on the Woodland Caribou (2002). Body weight calculated as a mean of the male and female upper range.

[f] Hinterland Who's Who. 2007. Average of males and females from http://www.hww.ca/en/wildlife/mammals/black-bear.html

[g] Moisture/dry weight fraction values are based on Beresford *et al,* 2008 (soil invertebrate - assume earthworm); Omnia 2019 (blueberries, lichen and small mammal - assuming vole); and CSA Standard N288.1-20 (all other receptors). The blueberry value is based on the fruit only.

[h] The total feed intake for the American Robin was used in the absence of a species-specific value.

[i] The body weight and total feed intake for the Meadow Vole was used in the absence of a species-specific value.

[j] Beyer *et al*, 1994

[k] Intake of Soil & Sediment (kg dw/d) = Total Feed Intake (kg dw/d) x Intake of Soil & Sediment (%)/100.

[l] Calculated using allometric equations in USEPA (1993)

[m] The % intake of soil or sediment is calculated from the combined % intake of soil and sediment, weighted to the relative proportions of terrestrial vs. aquatic dietary components for each receptor, based on the following equations.
Intake of Soil (%) = Total Intake of Soil & Sediment (%) x Feed Type Fraction Terrestrial. Intake of Sediment (%) = Total Intake of Soil & Sediment (%) x Feed Type Fraction Aquatic.

[n] U.S.FWS (Fish and Wildlife Service), 2017. Species Status Assessment for the Canada Lynx (Lynxcanadensis), Contiguous United States Distinct Population Segment. Version 1.0 - Final, October 2017. Lakewood, Colorado.

fw = fresh weight; dw = dry weight

5.2.4.2 Occupancy Factors, Dose Coefficients, Bioaccumulation Factors, and Transfer Factors

Short descriptions of the role of OFs, DCFs, BAFs, and TFs are provided in Table 5-8. Additional details and the numeric factors are presented in Appendix A.

Table 5-8: Exposure Factors Used in the IMPACT Model for the Wheeler River ERA

Exposure Factor	Description	Appendix A
OFs	An OF is defined as the fraction of time the receptor species spends in or on various media. The OFs are based on the experience and judgment of the risk assessor and the known behaviour of the receptor. The OFs for air, soil/sediment, soil/sediment surface, and water were used in the model.	Section 2.3.3.2, Occupancy Factor
DCFs	The DCFs represent the dose-equivalent rate per unit concentration of a radionuclide in the environment (or tissue) for a particular mode of exposure. The model used DCFs for external and internal exposures to radionuclides. Aquatic DCFs were based on values published by the ICRP for aquatic plants and northern pike (ICRP 2008), and were calculated with the ERICA Tool (Brown et al. 2008) for benthic invertebrates, zooplankton, and whitefish DCFs. Terrestrial plant and invertebrate DCFs were based on values published by the ICRP (ICRP 2008). Terrestrial animal DCFs follow the approach of ICRP (ICRP 2008).	Section 3.6.3, Dose Coefficients for Aquatic Receptors Section 3.7.3, Dose Coefficients for Terrestrial Plants and Invertebrates Section 3.7.6, Dose Coefficients for Terrestrial Animals, Birds, and Humans
TFs and BAFs	The TFs are the ratio of concentration in an animal to the animal's daily intake of a COPC. BAFs are the ratio of concentration in an organism to the concentration in an environmental medium. The TFs and BAFs are generally COPC- and biota-specific. Aquatic BAFs were generally obtained from CSA N288.1-20 and IAEA (2010), and from publicly available regional data from other uranium mine sites in northern Saskatchewan. The soil-to-plant BAFs were derived from regional data from Northern Saskatchewan. An allometric equation (transfer proportional to a -3/4 power of body weight) (CSA N288.6-22) was applied to transfer factors available for beef and poultry from CSA N288.1-20, IAEA (2010), or NCRP (1996) to estimate the	Section 3.6.1, Aquatic Bioaccumulation Factors Section 3.7.1, Soil-to-Plant Transfer Section 3.7.4, Ingestion Transfer Factors for Terrestrial Receptors Section 3.7.5, Inhalation Transfer Factors for Terrestrial Receptors

Exposure Factor	Description	Appendix A
	ingestion transfer factors for the mammal and bird receptors, respectively. Inhalation TFs for terrestrial receptors were calculated from the ingestion transfer factor by adjusting the ingestion transfer factor by a COPC-specific inhalation/ingestion ratio (II) from CSA N288.1-20.	

IAEA = International Atomic Energy Agency; BAF = bioaccumulation factor; OF = occupancy factor; TF = transfer factor; DCF = dose coefficient factor; NCRP = National Council on Radiation Protection and Measurements; ICRP = International Commission on Radiological Protection; CSA = Canadian Standards Association; COPC = constituent of potential concern.

5.2.5 Exposure Point Concentrations and Doses

This subsection presents the estimated non-radiological and radiological doses to aquatic and terrestrial ecological receptors due to releases from the Project during all phases of the Project. The results are presented as a total dose which includes both baseline and Project contributions. While non-radiological and radiological doses were predicted in IMPACT over the life of the Project, the maximum doses are represented in this section. The estimated non-radiological and radiological concentrations in environmental media and biota tissue concentrations are shown in Appendix B.

5.2.5.1 Non-radiological Dose

Non-radiological dose was only calculated for birds and mammals, as effects to aquatic animals (fish and invertebrates) and plants and soil invertebrates are assessed based on concentrations and not doses.

The estimated non-radiological doses to the selected birds and mammals during the Project phases are shown by COPC in Table 5-9. The doses shown represent the maximum dose by COPC over the assessment period, which is during the operation phase for the Project. The results are presented as a total dose which includes both baseline and Project contributions. The non-radiological dose to birds and mammals during the future centuries is also shown in Table 5-9.

Table 5-9: Estimated Non-radiological Project Total Doses to Ecological Receptors – Project Phases and Future Centuries

Biota		Location	Maximum Non-radiological Dose During Project Phases (mg/kg/d)											
			As	Cd	Cl-	Co	Cr	Cu	Mo	SO4	Se	U	V	Zn
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Terrestrial Animals	Black Bear	Reference (Kratchkowsky Lake)	4.84E-03	5.32E-04	2.01E-02	2.27E-03	3.90E-03	1.47E-01	1.75E-03	4.28E-02	5.43E-03	1.20E-03	4.72E-03	3.69E-01
		Whitefish Lake	4.86E-03	5.33E-04	1.57E-01	2.27E-03	3.97E-03	1.48E-01	2.32E-03	9.39E-01	1.52E-02	2.07E-03	4.89E-03	3.73E-01
	Canada Lynx	Reference (Kratchkowsky Lake)	1.61E-02	2.50E-03	2.44E-02	5.64E-04	6.54E-03	3.38E-01	5.49E-04	5.20E-02	2.87E-02	5.81E-04	1.02E-02	1.43E+01
		Whitefish Lake	1.62E-02	2.50E-03	4.65E-01	5.70E-04	6.64E-03	3.48E-01	2.43E-03	2.93E+00	2.91E-02	6.46E-03	1.04E-02	1.43E+01
		McGowan Lake	1.61E-02	2.50E-03	3.18E-01	5.66E-04	6.56E-03	3.39E-01	1.76E-03	1.97E+00	2.88E-02	1.37E-03	1.02E-02	1.43E+01
		Russell Lake Inlet	1.61E-02	2.50E-03	2.47E-01	5.65E-04	6.55E-03	3.38E-01	1.46E-03	1.51E+00	2.88E-02	8.02E-04	1.02E-02	1.43E+01
	Mink	Reference (Kratchkowsky Lake)	1.05E-02	7.71E-04	3.25E-02	1.04E-03	1.37E-02	1.46E-01	6.42E-04	6.81E-02	1.44E-02	7.02E-04	1.39E-02	3.17E-01
		Whitefish Lake	1.33E-02	9.39E-04	6.18E-01	1.20E-03	1.68E-02	1.83E-01	8.68E-02	3.83E+00	1.26E-01	6.74E-03	3.43E-02	4.62E-01
		McGowan Lake	1.16E-02	8.80E-04	4.23E-01	1.15E-03	1.57E-02	1.72E-01	6.23E-02	2.58E+00	8.23E-02	3.00E-03	2.19E-02	4.01E-01
		Russell Lake Inlet	1.11E-02	8.51E-04	3.29E-01	1.12E-03	1.52E-02	1.66E-01	4.74E-02	1.97E+00	6.45E-02	2.20E-03	1.89E-02	3.77E-01
	Moose	Reference (Kratchkowsky Lake)	2.47E-03	1.06E-03	1.78E-02	1.18E-03	1.84E-03	5.89E-02	7.36E-04	3.75E-02	5.98E-04	6.51E-04	4.20E-03	1.68E-01
		Whitefish Lake	2.82E-03	1.10E-03	3.40E-01	1.28E-03	2.08E-03	6.12E-02	1.06E-02	2.11E+00	2.44E-03	1.80E-02	9.84E-03	1.73E-01
		McGowan Lake	2.60E-03	1.08E-03	2.33E-01	1.24E-03	1.98E-03	5.96E-02	7.49E-03	1.42E+00	1.67E-03	3.48E-03	6.25E-03	1.70E-01
		Russell Lake Inlet	2.55E-03	1.08E-03	1.81E-01	1.22E-03	1.95E-03	5.94E-02	5.84E-03	1.08E+00	1.37E-03	1.73E-03	5.49E-03	1.70E-01
	Moose Organs	Reference (Kratchkowsky Lake)	2.47E-03	1.06E-03	1.78E-02	1.18E-03	1.84E-03	5.89E-02	7.36E-04	3.75E-02	5.98E-04	6.51E-04	4.20E-03	1.68E-01
		McGowan Lake	2.60E-03	1.08E-03	2.33E-01	1.24E-03	1.98E-03	5.96E-02	7.49E-03	1.42E+00	1.67E-03	3.48E-03	6.25E-03	1.70E-01
		Russell Lake Inlet	2.55E-03	1.08E-03	1.81E-01	1.22E-03	1.95E-03	5.94E-02	5.84E-03	1.08E+00	1.37E-03	1.73E-03	5.49E-03	1.70E-01
	Muskrat	Reference (Kratchkowsky Lake)	2.56E-02	1.21E-03	3.84E-02	4.50E-03	1.59E-02	3.72E-02	1.02E-03	6.70E-02	2.98E-03	1.81E-03	4.09E-02	1.20E-01
		Whitefish Lake	3.34E-02	1.86E-03	7.31E-01	5.67E-03	2.07E-02	4.88E-02	1.84E-01	3.77E+00	3.21E-02	2.48E-02	1.45E-01	1.78E-01
		McGowan Lake	2.87E-02	1.62E-03	5.00E-01	5.26E-03	1.91E-02	4.47E-02	1.29E-01	2.54E+00	2.03E-02	1.60E-02	8.07E-02	1.53E-01
		Russell Lake Inlet	2.75E-02	1.51E-03	3.89E-01	5.06E-03	1.82E-02	4.28E-02	9.81E-02	1.94E+00	1.55E-02	1.21E-02	6.61E-02	1.43E-01
	Snowshoe Hare	Reference (Kratchkowsky Lake)	6.76E-03	3.71E-03	3.04E-02	4.09E-03	8.23E-03	2.53E-01	3.19E-03	6.49E-02	2.24E-03	2.73E-03	1.30E-02	6.87E-01
		Whitefish Lake	6.78E-03	3.72E-03	5.80E-01	4.13E-03	8.31E-03	2.60E-01	5.51E-03	3.65E+00	2.30E-03	5.98E-02	1.32E-02	6.89E-01
		McGowan Lake	6.76E-03	3.71E-03	3.97E-01	4.09E-03	8.25E-03	2.54E-01	4.67E-03	2.46E+00	2.27E-03	1.02E-02	1.30E-02	6.88E-01
		Russell Lake Inlet	6.76E-03	3.71E-03	3.08E-01	4.09E-03	8.24E-03	2.53E-01	4.30E-03	1.88E+00	2.26E-03	4.75E-03	1.30E-02	6.87E-01
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	1.58E-01	2.40E-02	4.49E-02	9.13E-02	2.70E-02	6.31E+00	7.48E-02	9.57E-02	6.19E-02	4.17E-02	3.16E-02	1.56E+01
		Whitefish Lake	1.58E-01	2.40E-02	8.55E-01	9.18E-02	2.73E-02	6.52E+00	7.87E-02	5.38E+00	6.23E-02	5.43E-01	3.23E-02	1.57E+01
		McGowan Lake	1.58E-01	2.40E-02	5.85E-01	9.13E-02	2.70E-02	6.33E+00	7.70E-02	3.62E+00	6.20E-02	1.08E-01	3.17E-02	1.56E+01
		Russell Lake Inlet	1.58E-01	2.40E-02	4.54E-01	9.13E-02	2.70E-02	6.31E+00	7.65E-02	2.77E+00	6.19E-02	5.93E-02	3.17E-02	1.56E+01
	WoodLand Caribou	Reference (Kratchkowsky Lake)	5.33E-03	1.60E-03	1.99E-02	2.17E-03	2.09E-02	4.10E-02	1.35E-03	4.05E-02	1.53E-03	1.74E-03	1.70E-02	2.12E-01
		Whitefish Lake	5.55E-03	1.63E-03	1.56E-01	2.22E-03	2.12E-02	4.24E-02	1.04E-02	8.87E-01	2.52E-03	5.15E-02	1.96E-02	2.14E-01
	Canada Goose	Reference (Kratchkowsky Lake)	7.66E-04	5.49E-04	1.24E-02	4.51E-04	1.78E-03	2.35E-02	3.28E-04	2.64E-02	2.16E-04	3.80E-04	2.73E-03	6.71E-02
		Whitefish Lake	7.63E-04	5.49E-04	0.00E+00	4.51E-04	1.77E-03	2.41E-02	3.27E-04	0.00E+00	2.16E-04	7.94E-03	2.74E-03	6.72E-02
		McGowan Lake	7.66E-04	5.49E-04	1.61E-01	4.52E-04	1.78E-03	2.35E-02	9.29E-04	9.99E-01	2.25E-04	1.38E-03	2.74E-03	6.71E-02
		Russell Lake Inlet	7.66E-04	5.49E-04	1.25E-01	4.52E-04	1.78E-03	2.35E-02	7.78E-04	7.63E-01	2.22E-04	6.53E-04	2.74E-03	6.71E-02
	Bald Eagle	Reference (Kratchkowsky Lake)	1.01E-02	3.34E-03	1.07E-02	2.67E-03	3.40E-02	6.28E-02	1.05E-03	2.28E-02	2.18E-02	3.52E-03	4.53E-02	1.91E-01
		Whitefish Lake	1.01E-02	3.34E-03	2.43E-02	2.67E-03	3.40E-02	6.36E-02	1.45E-03	1.12E-01	3.07E-02	3.98E-03	4.55E-02	1.95E-01
	Olive-Sided Flycatcher	Reference (Kratchkowsky Lake)	2.82E-02	1.72E-01	5.95E-02	1.27E-02	1.34E-01	1.02E+00	1.53E-02	1.27E-01	4.15E-02	1.28E-02	1.25E-01	2.35E+00
		Whitefish Lake	3.01E-02	1.73E-01	0.00E+00	1.33E-02	1.41E-01	1.17E+00	3.72E-01	0.00E+00	7.37E-02	2.75E-01	1.40E-01	2.49E+00
		McGowan Lake	2.90E-02	1.72E-01	7.76E-01	1.31E-02	1.39E-01	1.12E+00	2.74E-01	4.81E+00	6.19E-02	4.93E-02	1.31E-01	2.44E+00
		Russell Lake Inlet	2.87E-02	1.72E-01	6.02E-01	1.30E-02	1.37E-01	1.10E+00	2.12E-01	3.67E+00	5.64E-02	2.38E-02	1.29E-01	2.42E+00
		Reference (Kratchkowsky Lake)	4.43E-03	7.86E-05	1.09E-02	3.76E-04	5.54E-03	9.10E-02	2.11E-04	2.33E-02	2.08E-02	1.03E-04	2.33E-03	1.85E-01

Biota		Location	Maximum Non-radiological Dose During Project Phases (mg/kg/d)											
			As	Cd	Cl-	Co	Cr	Cu	Mo	SO4	Se	U	V	Zn
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
	Common Loon	Whitefish Lake	5.49E-03	1.17E-04	2.09E-01	4.63E-04	7.52E-03	1.16E-01	3.60E-02	1.31E+00	1.73E-01	1.69E-03	8.94E-03	2.76E-01
		McGowan Lake	4.73E-03	1.03E-04	1.43E-01	4.35E-04	6.75E-03	1.08E-01	2.58E-02	8.84E-01	1.13E-01	1.02E-03	4.58E-03	2.37E-01
		Russell Lake Inlet	4.57E-03	9.68E-05	1.11E-01	4.21E-04	6.41E-03	1.04E-01	1.96E-02	6.75E-01	8.96E-02	7.68E-04	3.75E-03	2.22E-01
	Mallard	Reference (Kratchkowsky Lake)	2.33E-02	1.61E-03	2.32E-02	4.50E-03	4.22E-02	7.73E-01	3.38E-03	3.89E-02	6.71E-03	1.57E-03	3.04E-02	4.91E-01
		Whitefish Lake	3.07E-02	2.39E-03	4.42E-01	5.50E-03	5.47E-02	9.67E-01	5.76E-01	2.19E+00	6.05E-02	2.00E-02	1.03E-01	6.77E-01
		McGowan Lake	2.64E-02	2.12E-03	3.02E-01	5.20E-03	5.06E-02	9.12E-01	4.13E-01	1.47E+00	4.07E-02	1.32E-02	6.01E-02	6.12E-01
		Russell Lake Inlet	2.52E-02	1.98E-03	2.35E-01	5.03E-03	4.84E-02	8.79E-01	3.14E-01	1.13E+00	3.15E-02	1.00E-02	4.92E-02	5.80E-01
	American Robin	Reference (Kratchkowsky Lake)	1.39E-01	1.34E-01	4.07E-02	7.19E-02	2.86E-01	3.73E+00	5.54E-02	8.67E-02	6.44E-02	5.27E-02	3.83E-01	9.73E+00
		Whitefish Lake	1.39E-01	1.34E-01	0.00E+00	7.23E-02	2.86E-01	3.86E+00	5.57E-02	0.00E+00	6.47E-02	5.22E-01	3.83E-01	9.76E+00
		McGowan Lake	1.39E-01	1.34E-01	5.31E-01	7.20E-02	2.86E-01	3.75E+00	5.74E-02	3.29E+00	6.45E-02	1.14E-01	3.83E-01	9.74E+00
		Russell Lake Inlet	1.39E-01	1.34E-01	4.12E-01	7.19E-02	2.86E-01	3.74E+00	5.69E-02	2.51E+00	6.44E-02	6.92E-02	3.83E-01	9.74E+00
	Lesser Scaup	Reference (Kratchkowsky Lake)	4.05E-02	2.95E-03	2.72E-02	1.11E-02	7.12E-02	1.37E+00	5.83E-03	4.27E-02	1.26E-02	2.76E-03	5.85E-02	9.28E-01
		Whitefish Lake	5.30E-02	4.43E-03	5.19E-01	1.37E-02	9.24E-02	1.71E+00	1.00E+00	2.40E+00	1.18E-01	3.71E-02	2.06E-01	1.29E+00
		McGowan Lake	4.55E-02	3.90E-03	3.54E-01	1.29E-02	8.54E-02	1.61E+00	7.17E-01	1.62E+00	7.83E-02	2.40E-02	1.16E-01	1.16E+00
		Russell Lake Inlet	4.35E-02	3.64E-03	2.76E-01	1.24E-02	8.17E-02	1.55E+00	5.45E-01	1.24E+00	6.04E-02	1.82E-02	9.46E-02	1.10E+00

Biota		Location	Maximum Non-radiological Dose During Future Centuries (mg/kg/d)											
			As	Cd	Cl-	Co	Cr	Cu	Mo	SO4	Se	U	V	Zn
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Terrestrial Animals	Black Bear	Reference (Kratchkowsky Lake)	4.74E-03	5.32E-04	2.01E-02	2.27E-03	3.88E-03	1.47E-01	1.75E-03	4.28E-02	5.31E-03	1.20E-03	4.68E-03	3.68E-01
		Whitefish Lake	4.74E-03	5.32E-04	2.26E-02	2.27E-03	3.89E-03	1.47E-01	1.75E-03	4.37E-02	5.69E-03	1.25E-03	4.68E-03	3.69E-01
	Canada Lynx	Reference (Kratchkowsky Lake)	1.61E-02	2.50E-03	2.44E-02	5.64E-04	6.54E-03	3.38E-01	5.49E-04	5.20E-02	2.87E-02	5.81E-04	1.02E-02	1.43E+01
		Whitefish Lake	1.61E-02	2.50E-03	3.14E-02	5.66E-04	6.54E-03	3.38E-01	5.50E-04	5.46E-02	2.87E-02	7.82E-04	1.02E-02	1.43E+01
		McGowan Lake	1.61E-02	2.50E-03	2.97E-02	5.65E-04	6.54E-03	3.38E-01	5.50E-04	5.40E-02	2.87E-02	6.07E-04	1.02E-02	1.43E+01
		Russell Lake Inlet	1.61E-02	2.50E-03	2.85E-02	5.64E-04	6.54E-03	3.38E-01	5.50E-04	5.35E-02	2.87E-02	5.88E-04	1.02E-02	1.43E+01
	Mink	Reference (Kratchkowsky Lake)	1.01E-02	7.70E-04	3.25E-02	1.04E-03	1.37E-02	1.46E-01	6.42E-04	6.81E-02	1.40E-02	7.00E-04	1.36E-02	3.11E-01
		Whitefish Lake	1.05E-02	7.72E-04	4.18E-02	1.08E-03	1.38E-02	1.47E-01	6.88E-04	7.14E-02	1.81E-02	9.24E-04	1.37E-02	3.38E-01
		McGowan Lake	1.03E-02	7.72E-04	3.96E-02	1.07E-03	1.38E-02	1.47E-01	6.76E-04	7.06E-02	1.67E-02	7.59E-04	1.37E-02	3.30E-01
		Russell Lake Inlet	1.02E-02	7.71E-04	3.79E-02	1.06E-03	1.37E-02	1.47E-01	6.68E-04	7.00E-02	1.60E-02	7.33E-04	1.37E-02	3.25E-01
	Moose	Reference (Kratchkowsky Lake)	2.42E-03	1.06E-03	1.78E-02	1.18E-03	1.84E-03	5.89E-02	7.36E-04	3.75E-02	5.94E-04	6.50E-04	4.06E-03	1.68E-01
		Whitefish Lake	2.46E-03	1.06E-03	2.30E-02	1.20E-03	1.85E-03	5.90E-02	7.41E-04	3.93E-02	6.50E-04	7.86E-04	4.08E-03	1.68E-01
		McGowan Lake	2.43E-03	1.06E-03	2.17E-02	1.19E-03	1.84E-03	5.89E-02	7.40E-04	3.89E-02	6.31E-04	6.78E-04	4.07E-03	1.68E-01
		Russell Lake Inlet	2.43E-03	1.06E-03	2.08E-02	1.19E-03	1.84E-03	5.89E-02	7.39E-04	3.85E-02	6.21E-04	6.63E-04	4.07E-03	1.68E-01
	Moose Organs	Reference (Kratchkowsky Lake)	2.42E-03	1.06E-03	1.78E-02	1.18E-03	1.84E-03	5.89E-02	7.36E-04	3.75E-02	5.94E-04	6.50E-04	4.06E-03	1.68E-01
		McGowan Lake	2.43E-03	1.06E-03	2.17E-02	1.19E-03	1.84E-03	5.89E-02	7.40E-04	3.89E-02	6.31E-04	6.78E-04	4.07E-03	1.68E-01
		Russell Lake Inlet	2.43E-03	1.06E-03	2.08E-02	1.19E-03	1.84E-03	5.89E-02	7.39E-04	3.85E-02	6.21E-04	6.63E-04	4.07E-03	1.68E-01
	Muskrat	Reference (Kratchkowsky Lake)	2.50E-02	1.20E-03	3.84E-02	4.48E-03	1.58E-02	3.70E-02	1.02E-03	6.70E-02	2.93E-03	1.80E-03	3.92E-02	1.17E-01
		Whitefish Lake	2.59E-02	1.21E-03	4.94E-02	4.72E-03	1.60E-02	3.75E-02	1.11E-03	7.02E-02	3.90E-03	2.20E-03	3.96E-02	1.27E-01
		McGowan Lake	2.54E-02	1.21E-03	4.68E-02	4.66E-03	1.60E-02	3.73E-02	1.09E-03	6.95E-02	3.57E-03	2.07E-03	3.94E-02	1.24E-01
		Russell Lake Inlet	2.52E-02	1.21E-03	4.48E-02	4.62E-03	1.59E-02	3.73E-02	1.07E-03	6.89E-02	3.40E-03	2.00E-03	3.93E-02	1.22E-01
	Snowshoe Hare	Reference (Kratchkowsky Lake)	6.75E-03	3.71E-03	3.04E-02	4.09E-03	8.23E-03	2.53E-01	3.19E-03	6.49E-02	2.24E-03	2.73E-03	1.30E-02	6.87E-01
		Whitefish Lake	6.75E-03	3.71E-03	3.92E-02	4.10E-03	8.23E-03	2.53E-01	3.19E-03	6.81E-02	2.24E-03	3.46E-03	1.30E-02	6.88E-01
		McGowan Lake	6.75E-03	3.71E-03	3.71E-02	4.09E-03	8.23E-03	2.53E-01	3.19E-03	6.73E-02	2.24E-03	2.83E-03	1.30E-02	6.87E-01
		Russell Lake Inlet	6.75E-03	3.71E-03	3.56E-02	4.09E-03	8.23E-03	2.53E-01	3.19E-03	6.68E-02	2.24E-03	2.76E-03	1.30E-02	6.87E-01

Biota	Location	Maximum Non-radiological Dose During Future Centuries (mg/kg/d)											
		As	Cd	Cl-	Co	Cr	Cu	Mo	SO4	Se	U	V	Zn
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	1.58E-01	2.40E-02	4.49E-02	9.13E-02	2.70E-02	6.31E+00	7.48E-02	9.57E-02	6.19E-02	4.17E-02	3.16E-02	1.56E+01
	Whitefish Lake	1.58E-01	2.40E-02	5.77E-02	9.15E-02	2.70E-02	6.31E+00	7.48E-02	1.00E-01	6.19E-02	5.56E-02	3.16E-02	1.56E+01
	McGowan Lake	1.58E-01	2.40E-02	5.47E-02	9.13E-02	2.70E-02	6.31E+00	7.48E-02	9.92E-02	6.19E-02	4.35E-02	3.16E-02	1.56E+01
	Russell Lake Inlet	1.58E-01	2.40E-02	5.24E-02	9.13E-02	2.70E-02	6.31E+00	7.48E-02	9.84E-02	6.19E-02	4.22E-02	3.16E-02	1.56E+01
WoodLand Caribou	Reference (Kratchkowsky Lake)	5.27E-03	1.60E-03	1.99E-02	2.17E-03	2.09E-02	4.10E-02	1.35E-03	4.05E-02	1.52E-03	1.74E-03	1.68E-02	2.12E-01
	Whitefish Lake	5.30E-03	1.60E-03	2.23E-02	2.18E-03	2.09E-02	4.10E-02	1.36E-03	4.13E-02	1.56E-03	1.77E-03	1.69E-02	2.12E-01
Canada Goose	Reference (Kratchkowsky Lake)	7.65E-04	5.49E-04	1.24E-02	4.51E-04	1.78E-03	2.35E-02	3.28E-04	2.64E-02	2.16E-04	3.80E-04	2.73E-03	6.71E-02
	Whitefish Lake	7.61E-04	5.48E-04	0.00E+00	4.48E-04	1.76E-03	2.35E-02	3.24E-04	0.00E+00	2.14E-04	4.82E-04	2.72E-03	6.71E-02
	McGowan Lake	7.65E-04	5.49E-04	1.51E-02	4.51E-04	1.78E-03	2.35E-02	3.28E-04	2.74E-02	2.16E-04	3.93E-04	2.73E-03	6.71E-02
	Russell Lake Inlet	7.65E-04	5.49E-04	1.44E-02	4.51E-04	1.78E-03	2.35E-02	3.28E-04	2.71E-02	2.16E-04	3.84E-04	2.73E-03	6.71E-02
Bald Eagle	Reference (Kratchkowsky Lake)	9.63E-03	3.34E-03	1.07E-02	2.67E-03	3.39E-02	6.26E-02	1.05E-03	2.28E-02	2.13E-02	3.52E-03	4.51E-02	1.88E-01
	Whitefish Lake	9.64E-03	3.34E-03	1.09E-02	2.67E-03	3.39E-02	6.27E-02	1.06E-03	2.29E-02	2.17E-02	3.54E-03	4.51E-02	1.89E-01
Olive-Sided Flycatcher	Reference (Kratchkowsky Lake)	2.82E-02	1.72E-01	5.95E-02	1.27E-02	1.34E-01	1.02E+00	1.53E-02	1.27E-01	4.15E-02	1.28E-02	1.25E-01	2.35E+00
	Whitefish Lake	2.84E-02	1.72E-01	0.00E+00	1.28E-02	1.34E-01	1.03E+00	1.55E-02	0.00E+00	4.28E-02	1.63E-02	1.25E-01	2.39E+00
	McGowan Lake	2.83E-02	1.72E-01	7.25E-02	1.28E-02	1.34E-01	1.02E+00	1.55E-02	1.32E-01	4.24E-02	1.33E-02	1.25E-01	2.38E+00
	Russell Lake Inlet	2.83E-02	1.72E-01	6.95E-02	1.28E-02	1.34E-01	1.02E+00	1.54E-02	1.31E-01	4.21E-02	1.30E-02	1.25E-01	2.37E+00
Common Loon	Reference (Kratchkowsky Lake)	3.91E-03	7.84E-05	1.09E-02	3.75E-04	5.47E-03	9.09E-02	2.11E-04	2.33E-02	2.02E-02	1.01E-04	2.11E-03	1.81E-01
	Whitefish Lake	4.06E-03	7.89E-05	1.41E-02	3.95E-04	5.54E-03	9.21E-02	2.30E-04	2.45E-02	2.56E-02	1.23E-04	2.13E-03	1.97E-01
	McGowan Lake	3.97E-03	7.87E-05	1.33E-02	3.90E-04	5.52E-03	9.18E-02	2.25E-04	2.42E-02	2.39E-02	1.16E-04	2.11E-03	1.92E-01
	Russell Lake Inlet	3.95E-03	7.86E-05	1.28E-02	3.87E-04	5.51E-03	9.16E-02	2.22E-04	2.40E-02	2.29E-02	1.12E-04	2.11E-03	1.89E-01
Mallard	Reference (Kratchkowsky Lake)	2.32E-02	1.61E-03	2.32E-02	4.50E-03	4.22E-02	7.73E-01	3.38E-03	3.89E-02	6.70E-03	1.57E-03	3.00E-02	4.90E-01
	Whitefish Lake	2.40E-02	1.62E-03	2.99E-02	4.73E-03	4.27E-02	7.83E-01	3.68E-03	4.08E-02	8.93E-03	1.91E-03	3.03E-02	5.33E-01
	McGowan Lake	2.35E-02	1.62E-03	2.83E-02	4.67E-03	4.26E-02	7.81E-01	3.61E-03	4.04E-02	8.18E-03	1.80E-03	3.01E-02	5.19E-01
	Russell Lake Inlet	2.34E-02	1.62E-03	2.71E-02	4.63E-03	4.25E-02	7.79E-01	3.55E-03	4.00E-02	7.79E-03	1.74E-03	3.01E-02	5.12E-01
American Robin	Reference (Kratchkowsky Lake)	1.39E-01	1.34E-01	4.07E-02	7.19E-02	2.86E-01	3.73E+00	5.54E-02	8.67E-02	6.44E-02	5.27E-02	3.83E-01	9.73E+00
	Whitefish Lake	1.39E-01	1.34E-01	0.00E+00	7.21E-02	2.86E-01	3.74E+00	5.54E-02	0.00E+00	6.44E-02	7.14E-02	3.83E-01	9.74E+00
	McGowan Lake	1.39E-01	1.34E-01	4.96E-02	7.19E-02	2.86E-01	3.73E+00	5.54E-02	9.00E-02	6.44E-02	5.51E-02	3.83E-01	9.73E+00
	Russell Lake Inlet	1.39E-01	1.34E-01	4.75E-02	7.19E-02	2.86E-01	3.73E+00	5.54E-02	8.92E-02	6.44E-02	5.33E-02	3.83E-01	9.73E+00
Lesser Scaup	Reference (Kratchkowsky Lake)	3.97E-02	2.94E-03	2.72E-02	1.10E-02	7.11E-02	1.37E+00	5.83E-03	4.27E-02	1.25E-02	2.74E-03	5.64E-02	9.25E-01
	Whitefish Lake	4.12E-02	2.96E-03	3.51E-02	1.16E-02	7.20E-02	1.38E+00	6.35E-03	4.48E-02	1.67E-02	3.35E-03	5.69E-02	1.00E+00
	McGowan Lake	4.03E-02	2.95E-03	3.32E-02	1.15E-02	7.18E-02	1.38E+00	6.22E-03	4.43E-02	1.53E-02	3.15E-03	5.66E-02	9.80E-01
	Russell Lake Inlet	4.01E-02	2.95E-03	3.18E-02	1.14E-02	7.16E-02	1.38E+00	6.13E-03	4.40E-02	1.45E-02	3.04E-03	5.65E-02	9.66E-01

5.2.5.2 Radiological Dose

The estimated radiation doses to aquatic and terrestrial ecological receptors during the Project phases and the future centuries are shown in Table 5-10. The doses shown represent the maximum total dose from all radionuclides over the assessment period. The dose breakdown by radionuclide is shown in Appendix B. The results are presented as a total dose which includes both baseline and Project contributions.

The maximum predicted dose during the Project phases for terrestrial and riparian biota is to lichen near Whitefish Lake (0.99 mGy/d), and the main contributors to total dose are from uranium-234 and uranium-238 in air that deposits to lichen. The maximum predicted dose for aquatic biota is to zooplankton at Whitefish Lake (0.10 mGy/d), and the main contributor to total dose is from polonium-210 in water.

The maximum predicted dose during the future centuries to aquatic biota is to zooplankton (0.08 mGy/d) in Whitefish Lake from polonium-210 in water. The maximum predicted dose during the future centuries to terrestrial and riparian biota is to the scaup (0.05 mGy/d) who eats aquatic animals from Whitefish Lake. For terrestrial plants the dose during the future centuries is 0.22 mGy/d for lichen at all locations, due to background concentrations of polonium-210 in lichen.

Table 5-10: Estimated Radiological Project Total Doses to Ecological Receptors – Project Phases and Future Centuries

Biota		Location	Maximum Radiological Dose During Project Phases (mGy/d)							Maximum Radiological Dose During Future Centuries (mGy/d)						
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose	Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose
Aquatic Plants	Macrophytes	Reference (Kratchkowsky Lake)	1.13E-05	1.28E-05	1.53E-03	3.08E-03	6.21E-05	1.35E-03	**6.04E-03**	1.09E-05	1.24E-05	1.52E-03	3.01E-03	5.27E-05	1.15E-03	**5.75E-03**
		Whitefish Lake North (LA-6)	1.10E-05	1.25E-05	1.53E-03	3.04E-03	5.68E-05	1.23E-03	**5.88E-03**	1.09E-05	1.24E-05	1.52E-03	3.01E-03	5.27E-05	1.15E-03	**5.75E-03**
		Whitefish Lake Middle (LA-5 North)	2.06E-04	2.35E-04	2.82E-03	3.71E-03	8.35E-05	1.43E-03	**8.48E-03**	1.33E-05	1.51E-05	1.56E-03	3.45E-03	6.05E-05	1.31E-03	**6.42E-03**
		Whitefish Lake South (LA-5 South)	1.96E-04	2.23E-04	2.80E-03	3.63E-03	8.24E-05	1.54E-03	**8.47E-03**	1.32E-05	1.50E-05	1.56E-03	3.44E-03	5.91E-05	1.29E-03	**6.37E-03**
		McGowan Lake (LA-1)	1.21E-04	1.38E-04	2.37E-03	3.41E-03	6.67E-05	1.33E-03	**7.44E-03**	1.25E-05	1.42E-05	1.55E-03	3.32E-03	5.56E-05	1.21E-03	**6.16E-03**
		Russell Lake Inlet	9.04E-05	1.03E-04	2.16E-03	3.31E-03	6.40E-05	1.32E-03	**7.04E-03**	1.20E-05	1.37E-05	1.55E-03	3.24E-03	5.45E-05	1.18E-03	**6.05E-03**
	Phytoplankton	Reference (Kratchkowsky Lake)	1.13E-05	1.28E-05	1.53E-03	3.07E-03	6.15E-05	1.35E-03	**6.04E-03**	1.09E-05	1.24E-05	1.52E-03	3.01E-03	5.21E-05	1.15E-03	**5.75E-03**
		Whitefish Lake North (LA-6)	1.10E-05	1.25E-05	1.53E-03	3.03E-03	5.62E-05	1.23E-03	**5.87E-03**	1.09E-05	1.24E-05	1.52E-03	3.01E-03	5.21E-05	1.15E-03	**5.75E-03**
		Whitefish Lake Middle (LA-5 North)	2.06E-04	2.35E-04	2.82E-03	3.70E-03	8.26E-05	1.43E-03	**8.47E-03**	1.33E-05	1.51E-05	1.56E-03	3.45E-03	5.98E-05	1.31E-03	**6.41E-03**
		Whitefish Lake South (LA-5 South)	1.96E-04	2.23E-04	2.80E-03	3.63E-03	8.15E-05	1.54E-03	**8.47E-03**	1.32E-05	1.50E-05	1.56E-03	3.43E-03	5.84E-05	1.29E-03	**6.37E-03**
		McGowan Lake (LA-1)	1.21E-04	1.38E-04	2.37E-03	3.41E-03	6.60E-05	1.33E-03	**7.43E-03**	1.25E-05	1.42E-05	1.55E-03	3.31E-03	5.50E-05	1.21E-03	**6.16E-03**
		Russell Lake Inlet	9.04E-05	1.03E-04	2.16E-03	3.31E-03	6.33E-05	1.32E-03	**7.04E-03**	1.20E-05	1.37E-05	1.55E-03	3.24E-03	5.39E-05	1.18E-03	**6.04E-03**
Aquatic Animals	Benthic Invertebrate	Reference (Kratchkowsky Lake)	4.94E-09	6.45E-09	2.00E-08	8.13E-05	3.95E-05	1.79E-09	**1.21E-04**	4.94E-09	6.44E-09	2.00E-08	8.13E-05	3.95E-05	1.79E-09	**1.21E-04**
		Whitefish Lake North (LA-6)	4.94E-09	6.44E-09	2.00E-08	8.13E-05	3.95E-05	1.79E-09	**1.21E-04**	4.94E-09	6.44E-09	2.00E-08	8.13E-05	3.95E-05	1.79E-09	**1.21E-04**
		Whitefish Lake Middle (LA-5 North)	6.10E-08	7.96E-08	3.31E-08	9.45E-05	5.88E-05	2.62E-09	**1.53E-04**	6.04E-09	7.88E-09	2.06E-08	9.32E-05	4.53E-05	2.05E-09	**1.39E-04**
		Whitefish Lake South (LA-5 South)	5.84E-08	7.62E-08	3.29E-08	9.39E-05	5.49E-05	2.45E-09	**1.49E-04**	5.99E-09	7.82E-09	2.06E-08	9.28E-05	4.43E-05	2.01E-09	**1.37E-04**
		McGowan Lake (LA-1)	4.06E-08	5.30E-08	2.95E-08	9.02E-05	4.67E-05	2.10E-09	**1.37E-04**	5.67E-09	7.40E-09	2.04E-08	8.96E-05	4.17E-05	1.89E-09	**1.31E-04**
		Russell Lake Inlet	3.10E-08	4.04E-08	2.72E-08	8.79E-05	4.37E-05	1.98E-09	**1.32E-04**	5.47E-09	7.15E-09	2.03E-08	8.75E-05	4.08E-05	1.85E-09	**1.28E-04**
	Northern pike	Reference (Kratchkowsky Lake)	4.47E-06	5.09E-06	3.96E-05	2.29E-04	2.20E-06	6.93E-04	**9.74E-04**	4.31E-06	4.90E-06	3.94E-05	2.24E-04	1.87E-06	5.87E-04	**8.62E-04**
		Whitefish Lake North (LA-6)	4.38E-06	4.98E-06	3.94E-05	2.26E-04	2.01E-06	6.33E-04	**9.10E-04**	4.31E-06	4.90E-06	3.94E-05	2.24E-04	1.87E-06	5.87E-04	**8.62E-04**
		Whitefish Lake Middle (LA-5 North)	8.18E-05	9.31E-05	7.28E-05	2.76E-04	2.96E-06	7.35E-04	**1.26E-03**	5.27E-06	6.00E-06	4.04E-05	2.57E-04	2.14E-06	6.74E-04	**9.84E-04**
		Whitefish Lake South (LA-5 South)	7.79E-05	8.87E-05	7.23E-05	2.70E-04	2.92E-06	7.90E-04	**1.30E-03**	5.23E-06	5.95E-06	4.04E-05	2.56E-04	2.09E-06	6.59E-04	**9.68E-04**
		McGowan Lake (LA-1)	4.81E-05	5.48E-05	6.12E-05	2.54E-04	2.37E-06	6.82E-04	**1.10E-03**	4.95E-06	5.63E-06	4.02E-05	2.47E-04	1.97E-06	6.20E-04	**9.20E-04**
		Russell Lake Inlet	3.59E-05	4.08E-05	5.58E-05	2.46E-04	2.27E-06	6.75E-04	**1.06E-03**	4.78E-06	5.44E-06	4.00E-05	2.41E-04	1.93E-06	6.06E-04	**8.99E-04**
	White sucker	Reference (Kratchkowsky Lake)	3.33E-06	3.89E-06	2.96E-05	1.91E-04	2.02E-06	5.30E-05	**2.83E-04**	3.21E-06	3.74E-06	2.94E-05	1.87E-04	1.76E-06	4.49E-05	**2.70E-04**
		Whitefish Lake North (LA-6)	3.26E-06	3.80E-06	2.95E-05	1.88E-04	1.88E-06	4.84E-05	**2.75E-04**	3.21E-06	3.74E-06	2.94E-05	1.87E-04	1.76E-06	4.49E-05	**2.70E-04**
		Whitefish Lake Middle (LA-5 North)	6.10E-05	7.11E-05	5.45E-05	2.29E-04	2.76E-06	5.61E-05	**4.75E-04**	3.93E-06	4.58E-06	3.02E-05	2.14E-04	2.02E-06	5.15E-05	**3.06E-04**
		Whitefish Lake South (LA-5 South)	5.80E-05	6.77E-05	5.41E-05	2.25E-04	2.70E-06	6.04E-05	**4.68E-04**	3.90E-06	4.54E-06	3.02E-05	2.13E-04	1.98E-06	5.04E-05	**3.04E-04**
		McGowan Lake (LA-1)	3.59E-05	4.18E-05	4.57E-05	2.12E-04	2.21E-06	5.21E-05	**3.89E-04**	3.68E-06	4.30E-06	3.00E-05	2.06E-04	1.86E-06	4.74E-05	**2.93E-04**
		Russell Lake Inlet	2.67E-05	3.12E-05	4.17E-05	2.05E-04	2.11E-06	5.16E-05	**3.59E-04**	3.56E-06	4.15E-06	2.99E-05	2.01E-04	1.82E-06	4.63E-05	**2.87E-04**
	Zooplankton	Reference (Kratchkowsky Lake)	2.22E-05	2.59E-05	3.29E-03	4.70E-03	3.44E-05	7.43E-02	**8.24E-02**	2.14E-05	2.50E-05	3.27E-03	4.60E-03	2.91E-05	6.30E-02	**7.09E-02**
		Whitefish Lake North (LA-6)	2.17E-05	2.53E-05	3.28E-03	4.64E-03	3.14E-05	6.79E-02	**7.59E-02**	2.14E-05	2.50E-05	3.27E-03	4.60E-03	2.91E-05	6.30E-02	**7.09E-02**
		Whitefish Lake Middle (LA-5 North)	4.06E-04	4.74E-04	6.05E-03	5.66E-03	4.62E-05	7.88E-02	**9.14E-02**	2.62E-05	3.05E-05	3.36E-03	5.27E-03	3.34E-05	7.22E-02	**8.10E-02**
		Whitefish Lake South (LA-5 South)	3.87E-04	4.51E-04	6.01E-03	5.55E-03	4.56E-05	8.48E-02	**9.72E-02**	2.60E-05	3.03E-05	3.36E-03	5.25E-03	3.27E-05	7.07E-02	**7.93E-02**
		McGowan Lake (LA-1)	2.39E-04	2.79E-04	5.08E-03	5.22E-03	3.69E-05	7.31E-02	**8.40E-02**	2.46E-05	2.87E-05	3.34E-03	5.07E-03	3.07E-05	6.65E-02	**7.50E-02**
		Russell Lake Inlet	1.78E-04	2.08E-04	4.63E-03	5.06E-03	3.54E-05	7.23E-02	**8.25E-02**	2.37E-05	2.77E-05	3.32E-03	4.95E-03	3.01E-05	6.50E-02	**7.33E-02**
Terrestrial Plants	Blueberries	Reference (Kratchkowsky Lake)	2.46E-04	2.80E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.66E-02**	2.46E-04	2.80E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.66E-02**
		Whitefish Lake (LA-5)	2.05E-03	2.33E-03	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**3.04E-02**	3.36E-04	3.83E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.68E-02**
		McGowan Lake (LA-1)	4.83E-04	5.49E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.71E-02**	2.58E-04	2.93E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.66E-02**
		Russell Lake Inlet	3.09E-04	3.52E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.67E-02**	2.49E-04	2.83E-04	2.11E-04	1.62E-02	6.20E-05	9.60E-03	**2.66E-02**
	Browse	Reference (Kratchkowsky Lake)	2.16E-04	2.46E-04	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.13E-02**	2.16E-04	2.46E-04	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.13E-02**
		Whitefish Lake (LA-5)	7.48E-03	8.52E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**2.69E-02**	2.52E-04	2.87E-04	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.14E-02**
		McGowan Lake (LA-1)	1.17E-03	1.33E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.34E-02**	2.20E-04	2.51E-04	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.13E-02**
		Russell Lake Inlet	4.70E-04	5.35E-04	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.19E-02**	2.17E-04	2.47E-04	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.13E-02**

Biota		Location	Maximum Radiological Dose During Project Phases (mGy/d)							Maximum Radiological Dose During Future Centuries (mGy/d)						
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose	Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose
	Labrador Tea	Reference (Kratchkowsky Lake)	1.21E-03	1.38E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.34E-02**	1.21E-03	1.38E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.34E-02**
		Whitefish Lake (LA-5)	6.49E-02	7.39E-02	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.50E-01**	1.25E-03	1.42E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.35E-02**
		McGowan Lake (LA-1)	9.57E-03	1.09E-02	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**3.13E-02**	1.22E-03	1.39E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.35E-02**
		Russell Lake Inlet	3.45E-03	3.92E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.82E-02**	1.22E-03	1.38E-03	1.03E-04	6.74E-03	3.16E-04	3.69E-03	**1.35E-02**
	Lichen	Reference (Kratchkowsky Lake)	6.37E-04	7.24E-04	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**2.16E-01**	6.37E-04	7.24E-04	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**2.16E-01**
		Whitefish Lake (LA-5)	3.62E-01	4.11E-01	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**9.88E-01**	6.37E-04	7.24E-04	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**2.16E-01**
		McGowan Lake (LA-1)	4.80E-02	5.46E-02	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**3.18E-01**	6.37E-04	7.24E-04	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**2.16E-01**
		Russell Lake Inlet	1.33E-02	1.51E-02	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**2.43E-01**	6.37E-04	7.24E-04	7.32E-04	9.05E-03	1.81E-03	2.03E-01	**2.16E-01**
	Terrestrial Invertebrate	Reference (Kratchkowsky Lake)	1.41E-04	1.61E-04	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**6.61E-03**	1.41E-04	1.61E-04	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**6.61E-03**
		Whitefish Lake (LA-5)	6.92E-03	7.88E-03	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**2.11E-02**	1.50E-04	1.71E-04	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**6.62E-03**
		McGowan Lake (LA-1)	1.03E-03	1.17E-03	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**8.51E-03**	1.43E-04	1.62E-04	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**6.61E-03**
		Russell Lake Inlet	3.79E-04	4.31E-04	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**7.11E-03**	1.42E-04	1.61E-04	1.15E-04	4.85E-03	1.22E-05	1.33E-03	**6.61E-03**
Terrestrial Animals	Black Bear	Reference (Kratchkowsky Lake)	2.15E-06	2.45E-06	2.09E-06	8.38E-04	2.10E-06	9.90E-04	**1.84E-03**	2.15E-06	2.45E-06	2.09E-06	8.38E-04	2.09E-06	9.86E-04	**1.83E-03**
		Whitefish Lake (LA-5)	3.68E-06	4.19E-06	2.13E-06	8.38E-04	2.10E-06	9.90E-04	**1.84E-03**	2.23E-06	2.54E-06	2.10E-06	8.38E-04	2.09E-06	9.87E-04	**1.83E-03**
	Canada Lynx	Reference (Kratchkowsky Lake)	3.96E-07	4.60E-07	1.08E-06	6.67E-04	3.40E-06	3.42E-04	**1.01E-03**	3.96E-07	4.60E-07	1.08E-06	6.67E-04	3.40E-06	3.42E-04	**1.01E-03**
		Whitefish Lake (LA-5)	4.39E-06	5.06E-06	1.11E-06	6.67E-04	3.40E-06	3.42E-04	**1.02E-03**	5.33E-07	6.19E-07	1.08E-06	6.67E-04	3.40E-06	3.42E-04	**1.02E-03**
		McGowan Lake (LA-1)	9.31E-07	1.08E-06	1.10E-06	6.67E-04	3.40E-06	3.42E-04	**1.02E-03**	4.14E-07	4.81E-07	1.08E-06	6.67E-04	3.40E-06	3.42E-04	**1.01E-03**
		Russell Lake Inlet	5.46E-07	6.33E-07	1.09E-06	6.67E-04	3.40E-06	3.42E-04	**1.02E-03**	4.01E-07	4.65E-07	1.08E-06	6.67E-04	3.40E-06	3.42E-04	**1.01E-03**
	Mink	Reference (Kratchkowsky Lake)	2.40E-07	2.73E-07	2.76E-06	6.46E-05	2.77E-07	8.90E-04	**9.59E-04**	2.39E-07	2.72E-07	2.76E-06	6.45E-05	2.74E-07	8.87E-04	**9.55E-04**
		Whitefish Lake (LA-5)	2.32E-06	2.64E-06	4.29E-06	7.32E-05	3.89E-07	1.28E-03	**1.36E-03**	3.15E-07	3.59E-07	2.82E-06	7.21E-05	3.08E-07	1.01E-03	**1.09E-03**
		McGowan Lake (LA-1)	1.02E-06	1.17E-06	3.86E-06	7.03E-05	3.17E-07	1.04E-03	**1.11E-03**	2.59E-07	2.95E-07	2.81E-06	6.98E-05	2.87E-07	9.35E-04	**1.01E-03**
		Russell Lake Inlet	7.48E-07	8.52E-07	3.60E-06	6.88E-05	3.01E-07	9.75E-04	**1.05E-03**	2.51E-07	2.85E-07	2.80E-06	6.85E-05	2.82E-07	9.16E-04	**9.88E-04**
	Moose	Reference (Kratchkowsky Lake)	3.71E-06	4.22E-06	5.20E-06	8.25E-04	2.52E-06	9.41E-04	**1.78E-03**	3.70E-06	4.22E-06	5.18E-06	8.24E-04	2.44E-06	9.30E-04	**1.77E-03**
		Whitefish Lake (LA-5)	1.23E-04	1.40E-04	8.41E-06	8.39E-04	2.73E-06	9.78E-04	**2.09E-03**	4.36E-06	4.97E-06	5.29E-06	8.34E-04	2.51E-06	9.49E-04	**1.80E-03**
		McGowan Lake (LA-1)	2.02E-05	2.30E-05	7.29E-06	8.33E-04	2.57E-06	9.52E-04	**1.84E-03**	3.80E-06	4.33E-06	5.26E-06	8.31E-04	2.47E-06	9.37E-04	**1.78E-03**
		Russell Lake Inlet	8.61E-06	9.80E-06	6.77E-06	8.31E-04	2.54E-06	9.46E-04	**1.80E-03**	3.74E-06	4.26E-06	5.24E-06	8.29E-04	2.46E-06	9.34E-04	**1.78E-03**
	Moose Organs	Reference (Kratchkowsky Lake)	6.55E-06	7.46E-06	1.40E-03	5.97E-04	4.25E-05	9.41E-06	**2.07E-03**	6.55E-06	7.45E-06	1.40E-03	5.97E-04	4.00E-05	9.31E-06	**2.06E-03**
		McGowan Lake	3.58E-05	4.07E-05	1.98E-03	6.02E-04	4.41E-05	9.53E-06	**2.71E-03**	6.73E-06	7.66E-06	1.42E-03	6.01E-04	4.09E-05	9.38E-06	**2.09E-03**
		Russell Lake Inlet	1.52E-05	1.73E-05	1.83E-03	6.01E-04	4.32E-05	9.47E-06	**2.52E-03**	6.61E-06	7.53E-06	1.41E-03	6.00E-04	4.06E-05	9.35E-06	**2.08E-03**
	Muskrat	Reference (Kratchkowsky Lake)	6.39E-07	7.27E-07	1.18E-05	2.92E-04	2.02E-06	6.38E-04	**9.46E-04**	6.34E-07	7.21E-07	1.17E-05	2.89E-04	1.80E-06	6.07E-04	**9.10E-04**
		Whitefish Lake (LA-5)	8.72E-06	9.92E-06	2.15E-05	3.47E-04	2.80E-06	8.52E-04	**1.24E-03**	7.75E-07	8.82E-07	1.20E-05	3.31E-04	2.06E-06	6.96E-04	**1.04E-03**
		McGowan Lake (LA-1)	5.59E-06	6.36E-06	1.81E-05	3.24E-04	2.23E-06	7.11E-04	**1.07E-03**	7.28E-07	8.28E-07	1.19E-05	3.18E-04	1.90E-06	6.40E-04	**9.74E-04**
		Russell Lake Inlet	4.24E-06	4.82E-06	1.65E-05	3.15E-04	2.13E-06	6.77E-04	**1.02E-03**	7.03E-07	8.00E-07	1.19E-05	3.11E-04	1.86E-06	6.27E-04	**9.53E-04**
	Snowshoe Hare	Reference (Kratchkowsky Lake)	3.45E-06	3.93E-06	1.96E-06	1.07E-03	4.05E-06	8.65E-04	**1.95E-03**	3.45E-06	3.93E-06	1.96E-06	1.07E-03	4.05E-06	8.65E-04	**1.95E-03**
		Whitefish Lake (LA-5)	1.02E-04	1.17E-04	1.98E-06	1.07E-03	4.05E-06	8.65E-04	**2.16E-03**	4.16E-06	4.75E-06	1.96E-06	1.07E-03	4.05E-06	8.65E-04	**1.95E-03**
		McGowan Lake (LA-1)	1.64E-05	1.87E-05	1.97E-06	1.07E-03	4.05E-06	8.65E-04	**1.97E-03**	3.54E-06	4.04E-06	1.96E-06	1.07E-03	4.05E-06	8.65E-04	**1.95E-03**
		Russell Lake Inlet	6.92E-06	7.89E-06	1.97E-06	1.07E-03	4.05E-06	8.65E-04	**1.95E-03**	3.47E-06	3.96E-06	1.96E-06	1.07E-03	4.05E-06	8.65E-04	**1.95E-03**
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	1.47E-05	1.67E-05	6.56E-06	3.88E-03	8.24E-06	5.81E-03	**9.74E-03**	1.47E-05	1.67E-05	6.56E-06	3.88E-03	8.24E-06	5.81E-03	**9.74E-03**
		Whitefish Lake (LA-5)	2.65E-04	3.01E-04	6.57E-06	3.88E-03	8.24E-06	5.81E-03	**1.03E-02**	1.90E-05	2.17E-05	6.56E-06	3.88E-03	8.24E-06	5.81E-03	**9.75E-03**
		McGowan Lake (LA-1)	4.75E-05	5.41E-05	6.57E-06	3.88E-03	8.24E-06	5.81E-03	**9.81E-03**	1.53E-05	1.74E-05	6.56E-06	3.88E-03	8.24E-06	5.81E-03	**9.74E-03**
		Russell Lake Inlet	2.35E-05	2.67E-05	6.56E-06	3.88E-03	8.24E-06	5.81E-03	**9.76E-03**	1.48E-05	1.69E-05	6.56E-06	3.88E-03	8.24E-06	5.81E-03	**9.74E-03**
	Woodland Caribou	Reference (Kratchkowsky Lake)	3.34E-06	3.81E-06	6.25E-06	6.81E-04	1.20E-05	6.24E-03	**6.95E-03**	3.34E-06	3.81E-06	6.24E-06	6.80E-04	1.19E-05	6.23E-03	**6.94E-03**
		Whitefish Lake (LA-5)	8.19E-05	9.32E-05	7.30E-06	6.86E-04	1.20E-05	6.26E-03	**7.14E-03**	3.40E-06	3.87E-06	6.28E-06	6.85E-04	1.19E-05	6.24E-03	**6.95E-03**
	Canada Goose	Reference (Kratchkowsky Lake)	1.39E-05	1.59E-05	4.00E-07	5.61E-04	3.17E-06	7.77E-04	**1.37E-03**	1.39E-05	1.59E-05	4.00E-07	5.61E-04	3.17E-06	7.77E-04	**1.37E-03**
		Whitefish Lake (LA-5)	4.23E-04	4.82E-04	3.95E-07	5.61E-04	3.17E-06	7.76E-04	**2.25E-03**	1.67E-05	1.90E-05	3.95E-07	5.61E-04	3.17E-06	7.76E-04	**1.38E-03**
		McGowan Lake (LA-1)	6.78E-05	7.72E-05	4.04E-07	5.61E-04	3.17E-06	7.77E-04	**1.49E-03**	1.43E-05	1.63E-05	4.01E-07	5.61E-04	3.17E-06	7.77E-04	**1.37E-03**

Biota	Location	Maximum Radiological Dose During Project Phases (mGy/d)							Maximum Radiological Dose During Future Centuries (mGy/d)						
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose	Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose
	Russell Lake Inlet	2.84E-05	3.23E-05	4.03E-07	5.61E-04	3.17E-06	7.77E-04	**1.40E-03**	1.40E-05	1.60E-05	4.00E-07	5.61E-04	3.17E-06	7.77E-04	**1.37E-03**
Bald Eagle	Reference (Kratchkowsky Lake)	4.93E-05	5.61E-05	3.13E-06	3.72E-05	5.32E-07	7.06E-03	**7.21E-03**	4.93E-05	5.61E-05	3.13E-06	3.72E-05	5.27E-07	6.99E-03	**7.14E-03**
	Whitefish Lake (LA-5)	5.58E-05	6.35E-05	3.14E-06	3.73E-05	5.32E-07	7.12E-03	**7.28E-03**	4.96E-05	5.64E-05	3.13E-06	3.72E-05	5.27E-07	7.02E-03	**7.17E-03**
Olive-Sided Flycatcher	Reference (Kratchkowsky Lake)	1.29E-04	1.47E-04	5.91E-06	1.59E-04	1.07E-06	1.23E-02	**1.28E-02**	1.29E-04	1.47E-04	5.91E-06	1.59E-04	1.07E-06	1.23E-02	**1.28E-02**
	Whitefish Lake (LA-5)	4.95E-03	5.64E-03	7.77E-06	1.61E-04	1.16E-06	1.59E-02	**2.67E-02**	1.47E-04	1.67E-04	5.98E-06	1.61E-04	1.10E-06	1.35E-02	**1.40E-02**
	McGowan Lake (LA-1)	7.70E-04	8.76E-04	7.27E-06	1.61E-04	1.11E-06	1.37E-02	**1.55E-02**	1.32E-04	1.50E-04	5.97E-06	1.60E-04	1.08E-06	1.28E-02	**1.32E-02**
	Russell Lake Inlet	3.05E-04	3.47E-04	6.94E-06	1.60E-04	1.09E-06	1.31E-02	**1.40E-02**	1.30E-04	1.48E-04	5.96E-06	1.60E-04	1.08E-06	1.26E-02	**1.30E-02**
Common Loon	Reference (Kratchkowsky Lake)	1.43E-06	1.63E-06	1.11E-06	1.90E-05	1.82E-07	3.14E-03	**3.16E-03**	1.40E-06	1.59E-06	1.11E-06	1.90E-05	1.77E-07	3.07E-03	**3.10E-03**
	Whitefish Lake (LA-5)	2.39E-05	2.72E-05	1.86E-06	2.22E-05	2.66E-07	4.42E-03	**4.49E-03**	1.70E-06	1.94E-06	1.14E-06	2.17E-05	2.03E-07	3.53E-03	**3.55E-03**
	McGowan Lake (LA-1)	1.41E-05	1.60E-05	1.65E-06	2.11E-05	2.11E-07	3.60E-03	**3.65E-03**	1.60E-06	1.82E-06	1.14E-06	2.09E-05	1.87E-07	3.24E-03	**3.27E-03**
	Russell Lake Inlet	1.05E-05	1.20E-05	1.52E-06	2.05E-05	1.99E-07	3.41E-03	**3.45E-03**	1.55E-06	1.76E-06	1.13E-06	2.04E-05	1.83E-07	3.18E-03	**3.20E-03**
Mallard	Reference (Kratchkowsky Lake)	1.46E-05	1.66E-05	1.09E-05	7.92E-05	1.33E-06	2.66E-02	**2.67E-02**	1.46E-05	1.66E-05	1.09E-05	7.90E-05	1.28E-06	2.65E-02	**2.66E-02**
	Whitefish Lake (LA-5)	1.85E-04	2.11E-04	1.82E-05	9.24E-05	1.93E-06	3.88E-02	**3.93E-02**	1.79E-05	2.03E-05	1.12E-05	9.05E-05	1.47E-06	3.04E-02	**3.05E-02**
	McGowan Lake (LA-1)	1.22E-04	1.39E-04	1.61E-05	8.78E-05	1.54E-06	3.12E-02	**3.15E-02**	1.68E-05	1.91E-05	1.11E-05	8.71E-05	1.35E-06	2.80E-02	**2.81E-02**
	Russell Lake Inlet	9.31E-05	1.06E-04	1.49E-05	8.55E-05	1.45E-06	2.93E-02	**2.96E-02**	1.62E-05	1.84E-05	1.10E-05	8.50E-05	1.32E-06	2.74E-02	**2.75E-02**
American Robin	Reference (Kratchkowsky Lake)	4.34E-04	4.93E-04	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**3.84E-02**	4.34E-04	4.93E-04	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**3.84E-02**
	Whitefish Lake (LA-5)	6.70E-03	7.62E-03	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**5.18E-02**	5.70E-04	6.48E-04	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**3.87E-02**
	McGowan Lake (LA-1)	1.26E-03	1.43E-03	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**4.01E-02**	4.51E-04	5.14E-04	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**3.84E-02**
	Russell Lake Inlet	6.53E-04	7.43E-04	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**3.89E-02**	4.38E-04	4.99E-04	1.29E-05	1.28E-03	8.36E-06	3.62E-02	**3.84E-02**
Lesser Scaup	Reference (Kratchkowsky Lake)	2.37E-05	2.70E-05	2.25E-05	1.45E-04	3.17E-06	4.30E-02	**4.32E-02**	2.36E-05	2.68E-05	2.24E-05	1.44E-04	2.91E-06	4.27E-02	**4.29E-02**
	Whitefish Lake (LA-5)	3.19E-04	3.62E-04	3.85E-05	1.71E-04	4.47E-06	6.24E-02	**6.33E-02**	2.89E-05	3.28E-05	2.30E-05	1.65E-04	3.34E-06	4.90E-02	**4.93E-02**
	McGowan Lake (LA-1)	2.06E-04	2.34E-04	3.36E-05	1.61E-04	3.57E-06	5.02E-02	**5.08E-02**	2.71E-05	3.08E-05	2.29E-05	1.59E-04	3.07E-06	4.51E-02	**4.53E-02**
	Russell Lake Inlet	1.56E-04	1.78E-04	3.09E-05	1.57E-04	3.38E-06	4.72E-02	**4.77E-02**	2.62E-05	2.98E-05	2.28E-05	1.55E-04	3.01E-06	4.41E-02	**4.44E-02**

5.2.6 Uncertainties in Exposure Assessment

For the exposure assessment it was conservatively assumed that ecological receptors would be exposed to the maximum exposure concentrations at their location. The duration of exposure was assumed to be sufficient for each receptor to be in equilibrium with their environment. This resulted in conservatively high:

- direct exposure estimates for aquatic biota exposed to COPCs in water, and terrestrial plants and soil invertebrates exposed to COPCs in soil;
- predicted uptakes of COPCs by ecological receptors in the food chain; and
- estimated doses of COPCs to ecological receptors through the food chain.

The assumptions to address uncertainties in the exposure assessment are anticipated to produce conservative exposure estimates for ecological receptors. The risk that the exposure assessment underestimates potential exposure of ecological receptors to COPCs from the Project is low. That said, the following provides more detail about assessment uncertainty and how it was addressed.

5.2.6.1 Uncertainties in Uptake and Exposure Factors

Wildlife exposure factors, such as intake rates and diets, are a potential source of uncertainty. Reputable sources were used for these factors, and the factors are considered to be representative of the organisms assessed. Feed, water, and inhalation intake rates were obtained or calculated based on the following primary sources: Federal Contaminated Sites Action Plan (FCSAP, 2012; Sample and Suter, 1994; US EPA, 1993). These documents have undergone several stages of review and are considered appropriate literature values for use in this assessment; therefore, the uncertainty in these values is considered acceptable.

Bioaccumulation factors were used to calculate uptake into tissues (fish, invertebrates, plants). The BAFs were derived from regional biota and water data for a number of aquatic biota in this assessment. There is inherent uncertainty in using field data to calculate BAFs from metal concentrations in tissues of aquatic biota and surface water concentrations, because the actual exposure history of the organisms is unknown. Unless it is known that a metal concentration in surface water is at a steady state for an extended period of time, the use of tissue and water concentrations sampled at the same time from the same location may not reflect the average exposure of an organism. In addition, as a result of physiological control, intracellular storage and different excretion mechanisms, biota have an ability to actively regulate the body burden of many metals and maintain homeostatic control over a range of exposures (Chapman et al., 1996; Hamilton and Mehrle, 1986; Wood and Port, 2000). These homeostatic controls can produce a non-linear relationship between the steady-state tissue concentration and the environmental exposure (Newman and Unger, 2002). As a result, the validity of assuming a linear relationship between water and tissue concentrations is an area of uncertainty. In most cases it is difficult to assess whether non-linear relationships may exist; therefore, linear relationships are assumed by default (with the exception of selenium where a non-linear BAF was used). These complicating issues do not diminish the importance of BAFs in assessing the environmental hazard associated with metals.

5.2.6.2 Uncertainties in Dose Coefficients

Dose coefficients were obtained from reputable sources for reference organisms, but have not been derived specifically for all the organisms assessed. Dose coefficients for surrogate organisms were often used. They were selected with attention to similar body size and exposure habits and are believed to adequately represent the organism assessed. Dose coefficients for each receptor were not adjusted for body size and dimensions, which represents a possible source of uncertainty. For the maximum exposed receptors, the dose is primarily delivered through alpha emissions as over 95% of the dose can be attributed to polonium-210 in tissue. The geometry-scaling factor of alpha particles is 1 for all organisms and geometries; as such, geometry assumptions are expected to have very little effect on the total radiation dose.

5.3 Effects Assessment

5.3.1 Toxicological Benchmarks

For assessment of non-radiological COPCs, a TRV was used. A TRV is a toxicological index associating specific effects with a level of exposure to a chemical. The TRVs for aquatic biota are based on concentrations in water, while TRVs for mammals and birds are weight-normalized daily oral doses.

Arsenic, cadmium, chloride, chromium, cobalt, copper, molybdenum, selenium, sulphate, uranium, and zinc were identified as COPCs for further evaluation in the EcoRA for aquatic biota Arsenic, cadmium, chromium, cobalt, copper, molybdenum, selenium, uranium, and zinc were also evaluated in the EcoRA for terrestrial biota.

No COPCs in air were identified for further evaluation of potential risks for ecological health; therefore, TRVs for direct contact with air were not included in the toxicity assessment. Deposition of COPCs in dust to soil was evaluated; however, no COPCs in soil were identified for further evaluation; therefore, toxicity via direct contact with COPCs in soil for plants and soil invertebrates was not included in the toxicity assessment.

5.3.1.1 Toxicity Reference Values for Aquatic Biota

Water concentration-based TRVs for aquatic biota are based on chronic effects from long-term exposures. They are concentrations below which health risks to receptors are not anticipated. The TRVs were derived for aquatic biota in six categories: forage fish (lake whitefish), predator fish (northern pike), zooplankton, benthic invertebrates, phytoplankton, and aquatic plants.

The selected TRVs were 20% Effect Concentrations (i.e., EC_{20} values), which are concentrations at which only 20% of the test organisms respond. The EC_{20} value was preferred because 20% is near the level at which effects become statistically discernible or measurable in both laboratory and field studies (EC and HC, 2003; Suter, 1996), and therefore can be reliably reproduced.

However, chronic EC_{20} values are not always readily available; therefore, a protocol shown in Table 5-11 was established to derive chronic EC_{20} values from available data.

Table 5-11: Procedure for Adjusting Test Endpoints to Chronic 20% Effect Concentration

Test Endpoint [(a)]	Adjustment to Chronic EC_{20}
Chronic EC_{10}	Multiply by 2
Chronic EC_{25}	Multiply by 2/2.5
Chronic EC_{30}	Multiply by 2/3
Chronic EC_{50}	Multiply by 2/5
Chronic LC_{25}	Multiply by 0.5
Chronic LC_{50}	Divide by 4

a) IC endpoints were treated as EC endpoints.
EC = effect concentration; LC = lethal concentration; IC = inhibition concentration.

Toxicity data for effect endpoints involving growth, reproduction, and survival were selected because they are considered to be relevant to the persistence of aquatic populations. Chronic toxicity data were preferred, and acute data were only considered when chronic data were not sufficient (a minimum of 2 values required). If 20 or more chronic EC_{20} values were available in each taxonomic group, a 5th percentile of the EC_{20} values was used as a selected TRV. If there were less than 20 chronic EC_{20} values, the lowest EC_{20} was used as a selected TRV for the taxonomic category. Calculated values that fell below the CCME or provincial guideline were not considered appropriate as TRVs for aquatic biota and the CCME or provincial values were selected in their place. The selected TRVs for aquatic biota groups are summarized in Table 5-12. For aquatic TRVs that were based on the lowest chronic EC_{20} value, the reference is provided in Table 5-12.

In some cases, site-specific modifying factors (ambient conditions) may influence the toxicity of a chemical. For example, these modifying factors include water hardness for copper. In these cases, the TRV must be appropriate to the ambient condition.

The USEPA Ecotoxicology Database (ECOTOX) was generally used for the selection of TRVs for aquatic organisms. There were sufficient data available from ECOTOX to derive TRVs for arsenic, cadmium, copper and zinc. There were limited data available in the ECOTOX database pertaining to the effects of the other COPCs on aquatic biota. The TRVs for chloride and chromium were obtained from the CCME (CCME, 2011a, 2008). The TRVs for cobalt were selected from a recently published review of toxicological data (Stubblefield et al., 2020), in which a species sensitivity distribution approach was used. The TRVs for molybdenum were obtained from the Saskatchewan Water Quality Guideline (WSA, 2017). The TRVs for selenium in fish were estimated using the US EPA criteria of 11.3 mg/kg dw muscle (US EPA, 2021d) and converting to a water based TRV using a species-specific water to fish bioaccumulation factor. The TRVs for selenium for zooplankton and benthic invertebrates were the lowest observed ECs obtained from literature (Crane et al., 1992). The TRVs for sulphate were obtained from the BC MOE (BC MOE, 2013). The TRVs for uranium were derived from data available from toxicological reports (Liber et al., 2007; VST, 2004).

Table 5-12: Selected Toxicity Reference Values for Aquatic Biota

COPC	Biotic Group	TRV	Unit	Rationale	Data Source
Arsenic	Forage fish	0.123	mg/L	Lowest estimated chronic EC_{20} (survival)	ECOTOX (Birge et al., 1979)
	Predator fish	0.630	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=50)	ECOTOX
	Zooplankton	0.340	mg/L	Lowest estimated chronic EC_{20} (intoxication)	ECOTOX (May-Passino and Novak, 1987)
	Benthic invertebrates	0.122	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=27)	ECOTOX
	Phytoplankton	0.0192	mg/L	Lowest estimated chronic EC_{20} (growth)	ECOTOX (Vocke et al., 1980)
	Aquatic plants	0.252	mg/L	Lowest estimated chronic EC_{20} (population)	ECOTOX (Jenner and Janssen-Mommen, 1993)
Cadmium[(b)]	Forage Fish	0.00029	mg/L	5th percentile of estimated chronic EC_{20} (n=35)	ECOTOX
	Predator Fish	0.00036	mg/L	5th percentile of estimated chronic EC_{20} (n=73)	ECOTOX
	Zooplankton	0.00015	mg/L	5th percentile of estimated chronic EC_{20} (n=25)	ECOTOX
	Benthic Invertebrates	0.00048	mg/L	5th percentile of estimated chronic EC_{20} (n=49)	ECOTOX
	Phytoplankton	0.0025	mg/L	lowest estimated EC_{20} value	ECOTOX
	Aquatic Plants[(a)]	0.00763	mg/L	LOEC	ECOTOX (Sajwan and Ornes, 1994)
Chloride	Forage fish	693	mg/L	Chronic LOEC (survival)	(Birge et al., 1985; CCME, 2011a)
	Predator fish	989	mg/L	Chronic EC_{25} (reproduction)	(Beak International Inc, 1999; CCME, 2011a)
	Zooplankton	421	mg/L	Chronic EC_{25} (reproduction)	(CCME, 2011a; J. R. F. Elphick et al., 2011)
	Benthic invertebrates	421	mg/L	Chronic EC_{25} (growth)	(Bartlett, 2009; CCME, 2011a)
	Phytoplankton	6,066	mg/L	Chronic MATC (growth)	(CCME, 2011a; Kessler, 1974)
	Aquatic plants	3,150	mg/L	Chronic EC_{50} (population)	(Buckley et al., 1996; CCME, 2011a)
Chromium	Forage Fish	0.53	mg/L	Chronic value for the fathead minnow in hard water of 0.53 mg/L	(US EPA, 1985) cited in (CCME, 2008)
	Predator Fish	0.105	mg/L	60-day post hatch study with rainbow trout (*Oncorhynchus mykiss*)	(Sauter et al., 1976) cited in (CCME, 2008)
	Zooplankton	0.01	mg/L	Significant reduction in reproduction of Daphnia magna after 96-hours	(Trabalka and Gehrs, 1977) cited in (CCME, 2008)
	Benthic Invertebrates	2.2	mg/L	96-h LC_{50} with the mayfly (*Ephemerella subvaria*)	(CCME, 2008)
	Phytoplankton	0.02	mg/L	Photosynthesis inhibition in natural populations of river algae (*Chlorella pyrenoidosa, Chlamydomonas reinhardii*)	(Zarafonetis and Hampton, 1974) cited in (CCME, 2008)

COPC	Biotic Group	TRV	Unit	Rationale	Data Source
	Aquatic Plants	0.02	mg/L	TRV for phytoplankton used as surrogate for aquatic plants	
Cobalt	Forage fish	0.409	mg/L	Lowest chronic EC_{20} (survival)	(Stubblefield et al., 2020)
	Predator fish	2.495	mg/L	Lowest chronic EC_{20} (biomass)	(Stubblefield et al., 2020)
	Zooplankton	0.0111	mg/L	Lowest chronic EC_{20} (reproduction)	(Stubblefield et al., 2020)
	Benthic invertebrates	0.0176	mg/L	Lowest chronic EC_{20} (growth)	(Stubblefield et al., 2020)
	Phytoplankton	0.046	mg/L	Lowest estimated EC_{20} (growth)	(Stubblefield et al., 2020)
	Aquatic plants	0.0098	mg/L	lowest estimated EC_{20} (growth)	(Stubblefield et al., 2020)
Copper[b,c,d,f]	Forage fish	0.002	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=237)	ECOTOX
	Predator fish	0.003	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=89)	ECOTOX
	Zooplankton	*0.002*	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=117)	ECOTOX; CCME
	Benthic invertebrates	*0.002*	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=264)	ECOTOX; CCME
	Phytoplankton[a]	0.0092	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=101)	ECOTOX
	Aquatic plants[a]	0.038	mg/L	5th percentile of estimated chronic EC_{20} distribution (n=28)	ECOTOX
Molybdenum	Forage fish	31	mg/L	Saskatchewan Water Quality Guideline	(WSA, 2017)
	Predator fish	80	mg/L	lowest estimated EC_{20} value	ECOTOX; (Goettl et al., 1976; McConnell, 1977)
	Zooplankton	31	mg/L	Saskatchewan Water Quality Guideline	(WSA, 2017)
	Benthic invertebrates	31	mg/L	Saskatchewan Water Quality Guideline	(WSA, 2017)
	Phytoplankton	31	mg/L	Saskatchewan Water Quality Guideline	(WSA, 2017)
	Aquatic plants	31	mg/L	Saskatchewan Water Quality Guideline	(WSA, 2017)
Selenium[g]	Forage Fish	0.00063 842	mg/L	TRV for White Sucker was estimated using the US EPA (2021) criteria of 11.3 mg/kg dw muscle and converted to a waterbase TRV using a species-specific water to fish bioaccumulation factor of 4425 and a default dry content of 0.25.	(US EPA, 2021d)
	Predator Fish	0.00088 163	mg/L	TRV for Northern Pike was estimated using the US EPA (2021) criteria of 11.3 mg/kg dw muscle and	(US EPA, 2021d)

COPC	Biotic Group	TRV	Unit	Rationale	Data Source
				converted to a waterbase TRV using a species-specific water to fish bioaccumulation factor of 949 and a default dry content of 0.25.	
	Zooplankton	0.01	mg/L	LOEC	(Crane et al., 1992)
	Benthic Invertebrates	0.01	mg/L	LOEC	(Crane et al., 1992)
	Phytoplankton	0.0797	mg/L	5th percentile of estimated chronic EC_{20} (n=25)	ECOTOX
	Aquatic Plants	0.68	mg/L	lowest estimated EC_{20} value	ECOTOX; (Jenner and Janssen-Mommen, 1993)
Sulphate	Forage fish	2,999	mg/L	Lowest chronic EC_{25} (biomass)	(BC MOE, 2013); PESC data
	Predator fish	502	mg/L	Lowest chronic LC_{25} (survival)	(BC MOE, 2013); PESC data
	Zooplankton	425	mg/L	Lowest chronic EC_{25} (reproduction)	(BC MOE, 2013; J. R. Elphick et al., 2011)
	Benthic invertebrates	730	mg/L	Lowest chronic LC_{25} (survival)	(BC MOE, 2013); PESC data
	Phytoplankton	2,660	mg/L	Lowest chronic EC_{25} (cell yield)	(BC MOE, 2013; J. R. Elphick et al., 2011)
	Aquatic plants	2,310	mg/L	Lowest chronic EC_{10} (frond increase)	(BC MOE, 2013); PESC data
Uranium[(e)]	Forage fish	1.50	mg/L	Lowest estimated chronic EC_{20} (growth)	(Liber et al., 2007; VST, 2004)
	Predator fish	0.550	mg/L	Lowest estimated chronic EC_{20} (growth)	(Liber et al., 2007; VST, 2004)
	Zooplankton	0.060	mg/L	Lowest estimated chronic EC_{20} (growth)	(Liber et al., 2007; VST, 2004)
	Benthic invertebrates	0.027	mg/L	Lowest estimated chronic EC_{20} (growth)	(Liber et al., 2007; VST, 2004)
	Phytoplankton	0.440	mg/L	Geometric mean of 2 EC_{25} values	(Liber et al., 2007; VST, 2004)
	Aquatic plants	5.50	mg/L	Geometric mean of 2 EC_{25} values	(Liber et al., 2007; VST, 2004)
Vanadium	Forage Fish	0.08	mg/L	lowest chronic value for all aquatic organisms	(Suter and Tsao, 1996)
	Predator Fish	0.08	mg/L	lowest chronic value for all aquatic organisms	(Suter and Tsao, 1996)
	Zooplankton	1.9	mg/L	lowest chronic value for Daphnids	(Suter and Tsao, 1996)
	Benthic Invertebrates	0.08	mg/L	lowest chronic value for all aquatic organisms	(Suter and Tsao, 1996)
	Phytoplankton	0.08	mg/L	lowest chronic value for all aquatic organisms	(Suter and Tsao, 1996)
	Aquatic Plants	0.08	mg/L	lowest chronic value for all aquatic organisms	(Suter and Tsao, 1996)
Zinc[(b,d)]	Forage Fish	0.035	mg/L	Lowest estimated chronic EC_{20}	ECOTOX
	Predator Fish	*0.032*	mg/L	5th percentile of estimated chronic EC_{20} (n=39)	ECOTOX
	Zooplankton	*0.03*	mg/L	Lowest estimated chronic EC_{20}	ECOTOX

COPC	Biotic Group	TRV	Unit	Rationale	Data Source
	Benthic Invertebrates	*0.03*	mg/L	Lowest estimated chronic EC_{20}	ECOTOX
	Phytoplankton[(a)]	*0.03*	mg/L	5th percentile of estimated chronic EC_{20} (n=46)	ECOTOX
	Aquatic Plants	0.116	mg/L	Lowest estimated chronic EC_{20}	ECOTOX

a) Study specific hardness data was not available for the adjustment of TRVs.
b) The TRV is hardness dependent and is presented as dissolved metal in soft water (hardness of 25 mg $CaCO_3$/L).
c) Hardness dependent TRVs are presented for hardness of 25 mg $CaCO_3$/L and may be converted to reflect specific site hardness conditions using the equations presented.
d) The TRVs presented in italics are CCME guidelines used as a default when estimated TRVs are below the recommended guideline.
e) The TRVs are based on hardness of 60 mg/L, other than phytoplankton which is based on hardness of 120 mg/L.
f) Copper TRVs, calculated using the Federal Environmental Quality Guideline (FEQG) are included in Section 6.3.2.
g) Selenium TRVs for fish calculated using the Federal Environmental Quality Guideline (FEQG) are included in Section 6.3.1.EC_{XX} = effect concentration for XX% response; LOEC = lowest observed effect concentration; MATC = maximum acceptable toxicant concentration; $CaCO_3$ = calcium carbonate; TRV = toxicity reference value; PESC = Pacific Environmental Science Centre; CCME = Canadian Council of Ministers of the Environment.

5.3.1.1.1 Arsenic

The TRVs for arsenic were estimated chronic EC_{20} values that were selected based on EC_{50} and lethal concentration (LC_{50}) values obtained from the USEPA ECOTOX database (Table 5-12). The minimum adjusted EC_{20} value was selected as the TRV for aquatic plants, phytoplankton, zooplankton and forage fish. For benthic invertebrates and predator fish, the TRV was selected as the 5th percentile of the adjusted chronic EC20 values. The results suggest that phytoplankton, benthic invertebrates, and forage fish are the aquatic organisms most sensitive to arsenic exposure while predator fish are the least sensitive.

5.3.1.1.2 Cadmium

Water hardness can have a major influence on cadmium toxicity to aquatic biota. The toxicity data were adjusted to chronic EC_{20} and were hardness adjusted to soft water (hardness of 25 mg $CaCO_3$/L) with equations from the U.S. Geological Survey (USGS, 2006). According to the USGS (2006), the cadmium hardness-dependent criterion continuous concentration (CCC) can be calculated from the following:

$$CC = e^{0.6247 \times ln(hardness) - 3.384} \times (1.101672 - ln(hardness) \times 0.041838)$$

The second term in the equation above is a conversion factor (CF) which converts the total metal concentration to a dissolved metal concentration. For studies on chronic toxicity of cadmium to aquatic biota that reported the hardness of the water, H1 (in mg/L $CaCO_3$), the CCC for the hardness used in the study was calculated. The CCC values for two hardness levels provide a ratio that can be used to adjust an EC_{20} at the test hardness (H1) to an EC_{20} at some standard hardness (H2), which is relevant to the site, using the following relationship:

$$EC_{20}H2 = \frac{CCC_{H2}}{CCC_{H1}} \times EC_{20}H1$$

The lowest hardness adjusted chronic EC_{20} values are considered conservative and are deemed appropriate as TRVs at different hardness levels. Therefore, the TRVs for forage fish, predator fish, freshwater zooplankton, benthic invertebrates and phytoplankton are presented as dissolved cadmium in soft water with hardness of 25 mg $CaCO_3$/L (Table 5-12). No study specific hardness data were available for TRV adjustment for aquatic plants. A lower LOEC of 0.00763 mg/L for cadmium was applied based on a chronic study of duckweed growth (Sajwan and Ornes, 1994). The more conservative LOEC value is considered appropriate as the TRV for aquatic plants.

The results suggest that zooplankton is the aquatic organism most sensitive to cadmium exposure while aquatic plants are the least sensitive.

5.3.1.1.3 Chloride

Toxicity records were taken from data selected by CCME (CCME, 2011a) to derive the Canadian Water Quality Guideline value for the protection of freshwater aquatic life. The studies met the minimum primary or secondary requirements for data quality. No EC_{20} concentrations were available from the CCME data. Low effect levels including EC_{25}, LOEC, and maximum acceptable toxicant concentration were selected preferentially, and the lowest for each aquatic group were selected (Table 5-12). The results suggest that benthic invertebrates and zooplankton are the most sensitive to chloride exposure while phytoplankton are the least sensitive.

5.3.1.1.4 Chromium

Limited data were available in the USEPA ECOTOX database pertaining to the effects of chromium exposure on aquatic biota. The toxicity data for chromium was obtained from the CCME (CCME, 2008) which provides guidelines for the protection of freshwater aquatic life. Based on U.S. EPA data (US EPA, 1985) cited in CCME (CCME, 2008), the chronic value for the fathead minnow (*Pimephales promelas*) in hard water was selected as the TRV for forage fish. A maximum acceptable concentration of 0.105 mg/L based on a 60-day post hatch study with rainbow trout (*Oncorhynchus mykiss*) (Sauter et al., 1976) was selected as the TRV for predator fish. The TRV for zooplankton was based on the chromium exposure resulting in significant reduction in reproduction of *Daphnia magna* after 96-hours (Trabalka and Gehrs, 1977). The lowest 96-h LC_{50} value for mayfly (*Ephemerella subvaria*) was selected as the TRV for benthic invertebrates, without adjustment, based on CCME (CCME, 2008). The TRVs for phytoplankton and aquatic plants were selected based on the chromium concentration at which the photosynthesis in natural populations of river algae (*Chlorella pyrenoidosa, Chlamydomonas reinhardii*) was inhibited (Zarafonetis and Hampton, 1974).

The results suggest that zooplankton, phytoplankton and aquatic plants are the aquatic organisms most sensitive to chromium exposure while benthic invertebrates are the least sensitive.

5.3.1.1.5 Cobalt

The TRVs for cobalt are chronic EC_{20} values for aquatic animal groups and estimated chronic EC_{20} values for aquatic plant groups from (Stubblefield et al., 2020). Stubblefield et at. (2020) conducted a series of acute and chronic toxicity tests with the primary objective to generate data needed to derive international water quality guidelines for cobalt based on USEPA and European Union requirements. Early life stage tests were conducted on three fish species, one zooplankton species, three aquatic invertebrate species, one alga, and one aquatic macrophyte. The study produced chronic EC_{20} values for the aquatic animal species and chronic EC_{10} values for aquatic plants. The TRVs for phytoplankton and aquatic plants were derived from EC_{10} values using a factor of 2 to adjust to an EC_{20} (Table 5-12). The results suggest that zooplankton, benthic invertebrates, and macrophytes are among the most sensitive to cobalt and fish is the least sensitive.

5.3.1.1.6 Copper

The TRVs for copper for forage fish, predator fish, phytoplankton, and aquatic plants are estimated chronic EC_{20} values. They were estimated based on EC_{10}, EC_{25}, EC_{30}, EC_{50}, LC_{25}, LC_{50}, inhibition concentration (IC_{10}), IC_{25}, and IC_{50} values obtained from the USEPA ECOTOX database. In the case of zooplankton and benthic invertebrates, the derived TRVs were lower than the existing CCME guideline values; therefore, the CCME values were selected as the TRVs because the CCME guidelines are considered protective of all life forms of aquatic species in Canada.

According to the U.S. EPA (US EPA, 2007a), the copper hardness-dependent criterion continuous concentration (CCC) can be calculated from the following:

$$CCC = e^{0.8545 \times ln(hardness) - 1.702} \times 0.96$$

A conversion factor of 0.96 was used to convert the total mean concentration of copper to a dissolved copper concentration. The selected TRVs are summarized in Table 5-12 for dissolved copper in soft water conditions (hardness of 25 mg $CaCO_3$/L) using the same equation describing the relationship of the CCC values for two hardness levels which is discussed above for cadmium TRV adjustment. No study specific hardness data was available for TRV adjustment for phytoplankton and aquatic plants.

The EC_{20} values derived for copper, based on a hardness of 25 mg $CaCO_3$/L, were compared to the CCME water quality guidelines for the same hardness condition prior to selecting the appropriate TRVs (Table 5-12). The results suggest that zooplankton, benthic invertebrates, forage fish, and predator fish are the aquatic organisms most sensitive to copper exposure while aquatic plants are the least sensitive.

Additional copper TRVs, calculated using the Federal Environmental Guideline (FEQG), are included in Section 6.3.2.

5.3.1.1.7 Molybdenum

For forage fish, zooplankton, benthic invertebrates, phytoplankton, and aquatic plants, the Saskatchewan Water Security Agency water quality objective (WQO) for the protection of aquatic life (WSA, 2017) was selected as the TRV for molybdenum. The WQO is based on current understanding of aquatic toxicity of molybdenum to fresh-water aquatic organisms as discussed in Section 3.1.1. The TRV for predator fish is the lowest of three estimated chronic EC_{20} values, derived from LC_{50} values for rainbow trout (*Oncorhynchus mykiss),* obtained from the USEPA ECOTOX database. The selected TRV is from (Goettl et al., 1976) and was republished in 1977 by McConnell (McConnell, 1977), who provided detailed documentation as to the methods used to generate the data (cited in (Tetra Tech Inc., 2008)).

5.3.1.1.8 Selenium

The TRVs for selenium for fish were estimated using the US EPA criteria of 11.3 mg/kg dw muscle (US EPA, 2021d) and converting to a water based TRV using a species-specific water to fish bioaccumulation factor. The LOEC of 0.01 mg/L based on multi-generational mesocosm studies (Crane et al., 1992) is recommended as the TRV for zooplankton and benthic invertebrates. There were 25 chronic toxicity records for phytoplankton obtained from the USEPA ECOTOX database. The 5^{th} percentile of estimated chronic EC_{20} values (derived from EC_{50} values) is deemed appropriate as a TRV for freshwater phytoplankton. The lowest estimated chronic EC_{20} for aquatic plants is derived from EC_{50} values based on a 14-day laboratory test on duckweed (Jenner and Janssen-Mommen, 1993). The results suggest that forage fish and predator fish are the aquatic organisms most sensitive to selenium exposure while aquatic plants are the least sensitive.

Additional selenium TRVs were considered for whole body fish and egg-ovary using the ECCC (2022) published FEQG in Section 6.3.1.

5.3.1.1.9 Sulphate

Toxicity records were taken from data selected by the British Columbia Ministry of Environment (BC MOE, 2013) to derive British Columbia's Ambient Water Quality Guideline value for sulphate for the protection of freshwater aquatic life. The BC MOE used data from the Pacific Environmental Science Centre and Dr. Chris Kennedy (Simon Fraser University) and Elphick et al. ((J. R. Elphick et al., 2011)). The tests selected by BC MOE were conducted over a range of hardness levels. The BC MOE determined that, though dose-response curves of many organisms were influenced by water hardness, a consistent relationship among the species could not be established. The selected TRVs are LC_{25} or EC_{25} values, except for the aquatic plant TRV, which is an EC_{10} value (Table 5-12). The results suggest that aquatic animals are generally more sensitive to sulphate exposure than aquatic plants.

5.3.1.1.10 Uranium

Limited data were available in the USEPA ECOTOX database pertaining to the effects of uranium exposure on aquatic biota. Data were instead obtained from two reports (Liber et al., 2007; VST, 2004) that investigated the toxicity of uranium to aquatic biota in Northern Saskatchewan. The TRVs for uranium are all estimated chronic EC_{20} values, derived from EC_{25}, EC_{50} and LC_{25}, LC_{50}, IC_{25}, and IC_{50} values.

While uranium speciation and toxicity in fresh water are strongly determined by water characteristics such as hardness, pH, and temperature, the CCME (CCME, 2011b) does not consider that there is sufficient information available to quantitatively evaluate the influence of these factors. Therefore, the CCME recommends a water quality guideline for uranium that is not hardness dependent. The TRVs in Table 5-12 are therefore considered appropriate for use across a range of hardness and may be conservative for hard water environments because they were derived from tests conducted under soft water conditions (water hardness of 60 mg $CaCO_3$/L),except for phytoplankton which was based on a study using water hardness of 120 mg/L. The results suggest that zooplankton and benthic invertebrates are more sensitive to uranium exposure, and phytoplankton and aquatic plants are less sensitive.

5.3.1.1.11 Vanadium

Limited data were available in the USEPA ECOTOX database pertaining to the effects of vanadium exposure on aquatic biota. The toxicity data for vanadium was obtained from a report that recommends toxicological benchmarks for screening COPCs for effects on aquatic biota (Suter and Tsao, 1996). Based on the recommendation by Suter and Tsao (1996), the lowest chronic value for Daphnids was selected as the vanadium TRV for zooplankton, and the lowest chronic value for all aquatic organisms was conservatively selected as the vanadium TRV for the other aquatic groups.

5.3.1.1.12 Zinc

The TRVs for zinc were the lowest or 5th percentile of estimated chronic EC_{20} values, which were based on EC_{50} and LC_{50} values obtained from the USEPA ECOTOX database (Table 5-12).

Hardness is known to affect zinc toxicity. An increase in hardness results in a decrease in zinc toxicity. For zinc, the effect of hardness on fish toxicity may be due to changes in fish gills rather than metal speciation. According to the U.S. EPA, the zinc hardness-dependent criterion continuous concentration (CCC) can be calculated from the following:

$$CCC = e^{0.8473 \times ln(hardness) + 0.884} \times 0.986$$

A conversion factor of 0.986 was used to convert the total mean concentration of zinc to a dissolved zinc concentration. The selected TRVs are summarized in Table 5-12 for dissolved copper in soft water conditions (hardness of 25 mg $CaCO_3$/L) using the same equation describing the relationship of the CCC values for two hardness levels which is discussed above for cadmium TRV adjustment. No study specific hardness data were available for TRV adjustment for phytoplankton.

In the case of predator fish, zooplankton, benthic invertebrates and phytoplankton, the derived TRVs were lower than the existing CCME guideline values; therefore, the CCME values were selected as the TRVs because the CCME guidelines are considered protective of all life forms of aquatic species in Canada.

5.3.1.2 Toxicity Reference Values for Terrestrial Biota

Chronic dose-based TRVs for non-radiological COPCs were derived for birds and mammals based on endpoints (i.e., growth and reproduction) considered relevant for assessing the health of wildlife populations. Lowest observed adverse effect levels (LOAEL) were selected for each COPC. The LOAEL is the lowest exposure level at which the response of a test species in a toxicity study was statistically discernible. The LOAELs were used in the ERA to identify a threshold of exposure below which adverse effects are not expected. Exceeding a LOAEL does not mean that effects would necessarily occur; rather, it means that effects may occur. Particularly in large populations, localized effects on a few individuals can be compensated such that there is no discernible effect on the population as a whole.

The selected TRVs, shown in Table 5-13, are chronic daily intakes that are not expected to cause adverse effects to a particular ecological receptor. Where the TRV is based a single LOAEL, the specific reference is provided in Table 5-14 to Table 5-23.

Toxicity data for bird and mammal species were preferentially selected from the USEPA ecological soil screening levels (Eco-SSL) database (US EPA, 2005a). There were no data available in the USEPA Eco-SSL database pertaining to the effects of uranium exposure, so TRVs were derived from data available in toxicological reports previously used in risk assessments for uranium mines in northern Saskatchewan. Toxicity reference values were derived from the selected data for several test species of avian and mammalian wildlife. When possible, a test species was selected with a close taxonomic relationship to the ecological receptor in the risk assessment, such as within the same order, family, genus, or species. If there were several potential test species relevant to an ecological receptor, consideration was given to similar diet and body size. A sensitive test species of the same class was selected to represent an ecological receptor when no data were available for species with a closer taxonomic relationship.

Table 5-13: Selected Toxicity Reference Values for Terrestrial Biota

Ecological Receptor	Constituent of Potential Concern (mg/kg/d)									
	Arsenic	Cadmium	Chromium	Cobalt	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Mammals										
Black bear	3.1	103	91.1	13.4	11.5	2.6	0.21	5.6	2.18	35
Woodland caribou	14.4	5.7	91.1	13.4	1.5	4.1	0.33	5.6	2.18	76
Snowshoe hare	3.0	0.9	91.1	13.4	45.7	30.0	0.21	5.6	2.18	35
Lynx	3.1	103	91.1	13.4	11.5	2.6	0.21	5.6	2.18	35
Mink	3.1	103	91.1	13.4	11.5	2.6	0.21	5.6	2.18	35
Moose	14.4	5.7	91.1	13.4	1.5	4.1	0.33	5.6	2.18	76
Muskrat	14.2	6.8	91.1	13.4	119	3.8	0.63	5.6	2.18	249
Meadow vole	20.7	1.9	91.1	27.9	296	2.6	0.77	5.6	2.18	4395
Birds										
Bald eagle	3.6	4.4	75.4	14.1	27.0	20.8	0.68	16	0.49	123
Common loon	3.6	4.4	75.4	14.1	27.0	20.8	0.59	16	0.49	123
Mallard	5.1	25.6	2.8	14.1	75.2	20.8	1.29	16	0.49	63
Canada goose	3.6	4.4	75.4	14.1	27.0	20.8	0.59	16	0.49	123
Olive-sided Flycatcher	3.6	4.4	75.4	14.1	27.0	20.8	0.59	16	0.49	123
American Robin	3.6	4.4	75.4	14.1	27.0	20.8	0.59	16	0.49	123
Scaup	5.1	25.6	2.8	14.1	75.2	20.8	1.29	16	0.49	63

5.3.1.2.1 Arsenic

A summary of the TRVs selected for mammalian and avian species for arsenic is shown in Table 5-14.

Mammalian Toxicity Reference Values

Data for growth and reproduction for mammalian species were obtained from the Eco-SSL document for arsenic exposure (US EPA, 2005b). The data were based on a total of 14 LOAEL values from studies with dogs, goats, guinea pigs, mice, pigs, rabbits, and rats. The geometric means of the LOAELs within species ranged from 0.84 mg/kg/d for a guinea pig to 20.7 mg/kg/d for a mouse. Each of the species mean values of LOAEL can be considered as a TRV for arsenic for other mammals. In the event that a species has no closely related test species, the second lowest LOAEL value of 3.0 mg/kg/d for rabbit and dog can be used as a conservative default for the arsenic TRV. Although this LOAEL is not the minimum of the species LOAELs, it was selected over the minimum LOAEL of 0.84 mg/kg/d for guinea pig because the latter value was essentially at the same level as the minimum NOAEL from the same dataset. Of the total 14 LOAEL values used to derive the species LOAELs only two are below 3.0 mg/kg/d. As such, the LOAEL of 3.0 mg/kg/d was selected as the default LOAEL as it is more representative of the LOAEL data overall.

Avian Toxicity Reference Values

Data for growth and reproduction for avian species were obtained from the Eco-SSL document for arsenic exposure (US EPA, 2005b). The document was based on studies with chickens and ducks. After review of the data, two LOAEL values were retained for ducks and one was retained for chicken. The selected avian TRVs are 3.6 mg/kg/d for chickens based on a single LOAEL value, and 5.1 mg/kg/d for ducks based on the geometric mean of two LOAEL values.

Table 5-14: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Arsenic

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Dog (*Canis familiaris*)	3.1	Geometric mean of two LOAELs for the species
Goat (*Capra hircus*)	14.4	Geometric mean of two LOAELs for the species
Guinea pig (*Cavia porcellus*)	0.84	Single LOAEL for the species (Hunder et al., 1999)
Mouse (*Mus musculus*)	20.7	Geometric mean of three LOAELs for the species
Pig (*Sus scrofa*)	9.4	Single LOAEL for the species (Morrison and Chavez, 1983)
Rabbit (*Oryctolagus cuniculus*)	3.0	Single LOAEL for the species (Nemec et al., 1998)
Rat (*Rattus norvegicus*)	14.2	Geometric mean of four LOAELs for the species
Bird		
Mallard duck (*Anas platyrhynchos*)	5.1	Geometric mean of two LOAELs for the species
Chicken (*Gallus* sp.)	3.6	Single LOAEL for the species (Howell and Hill, 1978)

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.2 Cadmium

A summary of the TRVs selected for mammalian and avian species for cadmium is shown in Table 5-15.

Mammalian Toxicity Reference Values

There were 7 mammal species represented in the Eco-SSL database with growth or reproduction endpoints, and with LOAEL only or LOAEL plus NOAEL reported (US EPA, 2005c). The species mean values of NOAELs were in the range of 0.45 mg/kg/day for sheep to 4.05 mg/kg/day for pig. The species mean values of LOAELs were in the range of 0.9 mg/kg/day for sheep to 103 mg/kg/day for shrew. Each of the species mean values of LOAEL (Table 5-15) can be used as a surrogate TRV for other similar species in ecological risk assessment. If none of the test species are similar to the wildlife species of interest, the lowest LOAEL of 0.9 mg/kg/day can be used as a conservative default mammalian TRV for cadmium.

Avian Toxicity Reference Values

There were 3 species of birds represented in the Eco-SSL database with growth and reproduction endpoints, and with only LOAELs or paired LOAELs and NOAELs reported (US EPA, 2005c). A geometric mean of NOAEL or LOAEL was calculated for each species. Each of the species mean values of LOAEL (Table 5-15) can be used as a surrogate TRV for other similar species in ecological risk assessment. If none of the test species are similar to species of interest, the minimum LOAEL of 4.38 mg/kg/day can be used as a conservative default avian TRV for cadmium.

Table 5-15: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Cadmium

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Bank vole *(Microtus* sp)	1.9	Single LOAEL for the species (Swiergosz et al., 1998)
Shrew (*Sorex araneus*)	103	Single LOAEL for the species (Dodds-Smith et al., 1992)
Pig (*Sus scrofa*)	10.5	Geometric mean of four LOAEL for the species
Rat (R*attus norvegicus*)	6.8	Geometric mean of fifty-one LOAEL for the species
Sheep (*Ovis aires*)	0.9	Single LOAEL for the species (Doyle et al., 1974)
Cattle (*Bos taurus*)	5.7	Single LOAEL for the species (Lynch et al., 1976)
Mouse (*Mus musculus*)	9.6	Geometric mean of ten LOAEL for the species
Bird		
Chicken (*Gallus sp*)	4.4	Geometric mean of nineteen LOAEL for the species
Japanese Quail (*Coturnix japonica*)	11.3	Geometric mean of five LOAEL for the species;
Mallard (*Anas platyrhynchos*)	25.6	Geometric mean of three LOAEL for the species

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.3 Chromium

A summary of the TRVs selected for mammalian and avian species for trivalent chromium is shown in Table 5-16.

Mammalian Toxicity Reference Values

Data for reproduction for one mammalian species was obtained from the Eco-SSL document for chromium exposure (US EPA, 2005d). A single NOAEL value was provided, based studies with the mouse.

Avian Toxicity Reference Values

Data for reproduction for two avian species were obtained from the Eco-SSL document for chromium exposure (US EPA, 2005d). Two LOAEL values were provided, based on studies with chicken and duck, respectively.

Table 5-16: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Chromium

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Mouse (*Mus musculus*)	91.1	Single NOAEL for the species (Elbetieha and Al-Hamood, 1997)
Bird		
Black Duck *(Anas rubripes)*	2.8	Single LOAEL for the species (Haseltine et al., 1986)
Chicken (*Gallus sp*)	75.4	Single LOAEL for the species (Meluzzi et al., 1996)

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.4 Cobalt

A summary of the TRVs selected for mammalian and avian species for cobalt is shown in Table 5-17.

Mammalian Toxicity Reference Values

Two mammal species were represented in the Eco-SSL database with growth or reproduction endpoints and with LOAEL values reported (US EPA, 2005e). The species geometric mean values of LOAELs ranged from 13 mg/kg/d for rat to 28 mg/kg/d for mouse, from 6 and 7 LOAEL values respectively.

Avian Toxicity Reference Values

Data for growth and reproduction for avian species were obtained from the Eco-SSL database for cobalt exposure (US EPA, 2005a). The document was based on studies with chickens and ducks. Eight LOAEL values were retained for chicken and no LOAELs were retained for ducks because the LOAEL value was associated with high mortality. The selected avian TRV is 14 mg/kg/d for chickens based on the geometric mean of eight LOAEL values.

Table 5-17: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Cobalt

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Mouse (*Mus musculus*)	27.9	Geometric mean of six LOAELs for the species
Rat (*Rattus norvegicus*)	13.4	Geometric mean of seven LOAELs for the species
Bird		
Chicken (*Gallus* sp.)	14.1	Geometric mean of eight LOAELs for the species

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.5 Copper

A summary of the TRVs selected for mammalian and avian species for copper is shown in Table 5-18.

Mammalian Toxicity Reference Values

The mammalian data for growth and reproduction were obtained from the data presented in the Eco-SSL document for copper exposure (US EPA, 2007b). The data were based on studies with goats, minks, mice, pigs, rabbits, rats, and sheep. The TRVs for goat, rabbit, and sheep are each based on a single LOAEL value. The TRVs for mink, mouse, pig, and rat are geometric means of the LOAEL data for each test species. For rats, the geometric mean of the NOAEL values was larger than the geometric mean of the LOAEL values, due to the larger dataset for the LOAEL values. For this species, the LOAEL was therefore derived only from the studies that had both LOAEL and NOAEL values. The geometric mean of the LOAELs ranged from 1.47 mg/kg/d for a goat to 296 mg/kg/d for a mouse. In the event that a species had no closely related test species, the LOAEL of 8.8 mg/kg/d for pig was used as the default mammalian TRV. It is not the lowest LOAEL; however, it can be used as the default mammalian TRV as it is the lowest species LOAEL above the lowest NOAEL from the same dataset.

Avian Toxicity Reference Values

The avian data for growth and reproduction were obtained from the data presented in the Eco-SSL document for copper exposure (US EPA, 2007b). The data were based on studies with chickens, ducks, and turkeys. The geometric means of the LOAELs within species were selected to serve as the TRVs. The geometric means of the LOAELs for chickens, ducks, and turkeys were 34.9 mg/kg/d, 75.2 mg/kg/d, and 27 mg/kg/d respectively, based on 78, 3, and 9 LOAEL values, respectively. These values were used as TRVs for other similar species in the EcoRA.

Table 5-18: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Copper

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Goat (*Capra hircus*)	1.5	Single LOAEL for the species (Solaiman et al., 2001)
Mink *(Neovison vison*)	11.5	Geometric mean of two LOAELs for the species
Mouse (*Mus musculus*)	296	Geometric mean of five LOAELs for the species
Pig (*Sus scrofa*)	8.8	Geometric mean of four LOAELs for the species
Rabbit (*Oryctolagus cuniculus*)	45.7	Single LOAEL for the species (Grobner et al., 1986)
Rat (*Rattus norvegicus*)	119	Geometric mean of five LOAELs for the species
Sheep (*Ovis aires*)	3.0	Single LOAEL for the species (Ortolani et al., 2003)
Bird		
Chicken (*Gallus* sp.)	34.9	Geometric mean of 78 LOAELs for the species
Duck (*Anas platyrhynchos*)	75.2	Geometric mean of three LOAELs for the species
Turkey (*Meleagris gallopavo*)	27.0	Geometric mean of nine LOAELs for the species

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.6 Molybdenum

A summary of the TRVs selected for mammalian and avian species for molybdenum is shown in Table 5-19.

Mammalian Toxicity Reference Values

The selected TRVs for mammals are from studies with reported LOAEL values for growth and reproduction endpoints. Relevant LOAEL values for molybdenum were obtained from literature for four mammal species: rabbit (*Oryctolagus cunculus*), mouse (*Mus musculus*), cow (*Bos taurus*), and rat (*Rattus norvegicus*). The TRVs for rabbit, mouse, and cow are based on one LOAEL value and the TRV for rat is the geometric mean of two LOAEL values. The TRVs range from 2.6 mg/kg/d for a mouse to 30 mg/kg/d for a rabbit. In the event that a species had no closely related test species, the LOAEL of 2.6 mg/kg/d for the mouse was used as the default mammalian TRV.

Avian Toxicity Reference Values

The selected TRVs for birds are from studies with reported LOAEL values for growth and reproduction endpoints. Relevant LOAEL values for molybdenum were obtained from literature for two avian species: chicken (*Gallus* sp.) and turkey (*Meleagris gallopavo*). The TRV for chicken is the geometric mean of three LOAEL values and the TRV for turkey is based on one LOAEL value from Underwood (1971). The TRVs range from 21 mg/kg/d for a turkey to 39 mg/kg/d for a chicken. In the event that a species had no closely related test species, the LOAEL of 21 mg/kg/d for turkey was used as the default avian TRV.

Table 5-19: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Molybdenum

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Rabbit (*Oryctolagus cunculus*)	30	Single LOAEL for the species (Arrington and Davis, 1953)
Mouse (*Mus musculus*)	2.6	Single LOAEL for the species (Schroeder and Mitchener, 1971)
Cow (*Bos taurus*)	4.1	Single LOAEL for the species (Thomas and Moss, 1951)
Rat (*Rattus norvegicus*)	3.8	Geometric mean of two LOAELs for the species
Bird		
Chicken (*Gallus domesticus*)	38.6	Geometric mean of three LOAELs for the species
Turkey (*Melagris gallopavo*)	20.8	Single LOAEL for the species (Underwood, 1971)

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.7 Selenium

A summary of the TRVs selected for mammalian and avian species for selenium is shown in Table 5-20.

Mammalian Toxicity Reference Values

There were seven mammal species represented in the Eco-SSL database with growth or reproduction endpoints, and with LOAEL only or LOAEL plus NOAEL reported (US EPA, 2007c). The species mean values of NOAELs were in the range of 0.17 mg/kg/day for cattle and pig to 0.93 mg/kg/day for mouse. The species mean values of LOAELs were in the range of 0.21 mg/kg/day for dog to 1.53 mg/kg/day for mouse. Each of the species mean values of LOAEL (Table 5-20) can be used as a surrogate TRV for other similar species in ecological risk assessment. If none of the test species are similar to the wildlife species of interest, the lowest LOAEL of 0.21 mg/kg/day can be used as a conservative default mammalian TRV for selenium.

Avian Toxicity Reference Values

Five species of birds are represented in the Eco-SSL database with growth and reproduction endpoints, and with LOAEL only or paired LOAEL and NOAEL reported(US EPA, 2007c). A geometric mean of NOAEL or LOAEL for the records relating to growth and reproduction endpoints was calculated for each species. The geometric means of NOAEL were 0.36 and 1.18 mg/kg/day for chicken and mallard, respectively. The geometric means of LOAELs were in a range of 0.59 mg/kg/day for chicken to 4.49 mg/kg/day for owl. Each of the species mean values of LOAEL (Table 5-20) can be used as a surrogate TRV for other similar species. If none of the test species are similar to species of interest, the lowest LOAEL of 0.59 mg/kg/day can be used as a conservative default avian TRV for selenium.

Table 5-20: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Selenium

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Cattle (*Bos taurus*)	0.33	Single LOAEL for the species (Jenkins and Hidiroglou, 1986)
Dog (*Canis familiaris*)	0.21	Single LOAEL for the species (Rhian and Moxon, 1943)
Hamster (*Mesocricetus auratus*)	0.77	Geometric mean of seven LOAEL for the species
Mouse (*Mus musculus*)	1.53	Geometric mean of twenty-three LOAEL for the species
Pig (*Sus scrofa*)	0.33	Geometric mean of twenty-one LOAEL for the species
Pronghorn (*Antilocapra americana*)	0.49	Single LOAEL for the species (Raisbeck et al., 1996)
Rat (*Rattus norvegicus*)	0.63	Geometric mean of sixty-nine LOAEL for the species
Bird		
Black-crowned night-heron (*Nycticorax nycticorax*)	0.68	Single LOAEL for the species (Smith et al., 1988)
Chicken (*Gallus sp*)	0.59	Geometric mean of thirty-two LOAEL for the species
Japanese Quail (*Coturnix japonica*)	0.75	Geometric mean of six LOAEL for the species
Mallard (*Anas platyrhynchos*)	1.29	Geometric mean of twenty LOAEL for the species
Owl (*Megascops asio*)	4.49	Single LOAEL for the species (Wiemeyer and Hoffman, 1996)

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.8 Uranium

A summary of the TRVs selected for mammalian and avian species for uranium is shown in Table 5-21.

Mammalian Toxicity Reference Values

There is no Eco-SSL document for uranium. Previous risk assessments have used TRVs for mammalian exposure to uranium derived from Oak Ridge National Laboratory (ORNL) data (Sample et al., 1996). The Sample et al. (1996) data for mammalian species were based on a study by (Paternain et al., 1989) related to reproduction in mice. Sample et al. derived a LOAEL of 6.13 mg/kg/d from the study. The TRV quoted by the authors contains a small unit conversion error. Instead of 6.13 mg/kg/d as reported, the value should be 5.6 mg/kg/d. The difference arises from Sample's use of uranyl acetate molecular weight rather that uranyl acetate dehydrates molecular weight in converting the molecular dose to uranium dose. The correct value (5.6 mg/kg/d) can be found in the ATSDR toxicity profile for uranium. It represents the oral dose (to parents) at which viability of F1 offspring was reduced. Since the LOAEL value from (Paternain et al., 1989) is the only mammalian data available, this LOAEL value of 5.6 mg/kg/d was selected for evaluating uranium toxicity to mammalian species.

Avian Toxicity Reference Values

No data were available in the Eco-SSL database related to uranium exposure in avian species. Previous risk assessments used TRVs for avian exposure to uranium derived from the ORNL data (Sample et al., 1996). The data were based on a previous study (Haseltine and Sileo, 1983) describing mortality, body weight, liver, and kidney effects in ducks; Sample et al. derived a NOAEL of 16 mg/kg/d, but no LOAEL from the study. There are no other avian data available for uranium. The study used powdered metallic uranium. Uranium in this form would likely be oxidized to ionic form in the gut since uranium is strongly reducing in aqueous systems (Durante and Pugliese, 2002). Uranium in the environment similarly exists in an oxidized ionic form. Solubility differences among ionic forms in the gut can be bounded. The ICRP (ICRP, 1994) has determined that some oxidized species in the gut may be an order of magnitude less soluble than the most soluble species. Any reduced solubility in the gut would be offset by the fact that a NOAEL value is used in the absence of a LOAEL value. Since the NOAEL value (Haseltine and Sileo, 1983) is the only avian data available, this NOAEL value of 16 mg/kg/d was selected as the TRV for evaluating uranium toxicity to avian species.

Table 5-21: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Uranium

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Mouse *(Mus musculus)*	5.6	(Paternain et al., 1989), from (Sample et al., 1996)
Bird		
Black duck (*Anas rubripes*)	16	(Haseltine and Sileo, 1983), from (Sample et al., 1996)

TRV = toxicity reference value.

5.3.1.2.9 Vanadium

A summary of the TRVs selected for mammalian and avian species for vanadium is shown in Table 5-22.

Mammalian Toxicity Reference Values

The data for Mammalian species were obtained from the data presented in the Eco-SSL document for vanadium exposure (US EPA, 2005f). The selected TRVs for mammals are from studies with rat with reported LOAEL values for reproduction endpoints.

Avian Toxicity Reference Values

The data for avian species were obtained from the data presented in the Eco-SSL document for vanadium exposure (US EPA, 2005f). The selected TRVs for avian species are from studies with chickens with reported LOAEL values for growth endpoints.

Table 5-22: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Vanadium

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Rat (*Rattus norvegicus*)	2.18	Single LOAEL for the species (Domingo et al., 1986)
Bird		
Chicken (*Gallus sp*)	0.49	Single LOAEL for the species (Phillips et al., 1982)

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.1.2.10 Zinc

A summary of the TRVs selected for mammalian and avian species for zinc is shown in Table 5-23.

Mammalian Toxicity Reference Values

The data for growth and reproduction for mammalian species were obtained from the data presented in the Eco-SSL document for zinc exposure (US EPA, 2007d). The data were based on studies with cattle, mice, pigs, rats and sheep; these species served as the surrogates for mammalian wildlife. The geometric means of the NOAEL and LOAEL data were calculated for each surrogate species. The geometric mean of the NOAELs ranged from 15.5 mg/kg/day for a pig to 585 mg/kg/day for a mouse. The geometric mean of the LOAELs ranged from 35 mg/kg/day for sheep to 4,395 mg/kg/day for a mouse. Each of the species mean values of LOAEL (Table 5-23) can be used as a surrogate TRV for other similar species in ecological risk assessment. In the event that none of the species are similar, the lowest LOAEL of 35 mg/kg/day can be used as a conservative default for the zinc TRV for mammals.

Avian Toxicity Reference Values

The data for growth and reproduction for avian species were obtained from the data presented in the Eco-SSL document for zinc exposure (US EPA, 2007d). The data were based predominantly on studies with chickens, with some studies with Japanese quails, mallard ducks and turkeys; these four species served as the surrogates for avian wildlife. The geometric means of the LOAEL and NOAEL data were calculated for each species. None of the studies for ducks presented in the Eco-SSL document reported both LOAEL and NOAEL data; therefore, no NOAEL for ducks was calculated. The geometric means of the NOAELs ranged from 61 mg/kg/day for a Japanese quail to 148 mg/kg/day for a turkey, and the geometric means of the LOAELs ranged from 63 mg/kg/day for a duck to 297 mg/kg/day for a turkey. Each of the geometric mean values of LOAEL for zinc (Table 5-23) can be used as a surrogate TRV for other similar species. In the event that none of the species are similar, the LOAEL of 123 mg/kg/day can be selected as the default TRV for avian species. The minimum LOAEL of 63 mg/kg/day was not selected as the default TRV because this value is equivalent to the minimum NOAEL of 61 mg/kg/day. Of the 52 LOAEL values obtained from the Eco SSL data, only 12 (i.e., 23%) are below 100 mg/kg/day. Additionally, the minimum LOAEL is less than half of the LOAEL value derived by Sample et al. (Sample et al., 1996), therefore it was not selected as the default TRV.

Table 5-23: Summary of Selected Toxicity Reference Values for Mammal and Bird Test Species – Zinc

Test Species	TRV (mg/kg/d)	Rationale
Mammal		
Cattle (*Bos taurus*)	76	Single LOAEL for the species (Miller et al., 1989)
Mouse (*Mus musculus*)	4395	Geometric mean of five LOAEL for the species
Pig (*Sus scrofa*)	90	Geometric mean of four LOAEL for the species
Rat (*Rattus norvegicus*)	249	Geometric mean of seventeen LOAEL for the species
Sheep (*Ovis aries*)	35	Geometric mean of two LOAEL for the species
Bird		
Chicken (*Gallus sp*)	179	Geometric mean of forty-seven LOAEL for the species
Japanese quail (*Cotumix japonica*)	123	Geometric mean of two LOAEL for the species
Mallard duck (*Anas platyrhynchos*)	63	Geometric mean of two LOAEL for the species
Turkey (*Maleagris gallopavo*)	297	Single LOAEL for the species (Vohra and Kratzer, 1968)

LOAEL = lowest observed adverse effect level; TRV = toxicity reference value.

5.3.2 Radiation Benchmarks

Radiation dose benchmarks of 0.4 mGy/h (9.6 mGy/d) and 0.1 mGy/h (2.4 mGy/d) (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in the CSA N288.6-22 standard (CSA, 2022) . This is a total dose benchmark, therefore the dose to biota due to each radionuclide of concern is summed to compare against this benchmark.

The aquatic biota considered by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) are organisms such as fish and benthic invertebrates that reside in water. Birds and mammals with riparian habits are considered to be terrestrial biota. Dose calculations in this ERA follow the same convention.

Exceedance of the aquatic or terrestrial dose benchmarks is considered to indicate the potential for adverse effects to occur, and the need for more detailed assessment.

5.3.3 Uncertainties in the Effects Assessment

Uncertainties associated with the estimation of ecotoxicological effect levels for COPCs are inherent in the ERA process. Many uncertainties are associated with the use of literature-based TRVs. These uncertainties may include: extrapolation of results from laboratory tests to the field, differences in sensitivity between the test organism and resident organisms, laboratory conditions that are not representative of field conditions, and the form of the COPC used in toxicity testing, which may not be representative of the form that would be found at the Project.

The use of TRVs from laboratory studies tends to be conservative because these studies are typically chemical-specific and use highly bioavailable forms of the COPC studied. In field situations, the chemical form of the same COPC may be less bioavailable, and toxicity-modifying factors may be present that were not acting in laboratory tests.

The EC_{20} values were used for aquatic biota to reduce uncertainty by representing a standard threshold level of low magnitude effects. Depending on the size of the available dataset, selection of the 5th percentile or lowest EC_{20} value as the TRV for an aquatic biota group was intended to reduce the likelihood that risks would be underestimated.

There is inherent uncertainty associated with the use of LOAEL values as TRVs for birds and mammals as these values are not precisely related to a particular magnitude of effect. However, LOAEL values have widespread use in the risk assessment community and the science is not currently available to change this approach to TRVs. Defaulting to the most conservative TRV for ecological receptors that are not closely related taxonomically to the test species was meant to reduce the likelihood that risks would be underestimated.

5.4 Risk Characterization

Risk assessment is the process of estimating the likelihood of undesirable effects on ecological health resulting from exposure to chemical or radiological constituents. Three components must be present for risks to ecological health to exist:

- The COPC must be present at concentrations sufficient to cause a possible adverse effect.
- A receptor must be present.
- There must be a complete exposure pathway by which the receptor can come into contact with the COPC

5.4.1 Risk Estimation and Discussion

Risk characterization is the process in the EcoRA that integrates the results from the exposure and effects assessments to estimate the risk of adverse effects on ecological receptors. The risk characterization also evaluates the uncertainties associated with the overall conclusion of risk.

The hazard quotient (HQ) is a simple approach that provides a quantitative estimate of overall risk. The HQ is the ratio between the exposure estimate and a TRV:

$$HQ = \frac{Exposure\ (Dose)\ Estimate}{TRV}$$

If the HQ is less than or equal to 1, this suggests low risk to the ecological receptor because exposure estimates are below levels known to cause adverse effects. If the HQ is greater than 1, adverse effects may be possible, and further investigation of the assumptions of the exposure and effects assessments could be considered to reduce the conservatism inherent in the EcoRA. Risk assessment is often an iterative process of refining information, and the identified risk in the first iteration is often an artefact of conservative assumptions. If further evaluation under more realistic assumptions confirms the risk, this information can be used to inform mitigation to avoid, eliminate, or reduce the source of the risk.

5.4.1.1 Non-radiological Risk

The predicted total HQs (baseline and Project) for all aquatic and terrestrial ecological receptors at all assessed locations during the Project phases and in the future centuries are shown in Table 5-24. The HQs represent the maximum HQ over the life of the Project for relevant COPCs, which is a conservative representation of risk. Additional copper HQ values for some aquatic ecological receptors are presented in Section 6.3.2 using TRVs re-evaluated from the copper FEQG. Additional evaluation of selenium in fish (whole body and egg-ovary) is presented in Section 6.3.1 using TRVs from the selenium FEQG.

No significant adverse effect on either aquatic or terrestrial populations or communities as a result of releases from the Project are predicted during the Project phases.

The predicted total HQs are less than 1 for terrestrial and riparian receptors for all non-radiological COPCs during all phases of the Project and the future centuries, including for invertebrates, vegetation, mammals, and birds. This includes receptors residing and feeding in and around Whitefish Lake, McGowan Lake, and Russell Lake (exposure locations) as well as Kratchkowsky Lake (a reference location).

Since there are no exceedances of TRVs (all HQs less than 1) for birds and mammals, individual SAR would also be considered protected.

The predicted total HQs are less than 1 for aquatic receptors for all non-radiological COPCs, except copper, during all phases of the Project and the future centuries, including aquatic plants, invertebrates and fish (including northern pike and white sucker). This includes receptors at Whitefish Lake, McGowan Lake, and Russell Lake (exposure locations) as well as Kratchkowsky Lake (a reference location). When copper is re-evaluated using updated TRVs as shown in Section 6.3.2, under baseline conditions as well as the future centuries, copper HQs for all aquatic organisms are less than 1 with the exception of predator fish in Whitefish Lake, and benthic invertebrates at all locations where HQs are slightly above 1. Using predicted operational site conditions for hardness of 9 mg/L and pH of 7 during periods of treated effluent discharge, copper HQs for all aquatic organisms are less than 1 at all downstream locations, indicating no adverse effects to aquatic organisms from facility related copper (Section 6.3.2).

For assessment of risk to benthic invertebrates, risk was calculated based on toxicity benchmarks as water concentrations. However, considering that benthic invertebrates also reside in sediment, a comparison of predicted sediment concentrations against sediment toxicity benchmarks was warranted. This only applied to molybdenum and selenium in sediment, as no other COPC exceeded sediment screening values (Table 3-6). Molybdenum and selenium in sediment in Whitefish Lake (LA-5) were predicted to exceed the REF screening values from Burnett-Seidel and Liber (2013), but were predicted to be below the NE2 values in Whitefish Lake and all other downstream locations. Concentrations below the NE2 values indicate that benthic invertebrate community metrics (abundance, richness, and evenness) downstream of discharges are not expected to differ significantly (i.e., by 20%) from those observed at natural background conditions.

Table 5-24: Estimated Non-radiological Total Risk to Ecological Receptors – Project Phases and Future Centuries

Biota		Location	Maximum HQs during Project Phases											
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Aquatic Plants[(a)]	Macrophytes	Reference (Kratchkowsky Lake)	4.73E-04	3.13E-03	1.02E-04	1.04E-02	2.65E-02	1.64E-02	3.47E-06	2.98E-04	4.93E-05	5.67E-06	2.09E-03	6.03E-03
		Whitefish Lake North	4.37E-04	3.08E-03	1.02E-04	1.03E-02	2.62E-02	1.63E-02	3.46E-06	2.98E-04	4.83E-05	5.55E-06	1.93E-03	5.94E-03
		Whitefish Lake Middle	5.81E-04	5.23E-03	1.95E-03	1.31E-02	3.73E-02	2.16E-02	7.84E-04	1.67E-02	6.37E-04	1.04E-04	8.38E-03	9.16E-03
		Whitefish Lake South	5.91E-04	5.08E-03	1.94E-03	1.31E-02	3.65E-02	2.15E-02	7.73E-04	1.67E-02	6.07E-04	9.94E-05	7.06E-03	8.91E-03
		McGowan Lake	5.00E-04	4.31E-03	1.33E-03	1.21E-02	3.27E-02	1.97E-02	5.09E-04	1.13E-02	3.81E-04	6.14E-05	4.10E-03	7.77E-03
		Russell Lake Inlet	4.85E-04	3.96E-03	1.04E-03	1.17E-02	3.09E-02	1.89E-02	3.82E-04	8.61E-03	2.87E-04	4.57E-05	3.36E-03	7.24E-03
	Phytoplankton	Reference (Kratchkowsky Lake)	6.21E-03	9.53E-03	5.31E-05	2.21E-03	2.65E-02	6.76E-02	3.47E-06	2.58E-04	4.21E-04	7.09E-05	2.09E-03	2.33E-02
		Whitefish Lake North	5.73E-03	9.37E-03	5.31E-05	2.20E-03	2.62E-02	6.74E-02	3.46E-06	2.58E-04	4.12E-04	6.94E-05	1.93E-03	2.30E-02
		Whitefish Lake Middle	7.63E-03	1.59E-02	1.01E-03	2.80E-03	3.73E-02	8.94E-02	7.84E-04	1.45E-02	5.43E-03	1.31E-03	8.38E-03	3.54E-02
		Whitefish Lake South	7.76E-03	1.54E-02	1.01E-03	2.78E-03	3.65E-02	8.88E-02	7.73E-04	1.45E-02	5.18E-03	1.24E-03	7.06E-03	3.44E-02
		McGowan Lake	6.57E-03	1.31E-02	6.93E-04	2.59E-03	3.27E-02	8.15E-02	5.09E-04	9.78E-03	3.25E-03	7.68E-04	4.10E-03	3.00E-02
		Russell Lake Inlet	6.36E-03	1.20E-02	5.38E-04	2.49E-03	3.09E-02	7.79E-02	3.82E-04	7.47E-03	2.45E-03	5.72E-04	3.36E-03	2.80E-02
Aquatic Animals[(a)]	Benthic Invertebrate	Reference (Kratchkowsky Lake)	7.10E-04	4.68E-02	7.66E-04	5.70E-03	2.30E-04	3.07E-01	3.42E-06	9.42E-04	3.11E-03	1.07E-03	1.54E-03	2.20E-02
		Whitefish Lake North	7.10E-04	4.68E-02	7.66E-04	5.70E-03	2.30E-04	3.07E-01	3.42E-06	9.42E-04	3.11E-03	1.07E-03	1.54E-03	2.20E-02
		Whitefish Lake Middle	9.38E-04	6.89E-02	1.45E-02	6.90E-03	2.99E-04	3.84E-01	5.80E-04	5.28E-02	2.74E-02	1.33E-02	5.11E-03	3.02E-02
		Whitefish Lake South	8.96E-04	6.79E-02	1.45E-02	6.88E-03	2.96E-04	3.82E-01	5.70E-04	5.25E-02	2.63E-02	1.27E-02	4.58E-03	2.98E-02
		McGowan Lake	8.05E-04	6.13E-02	9.87E-03	6.57E-03	2.77E-04	3.62E-01	4.17E-04	3.52E-02	1.86E-02	8.84E-03	3.05E-03	2.74E-02
		Russell Lake Inlet	7.69E-04	5.75E-02	7.77E-03	6.36E-03	2.65E-04	3.49E-01	3.17E-04	2.73E-02	1.44E-02	6.75E-03	2.50E-03	2.60E-02
	Northern pike	Reference (Kratchkowsky Lake)	1.89E-04	6.62E-02	3.26E-04	4.07E-05	5.05E-03	2.07E-01	1.34E-06	1.37E-03	3.80E-02	5.67E-05	2.09E-03	2.19E-02
		Whitefish Lake North	1.75E-04	6.51E-02	3.26E-04	4.06E-05	4.99E-03	2.07E-01	1.34E-06	1.37E-03	3.72E-02	5.55E-05	1.93E-03	2.15E-02
		Whitefish Lake Middle	2.33E-04	1.10E-01	6.21E-03	5.16E-05	7.10E-03	2.74E-01	3.04E-04	7.70E-02	4.91E-01	1.04E-03	8.38E-03	3.32E-02
		Whitefish Lake South	2.36E-04	1.07E-01	6.18E-03	5.13E-05	6.95E-03	2.72E-01	3.00E-04	7.67E-02	4.68E-01	9.94E-04	7.06E-03	3.23E-02
		McGowan Lake	2.00E-04	9.10E-02	4.25E-03	4.77E-05	6.23E-03	2.50E-01	1.97E-04	5.18E-02	2.93E-01	6.14E-04	4.10E-03	2.82E-02
		Russell Lake Inlet	1.94E-04	8.37E-02	3.30E-03	4.59E-05	5.88E-03	2.39E-01	1.48E-04	3.96E-02	2.22E-01	4.57E-04	3.36E-03	2.63E-02
	White sucker	Reference (Kratchkowsky Lake)	9.03E-04	8.10E-02	4.65E-04	2.47E-04	9.90E-04	3.10E-01	3.46E-06	2.29E-04	5.16E-02	2.04E-05	1.95E-03	1.97E-02
		Whitefish Lake North	8.47E-04	8.00E-02	4.65E-04	2.47E-04	9.80E-04	3.09E-01	3.45E-06	2.29E-04	5.07E-02	2.01E-05	1.84E-03	1.95E-02
		Whitefish Lake Middle	1.13E-03	1.31E-01	8.85E-03	3.10E-04	1.37E-03	4.04E-01	7.33E-04	1.29E-02	6.16E-01	3.47E-04	7.56E-03	2.92E-02
		Whitefish Lake South	1.13E-03	1.28E-01	8.81E-03	3.09E-04	1.34E-03	4.02E-01	7.22E-04	1.28E-02	5.87E-01	3.31E-04	6.44E-03	2.85E-02
		McGowan Lake	9.69E-04	1.10E-01	6.05E-03	2.89E-04	1.21E-03	3.72E-01	4.86E-04	8.65E-03	3.77E-01	2.09E-04	3.84E-03	2.52E-02
		Russell Lake Inlet	9.35E-04	1.02E-01	4.71E-03	2.78E-04	1.15E-03	3.56E-01	3.66E-04	6.63E-03	2.86E-01	1.56E-04	3.14E-03	2.36E-02
	Zooplankton	Reference (Kratchkowsky Lake)	3.51E-04	1.59E-01	7.66E-04	9.14E-03	5.30E-02	3.11E-01	3.47E-06	1.62E-03	3.35E-03	5.20E-04	8.80E-05	2.33E-02
		Whitefish Lake North	3.24E-04	1.56E-01	7.66E-04	9.12E-03	5.24E-02	3.10E-01	3.46E-06	1.62E-03	3.28E-03	5.09E-04	8.14E-05	2.30E-02
		Whitefish Lake Middle	4.31E-04	2.65E-01	1.46E-02	1.16E-02	7.46E-02	4.11E-01	7.84E-04	9.10E-02	4.33E-02	9.57E-03	3.53E-04	3.54E-02
		Whitefish Lake South	4.38E-04	2.57E-01	1.45E-02	1.15E-02	7.30E-02	4.08E-01	7.73E-04	9.06E-02	4.12E-02	9.11E-03	2.97E-04	3.44E-02
		McGowan Lake	3.71E-04	2.18E-01	9.99E-03	1.07E-02	6.54E-02	3.75E-01	5.09E-04	6.12E-02	2.59E-02	5.63E-03	1.73E-04	3.00E-02
		Russell Lake Inlet	3.59E-04	2.01E-01	7.75E-03	1.03E-02	6.17E-02	3.58E-01	3.82E-04	4.68E-02	1.95E-02	4.19E-03	1.41E-04	2.80E-02

Biota		Location	Maximum HQs during Project Phases											
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Terrestrial Animals	Black Bear	Reference (Kratchkowsky Lake)	1.59E-03	5.16E-06	0.00E+00	1.70E-04	4.28E-05	1.27E-02	6.73E-04	0.00E+00	2.60E-02	2.15E-04	2.17E-03	1.06E-02
		Whitefish Lake	1.59E-03	5.17E-06	0.00E+00	1.70E-04	4.36E-05	1.28E-02	8.93E-04	0.00E+00	7.27E-02	3.70E-04	2.24E-03	1.07E-02
	Canada Lynx	Reference (Kratchkowsky Lake)	5.28E-03	2.43E-05	0.00E+00	4.21E-05	7.18E-05	2.94E-02	2.11E-04	0.00E+00	1.37E-01	1.04E-04	4.67E-03	4.09E-01
		Whitefish Lake	5.30E-03	2.43E-05	0.00E+00	4.25E-05	7.28E-05	3.03E-02	9.33E-04	0.00E+00	1.39E-01	1.15E-03	4.75E-03	4.10E-01
		McGowan Lake	5.28E-03	2.43E-05	0.00E+00	4.23E-05	7.20E-05	2.95E-02	6.78E-04	0.00E+00	1.38E-01	2.45E-04	4.68E-03	4.09E-01
		Russell Lake Inlet	5.28E-03	2.43E-05	0.00E+00	4.22E-05	7.19E-05	2.94E-02	5.61E-04	0.00E+00	1.38E-01	1.43E-04	4.67E-03	4.09E-01
	Mink	Reference (Kratchkowsky Lake)	3.43E-03	7.48E-06	0.00E+00	7.74E-05	1.51E-04	1.27E-02	2.47E-04	0.00E+00	6.87E-02	1.25E-04	6.37E-03	9.08E-03
		Whitefish Lake	4.38E-03	9.12E-06	0.00E+00	8.93E-05	1.84E-04	1.59E-02	3.34E-02	0.00E+00	6.04E-01	1.20E-03	1.57E-02	1.32E-02
		McGowan Lake	3.79E-03	8.54E-06	0.00E+00	8.58E-05	1.73E-04	1.50E-02	2.39E-02	0.00E+00	3.94E-01	5.36E-04	1.00E-02	1.15E-02
		Russell Lake Inlet	3.65E-03	8.26E-06	0.00E+00	8.38E-05	1.67E-04	1.44E-02	1.82E-02	0.00E+00	3.09E-01	3.92E-04	8.69E-03	1.08E-02
	Moose	Reference (Kratchkowsky Lake)	1.71E-04	1.85E-04	0.00E+00	8.80E-05	2.02E-05	3.93E-02	1.80E-04	0.00E+00	1.81E-03	1.16E-04	1.93E-03	2.21E-03
		Whitefish Lake	1.96E-04	1.92E-04	0.00E+00	9.53E-05	2.28E-05	4.08E-02	2.58E-03	0.00E+00	7.38E-03	3.21E-03	4.52E-03	2.27E-03
		McGowan Lake	1.81E-04	1.89E-04	0.00E+00	9.24E-05	2.18E-05	3.98E-02	1.83E-03	0.00E+00	5.05E-03	6.21E-04	2.87E-03	2.24E-03
		Russell Lake Inlet	1.77E-04	1.88E-04	0.00E+00	9.12E-05	2.14E-05	3.96E-02	1.42E-03	0.00E+00	4.15E-03	3.09E-04	2.52E-03	2.23E-03
	Moose Organs	Reference (Kratchkowsky Lake)	1.71E-04	1.85E-04	0.00E+00	8.80E-05	2.02E-05	3.93E-02	1.80E-04	0.00E+00	1.81E-03	1.16E-04	1.93E-03	2.21E-03
		McGowan Lake	1.81E-04	1.89E-04	0.00E+00	9.24E-05	2.18E-05	3.98E-02	1.83E-03	0.00E+00	5.05E-03	6.21E-04	2.87E-03	2.24E-03
		Russell Lake Inlet	1.77E-04	1.88E-04	0.00E+00	9.12E-05	2.14E-05	3.96E-02	1.42E-03	0.00E+00	4.15E-03	3.09E-04	2.52E-03	2.23E-03
	Muskrat	Reference (Kratchkowsky Lake)	1.81E-03	1.79E-04	0.00E+00	3.36E-04	1.74E-04	3.12E-04	2.69E-04	0.00E+00	4.75E-03	3.24E-04	1.88E-02	4.80E-04
		Whitefish Lake	2.35E-03	2.75E-04	0.00E+00	4.23E-04	2.27E-04	4.10E-04	4.84E-02	0.00E+00	5.13E-02	4.43E-03	6.64E-02	7.14E-04
		McGowan Lake	2.02E-03	2.39E-04	0.00E+00	3.93E-04	2.09E-04	3.76E-04	3.40E-02	0.00E+00	3.24E-02	2.85E-03	3.70E-02	6.14E-04
		Russell Lake Inlet	1.94E-03	2.22E-04	0.00E+00	3.78E-04	2.00E-04	3.59E-04	2.58E-02	0.00E+00	2.47E-02	2.16E-03	3.03E-02	5.74E-04
	Snowshoe Hare	Reference (Kratchkowsky Lake)	2.25E-03	4.08E-03	0.00E+00	3.05E-04	9.04E-05	5.53E-03	1.06E-04	0.00E+00	1.07E-02	4.88E-04	5.96E-03	1.97E-02
		Whitefish Lake	2.26E-03	4.09E-03	0.00E+00	3.08E-04	9.13E-05	5.69E-03	1.84E-04	0.00E+00	1.10E-02	1.07E-02	6.04E-03	1.97E-02
		McGowan Lake	2.25E-03	4.08E-03	0.00E+00	3.06E-04	9.06E-05	5.55E-03	1.56E-04	0.00E+00	1.08E-02	1.83E-03	5.97E-03	1.97E-02
		Russell Lake Inlet	2.25E-03	4.08E-03	0.00E+00	3.06E-04	9.05E-05	5.54E-03	1.43E-04	0.00E+00	1.08E-02	8.49E-04	5.97E-03	1.97E-02
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.96E-04	2.13E-02	2.88E-02	0.00E+00	8.08E-02	7.45E-03	1.45E-02	3.56E-03
		Whitefish Lake	7.63E-03	1.28E-02	0.00E+00	3.29E-03	3.00E-04	2.20E-02	3.03E-02	0.00E+00	8.14E-02	9.70E-02	1.48E-02	3.57E-03
		McGowan Lake	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.97E-04	2.14E-02	2.96E-02	0.00E+00	8.09E-02	1.92E-02	1.45E-02	3.56E-03
		Russell Lake Inlet	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.96E-04	2.13E-02	2.94E-02	0.00E+00	8.08E-02	1.06E-02	1.45E-02	3.56E-03
	WoodLand Caribou	Reference (Kratchkowsky Lake)	3.70E-04	2.79E-04	0.00E+00	1.62E-04	2.30E-04	2.74E-02	3.30E-04	0.00E+00	4.63E-03	3.10E-04	7.79E-03	2.80E-03
		Whitefish Lake	3.85E-04	2.84E-04	0.00E+00	1.66E-04	2.33E-04	2.83E-02	2.54E-03	0.00E+00	7.65E-03	9.19E-03	8.98E-03	2.82E-03
	Canada Goose	Reference (Kratchkowsky Lake)	2.13E-04	1.25E-04	0.00E+00	3.19E-05	2.36E-05	8.69E-04	1.57E-05	0.00E+00	3.66E-04	2.37E-05	5.58E-03	5.45E-04
		Whitefish Lake	2.12E-04	1.25E-04	0.00E+00	3.20E-05	2.34E-05	8.91E-04	1.57E-05	0.00E+00	3.67E-04	4.96E-04	5.61E-03	5.46E-04

Biota		Location	Maximum HQs during Project Phases											
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
		McGowan Lake	2.13E-04	1.25E-04	0.00E+00	3.20E-05	2.37E-05	8.72E-04	4.46E-05	0.00E+00	3.81E-04	8.65E-05	5.60E-03	5.46E-04
		Russell Lake Inlet	2.13E-04	1.25E-04	0.00E+00	3.20E-05	2.36E-05	8.70E-04	3.74E-05	0.00E+00	3.76E-04	4.08E-05	5.59E-03	5.46E-04
	Bald Eagle	Reference (Kratchkowsky Lake)	2.80E-03	7.63E-04	0.00E+00	1.89E-04	4.50E-04	2.33E-03	5.06E-05	0.00E+00	3.23E-02	2.20E-04	9.26E-02	1.56E-03
		Whitefish Lake	2.81E-03	7.64E-04	0.00E+00	1.89E-04	4.52E-04	2.36E-03	6.94E-05	0.00E+00	4.54E-02	2.49E-04	9.31E-02	1.58E-03
	Olive-Sided Flycatcher	Reference (Kratchkowsky Lake)	7.84E-03	3.93E-02	0.00E+00	8.99E-04	1.77E-03	2.92E-02	5.67E-04	0.00E+00	7.03E-02	8.03E-04	2.56E-01	1.91E-02
		Whitefish Lake	8.36E-03	3.94E-02	0.00E+00	9.43E-04	1.87E-03	3.36E-02	1.38E-02	0.00E+00	1.25E-01	1.72E-02	2.86E-01	2.02E-02
		McGowan Lake	8.05E-03	3.93E-02	0.00E+00	9.27E-04	1.84E-03	3.22E-02	1.02E-02	0.00E+00	1.05E-01	3.08E-03	2.68E-01	1.98E-02
		Russell Lake Inlet	7.97E-03	3.93E-02	0.00E+00	9.19E-04	1.82E-03	3.15E-02	7.84E-03	0.00E+00	9.56E-02	1.49E-03	2.64E-01	1.97E-02
	Common Loon	Reference (Kratchkowsky Lake)	1.23E-03	1.80E-05	0.00E+00	2.66E-05	7.35E-05	3.37E-03	1.01E-05	0.00E+00	3.53E-02	6.44E-06	4.77E-03	1.51E-03
		Whitefish Lake	1.52E-03	2.67E-05	0.00E+00	3.27E-05	9.98E-05	4.30E-03	1.73E-03	0.00E+00	2.93E-01	1.05E-04	1.83E-02	2.25E-03
		McGowan Lake	1.31E-03	2.36E-05	0.00E+00	3.08E-05	8.95E-05	4.01E-03	1.24E-03	0.00E+00	1.92E-01	6.40E-05	9.37E-03	1.93E-03
		Russell Lake Inlet	1.27E-03	2.21E-05	0.00E+00	2.98E-05	8.50E-05	3.85E-03	9.43E-04	0.00E+00	1.52E-01	4.80E-05	7.68E-03	1.80E-03
	Mallard	Reference (Kratchkowsky Lake)	4.57E-03	6.31E-05	0.00E+00	3.21E-04	1.51E-02	1.03E-02	1.62E-04	0.00E+00	5.20E-03	9.80E-05	6.22E-02	7.83E-03
		Whitefish Lake	6.02E-03	9.34E-05	0.00E+00	3.93E-04	1.95E-02	1.29E-02	2.76E-02	0.00E+00	4.69E-02	1.25E-03	2.10E-01	1.08E-02
		McGowan Lake	5.17E-03	8.28E-05	0.00E+00	3.71E-04	1.81E-02	1.21E-02	1.98E-02	0.00E+00	3.15E-02	8.24E-04	1.23E-01	9.76E-03
		Russell Lake Inlet	4.94E-03	7.76E-05	0.00E+00	3.59E-04	1.73E-02	1.17E-02	1.51E-02	0.00E+00	2.44E-02	6.27E-04	1.01E-01	9.25E-03
	American Robin	Reference (Kratchkowsky Lake)	3.87E-02	3.05E-02	0.00E+00	5.09E-03	3.79E-03	1.38E-01	2.66E-03	0.00E+00	1.09E-01	3.29E-03	7.82E-01	7.91E-02
		Whitefish Lake	3.87E-02	3.06E-02	0.00E+00	5.12E-03	3.80E-03	1.43E-01	2.68E-03	0.00E+00	1.10E-01	3.27E-02	7.84E-01	7.94E-02
		McGowan Lake	3.87E-02	3.05E-02	0.00E+00	5.09E-03	3.79E-03	1.39E-01	2.75E-03	0.00E+00	1.09E-01	7.15E-03	7.82E-01	7.92E-02
		Russell Lake Inlet	3.87E-02	3.05E-02	0.00E+00	5.09E-03	3.79E-03	1.38E-01	2.73E-03	0.00E+00	1.09E-01	4.32E-03	7.82E-01	7.91E-02
	Lesser Scaup	Reference (Kratchkowsky Lake)	7.95E-03	1.15E-04	0.00E+00	7.91E-04	2.54E-02	1.82E-02	2.80E-04	0.00E+00	9.74E-03	1.72E-04	1.20E-01	1.48E-02
		Whitefish Lake	1.04E-02	1.73E-04	0.00E+00	9.77E-04	3.30E-02	2.27E-02	4.81E-02	0.00E+00	9.17E-02	2.32E-03	4.21E-01	2.06E-02
		McGowan Lake	8.92E-03	1.52E-04	0.00E+00	9.18E-04	3.05E-02	2.14E-02	3.44E-02	0.00E+00	6.07E-02	1.50E-03	2.36E-01	1.85E-02
		Russell Lake Inlet	8.53E-03	1.42E-04	0.00E+00	8.86E-04	2.92E-02	2.06E-02	2.62E-02	0.00E+00	4.68E-02	1.14E-03	1.94E-01	1.75E-02

Biota		Location	Maximum HQs during Future Centuries											
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Aquatic Plants[a]	Macrophytes	Reference (Kratchkowsky Lake)	4.10E-04	3.05E-03	1.02E-04	1.03E-02	2.59E-02	1.63E-02	3.45E-06	2.98E-04	4.75E-05	5.46E-06	1.82E-03	5.87E-03
		Whitefish Lake North	4.10E-04	3.05E-03	1.02E-04	1.03E-02	2.59E-02	1.63E-02	3.45E-06	2.98E-04	4.75E-05	5.46E-06	1.82E-03	5.87E-03
		Whitefish Lake Middle	4.25E-04	3.07E-03	1.32E-04	1.09E-02	2.63E-02	1.65E-02	3.76E-06	3.12E-04	6.33E-05	6.68E-06	1.84E-03	6.38E-03
		Whitefish Lake South	4.23E-04	3.06E-03	1.31E-04	1.08E-02	2.63E-02	1.65E-02	3.75E-06	3.12E-04	6.26E-05	6.63E-06	1.83E-03	6.36E-03
		McGowan Lake	4.16E-04	3.06E-03	1.25E-04	1.07E-02	2.62E-02	1.64E-02	3.68E-06	3.09E-04	5.80E-05	6.28E-06	1.83E-03	6.22E-03
		Russell Lake Inlet	4.14E-04	3.06E-03	1.19E-04	1.06E-02	2.61E-02	1.64E-02	3.62E-06	3.06E-04	5.52E-05	6.06E-06	1.82E-03	6.13E-03
	Phytoplankton	Reference (Kratchkowsky Lake)	5.38E-03	9.26E-03	5.31E-05	2.20E-03	2.59E-02	6.72E-02	3.45E-06	2.58E-04	4.05E-04	6.83E-05	1.82E-03	2.27E-02

Biota		Location	Maximum HQs during Future Centuries											
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
		Whitefish Lake North	5.38E-03	9.26E-03	5.31E-05	2.20E-03	2.59E-02	6.72E-02	3.45E-06	2.58E-04	4.05E-04	6.83E-05	1.82E-03	2.27E-02
		Whitefish Lake Middle	5.58E-03	9.32E-03	6.84E-05	2.31E-03	2.63E-02	6.81E-02	3.76E-06	2.71E-04	5.40E-04	8.36E-05	1.84E-03	2.47E-02
		Whitefish Lake South	5.55E-03	9.32E-03	6.82E-05	2.31E-03	2.63E-02	6.81E-02	3.75E-06	2.71E-04	5.34E-04	8.29E-05	1.83E-03	2.46E-02
		McGowan Lake	5.47E-03	9.30E-03	6.48E-05	2.28E-03	2.62E-02	6.79E-02	3.68E-06	2.68E-04	4.95E-04	7.84E-05	1.83E-03	2.40E-02
		Russell Lake Inlet	5.43E-03	9.29E-03	6.21E-05	2.26E-03	2.61E-02	6.77E-02	3.62E-06	2.66E-04	4.71E-04	7.57E-05	1.82E-03	2.37E-02
Aquatic Animals[(a)]	Benthic Invertebrate	Reference (Kratchkowsky Lake)	7.10E-04	4.68E-02	7.66E-04	5.70E-03	2.30E-04	3.07E-01	3.42E-06	9.42E-04	3.11E-03	1.07E-03	1.54E-03	2.20E-02
		Whitefish Lake North	7.10E-04	4.68E-02	7.66E-04	5.70E-03	2.30E-04	3.07E-01	3.42E-06	9.42E-04	3.11E-03	1.07E-03	1.54E-03	2.20E-02
		Whitefish Lake Middle	7.36E-04	4.71E-02	9.85E-04	6.00E-03	2.33E-04	3.11E-01	3.73E-06	9.87E-04	4.14E-03	1.31E-03	1.55E-03	2.39E-02
		Whitefish Lake South	7.33E-04	4.71E-02	9.83E-04	6.00E-03	2.33E-04	3.11E-01	3.73E-06	9.87E-04	4.09E-03	1.30E-03	1.55E-03	2.39E-02
		McGowan Lake	7.21E-04	4.70E-02	9.33E-04	5.93E-03	2.33E-04	3.10E-01	3.65E-06	9.77E-04	3.79E-03	1.23E-03	1.55E-03	2.33E-02
		Russell Lake Inlet	7.17E-04	4.70E-02	8.94E-04	5.88E-03	2.32E-04	3.09E-01	3.60E-06	9.68E-04	3.61E-03	1.19E-03	1.54E-03	2.30E-02
	Northern pike	Reference (Kratchkowsky Lake)	1.64E-04	6.43E-02	3.26E-04	4.05E-05	4.94E-03	2.06E-01	1.34E-06	1.37E-03	3.67E-02	5.46E-05	1.82E-03	2.13E-02
		Whitefish Lake North	1.64E-04	6.43E-02	3.26E-04	4.05E-05	4.94E-03	2.06E-01	1.34E-06	1.37E-03	3.67E-02	5.46E-05	1.82E-03	2.13E-02
		Whitefish Lake Middle	1.70E-04	6.47E-02	4.19E-04	4.26E-05	5.01E-03	2.09E-01	1.46E-06	1.44E-03	4.88E-02	6.68E-05	1.84E-03	2.31E-02
		Whitefish Lake South	1.69E-04	6.47E-02	4.18E-04	4.26E-05	5.00E-03	2.09E-01	1.45E-06	1.44E-03	4.83E-02	6.63E-05	1.83E-03	2.30E-02
		McGowan Lake	1.67E-04	6.46E-02	3.97E-04	4.21E-05	4.99E-03	2.08E-01	1.43E-06	1.42E-03	4.47E-02	6.28E-05	1.83E-03	2.25E-02
		Russell Lake Inlet	1.66E-04	6.45E-02	3.81E-04	4.17E-05	4.98E-03	2.08E-01	1.40E-06	1.41E-03	4.26E-02	6.06E-05	1.82E-03	2.22E-02
	White sucker	Reference (Kratchkowsky Lake)	8.06E-04	7.93E-02	4.65E-04	2.47E-04	9.74E-04	3.09E-01	3.44E-06	2.29E-04	5.01E-02	1.98E-05	1.75E-03	1.93E-02
		Whitefish Lake North	8.06E-04	7.93E-02	4.65E-04	2.47E-04	9.74E-04	3.09E-01	3.44E-06	2.29E-04	5.01E-02	1.98E-05	1.75E-03	1.93E-02
		Whitefish Lake Middle	8.36E-04	7.97E-02	5.99E-04	2.60E-04	9.86E-04	3.13E-01	3.75E-06	2.40E-04	6.68E-02	2.43E-05	1.77E-03	2.10E-02
		Whitefish Lake South	8.32E-04	7.97E-02	5.97E-04	2.59E-04	9.86E-04	3.13E-01	3.75E-06	2.40E-04	6.61E-02	2.41E-05	1.76E-03	2.09E-02
		McGowan Lake	8.19E-04	7.96E-02	5.67E-04	2.56E-04	9.82E-04	3.12E-01	3.67E-06	2.38E-04	6.12E-02	2.28E-05	1.76E-03	2.04E-02
		Russell Lake Inlet	8.14E-04	7.95E-02	5.43E-04	2.54E-04	9.80E-04	3.11E-01	3.62E-06	2.36E-04	5.82E-02	2.20E-05	1.75E-03	2.02E-02
	Zooplankton	Reference (Kratchkowsky Lake)	3.04E-04	1.54E-01	7.66E-04	9.10E-03	5.19E-02	3.09E-01	3.45E-06	1.62E-03	3.23E-03	5.01E-04	7.66E-05	2.27E-02
		Whitefish Lake North	3.04E-04	1.54E-01	7.66E-04	9.10E-03	5.19E-02	3.09E-01	3.45E-06	1.62E-03	3.23E-03	5.01E-04	7.66E-05	2.27E-02
		Whitefish Lake Middle	3.15E-04	1.55E-01	9.85E-04	9.58E-03	5.26E-02	3.13E-01	3.76E-06	1.70E-03	4.30E-03	6.13E-04	7.73E-05	2.47E-02
		Whitefish Lake South	3.14E-04	1.55E-01	9.83E-04	9.57E-03	5.26E-02	3.13E-01	3.75E-06	1.70E-03	4.26E-03	6.08E-04	7.72E-05	2.46E-02
		McGowan Lake	3.09E-04	1.55E-01	9.33E-04	9.46E-03	5.24E-02	3.12E-01	3.68E-06	1.68E-03	3.94E-03	5.75E-04	7.69E-05	2.40E-02
		Russell Lake Inlet	3.07E-04	1.55E-01	8.94E-04	9.37E-03	5.23E-02	3.11E-01	3.62E-06	1.66E-03	3.76E-03	5.55E-04	7.68E-05	2.37E-02
Terrestrial Animals	Black Bear	Reference (Kratchkowsky Lake)	1.55E-03	5.16E-06	0.00E+00	1.70E-04	4.26E-05	1.27E-02	6.73E-04	0.00E+00	2.54E-02	2.15E-04	2.15E-03	1.06E-02
		Whitefish Lake	1.55E-03	5.16E-06	0.00E+00	1.70E-04	4.27E-05	1.27E-02	6.73E-04	0.00E+00	2.72E-02	2.22E-04	2.15E-03	1.06E-02
	Canada Lynx	Reference (Kratchkowsky Lake)	5.28E-03	2.43E-05	0.00E+00	4.21E-05	7.18E-05	2.94E-02	2.11E-04	0.00E+00	1.37E-01	1.04E-04	4.67E-03	4.09E-01
		Whitefish Lake	5.28E-03	2.43E-05	0.00E+00	4.22E-05	7.18E-05	2.94E-02	2.11E-04	0.00E+00	1.37E-01	1.40E-04	4.67E-03	4.09E-01
		McGowan Lake	5.28E-03	2.43E-05	0.00E+00	4.22E-05	7.18E-05	2.94E-02	2.11E-04	0.00E+00	1.37E-01	1.08E-04	4.67E-03	4.09E-01
		Russell Lake Inlet	5.28E-03	2.43E-05	0.00E+00	4.21E-05	7.18E-05	2.94E-02	2.11E-04	0.00E+00	1.37E-01	1.05E-04	4.67E-03	4.09E-01
	Mink	Reference (Kratchkowsky Lake)	3.32E-03	7.48E-06	0.00E+00	7.74E-05	1.50E-04	1.27E-02	2.47E-04	0.00E+00	6.72E-02	1.25E-04	6.26E-03	8.92E-03

Biota	Location	Maximum HQs during Future Centuries											
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
	Whitefish Lake	3.43E-03	7.50E-06	0.00E+00	8.03E-05	1.52E-04	1.28E-02	2.64E-04	0.00E+00	8.66E-02	1.65E-04	6.29E-03	9.68E-03
	McGowan Lake	3.37E-03	7.49E-06	0.00E+00	7.95E-05	1.51E-04	1.28E-02	2.60E-04	0.00E+00	8.01E-02	1.36E-04	6.27E-03	9.44E-03
	Russell Lake Inlet	3.35E-03	7.49E-06	0.00E+00	7.90E-05	1.51E-04	1.28E-02	2.57E-04	0.00E+00	7.67E-02	1.31E-04	6.27E-03	9.31E-03
Moose	Reference (Kratchkowsky Lake)	1.68E-04	1.85E-04	0.00E+00	8.79E-05	2.02E-05	3.93E-02	1.80E-04	0.00E+00	1.80E-03	1.16E-04	1.86E-03	2.21E-03
	Whitefish Lake	1.71E-04	1.85E-04	0.00E+00	8.93E-05	2.03E-05	3.93E-02	1.81E-04	0.00E+00	1.97E-03	1.40E-04	1.87E-03	2.22E-03
	McGowan Lake	1.69E-04	1.85E-04	0.00E+00	8.89E-05	2.02E-05	3.93E-02	1.80E-04	0.00E+00	1.91E-03	1.21E-04	1.87E-03	2.22E-03
	Russell Lake Inlet	1.69E-04	1.85E-04	0.00E+00	8.87E-05	2.02E-05	3.93E-02	1.80E-04	0.00E+00	1.88E-03	1.18E-04	1.87E-03	2.21E-03
Muskrat	Reference (Kratchkowsky Lake)	1.76E-03	1.78E-04	0.00E+00	3.35E-04	1.74E-04	3.11E-04	2.69E-04	0.00E+00	4.67E-03	3.22E-04	1.80E-02	4.69E-04
	Whitefish Lake	1.83E-03	1.79E-04	0.00E+00	3.52E-04	1.76E-04	3.15E-04	2.93E-04	0.00E+00	6.22E-03	3.93E-04	1.81E-02	5.10E-04
	McGowan Lake	1.79E-03	1.79E-04	0.00E+00	3.48E-04	1.75E-04	3.14E-04	2.87E-04	0.00E+00	5.70E-03	3.69E-04	1.81E-02	4.97E-04
	Russell Lake Inlet	1.78E-03	1.78E-04	0.00E+00	3.45E-04	1.75E-04	3.13E-04	2.83E-04	0.00E+00	5.42E-03	3.57E-04	1.80E-02	4.90E-04
Snowshoe Hare	Reference (Kratchkowsky Lake)	2.25E-03	4.08E-03	0.00E+00	3.05E-04	9.04E-05	5.53E-03	1.06E-04	0.00E+00	1.07E-02	4.88E-04	5.96E-03	1.97E-02
	Whitefish Lake	2.25E-03	4.08E-03	0.00E+00	3.06E-04	9.04E-05	5.54E-03	1.06E-04	0.00E+00	1.07E-02	6.18E-04	5.96E-03	1.97E-02
	McGowan Lake	2.25E-03	4.08E-03	0.00E+00	3.05E-04	9.04E-05	5.53E-03	1.06E-04	0.00E+00	1.07E-02	5.05E-04	5.96E-03	1.97E-02
	Russell Lake Inlet	2.25E-03	4.08E-03	0.00E+00	3.05E-04	9.04E-05	5.53E-03	1.06E-04	0.00E+00	1.07E-02	4.93E-04	5.96E-03	1.97E-02
Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.96E-04	2.13E-02	2.88E-02	0.00E+00	8.08E-02	7.45E-03	1.45E-02	3.56E-03
	Whitefish Lake	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.96E-04	2.13E-02	2.88E-02	0.00E+00	8.08E-02	9.92E-03	1.45E-02	3.56E-03
	McGowan Lake	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.96E-04	2.13E-02	2.88E-02	0.00E+00	8.08E-02	7.77E-03	1.45E-02	3.56E-03
	Russell Lake Inlet	7.62E-03	1.28E-02	0.00E+00	3.27E-03	2.96E-04	2.13E-02	2.88E-02	0.00E+00	8.08E-02	7.54E-03	1.45E-02	3.56E-03
WoodLand Caribou	Reference (Kratchkowsky Lake)	3.66E-04	2.79E-04	0.00E+00	1.62E-04	2.30E-04	2.74E-02	3.30E-04	0.00E+00	4.62E-03	3.10E-04	7.73E-03	2.79E-03
	Whitefish Lake	3.68E-04	2.79E-04	0.00E+00	1.63E-04	2.30E-04	2.74E-02	3.31E-04	0.00E+00	4.73E-03	3.16E-04	7.73E-03	2.80E-03
Canada Goose	Reference (Kratchkowsky Lake)	2.13E-04	1.25E-04	0.00E+00	3.19E-05	2.36E-05	8.69E-04	1.57E-05	0.00E+00	3.65E-04	2.37E-05	5.58E-03	5.45E-04
	Whitefish Lake	2.11E-04	1.25E-04	0.00E+00	3.17E-05	2.33E-05	8.69E-04	1.55E-05	0.00E+00	3.63E-04	3.01E-05	5.57E-03	5.45E-04
	McGowan Lake	2.13E-04	1.25E-04	0.00E+00	3.20E-05	2.36E-05	8.69E-04	1.57E-05	0.00E+00	3.66E-04	2.46E-05	5.58E-03	5.45E-04
	Russell Lake Inlet	2.13E-04	1.25E-04	0.00E+00	3.20E-05	2.36E-05	8.69E-04	1.57E-05	0.00E+00	3.66E-04	2.40E-05	5.58E-03	5.45E-04
Bald Eagle	Reference (Kratchkowsky Lake)	2.67E-03	7.63E-04	0.00E+00	1.89E-04	4.50E-04	2.32E-03	5.06E-05	0.00E+00	3.15E-02	2.20E-04	9.22E-02	1.53E-03
	Whitefish Lake	2.68E-03	7.63E-04	0.00E+00	1.89E-04	4.50E-04	2.32E-03	5.07E-05	0.00E+00	3.21E-02	2.21E-04	9.22E-02	1.53E-03
Olive-Sided Flycatcher	Reference (Kratchkowsky Lake)	7.83E-03	3.93E-02	0.00E+00	8.99E-04	1.77E-03	2.92E-02	5.67E-04	0.00E+00	7.03E-02	8.03E-04	2.56E-01	1.91E-02
	Whitefish Lake	7.89E-03	3.93E-02	0.00E+00	9.08E-04	1.78E-03	2.94E-02	5.73E-04	0.00E+00	7.26E-02	1.02E-03	2.56E-01	1.94E-02
	McGowan Lake	7.86E-03	3.93E-02	0.00E+00	9.06E-04	1.78E-03	2.93E-02	5.72E-04	0.00E+00	7.18E-02	8.33E-04	2.56E-01	1.93E-02
	Russell Lake Inlet	7.85E-03	3.93E-02	0.00E+00	9.04E-04	1.78E-03	2.93E-02	5.71E-04	0.00E+00	7.14E-02	8.12E-04	2.56E-01	1.93E-02
Common Loon	Reference (Kratchkowsky Lake)	1.09E-03	1.79E-05	0.00E+00	2.65E-05	7.26E-05	3.37E-03	1.01E-05	0.00E+00	3.43E-02	6.29E-06	4.31E-03	1.47E-03
	Whitefish Lake	1.13E-03	1.80E-05	0.00E+00	2.80E-05	7.35E-05	3.41E-03	1.10E-05	0.00E+00	4.35E-02	7.69E-06	4.35E-03	1.60E-03
	McGowan Lake	1.10E-03	1.80E-05	0.00E+00	2.76E-05	7.32E-05	3.40E-03	1.08E-05	0.00E+00	4.04E-02	7.22E-06	4.33E-03	1.56E-03

Biota		Location	Maximum HQs during Future Centuries											
			Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
		Russell Lake Inlet	1.10E-03	1.80E-05	0.00E+00	2.74E-05	7.31E-05	3.39E-03	1.06E-05	0.00E+00	3.88E-02	6.97E-06	4.32E-03	1.54E-03
	Mallard	Reference (Kratchkowsky Lake)	4.54E-03	6.30E-05	0.00E+00	3.21E-04	1.51E-02	1.03E-02	1.62E-04	0.00E+00	5.19E-03	9.78E-05	6.14E-02	7.82E-03
		Whitefish Lake	4.72E-03	6.33E-05	0.00E+00	3.38E-04	1.53E-02	1.04E-02	1.77E-04	0.00E+00	6.92E-03	1.20E-04	6.19E-02	8.50E-03
		McGowan Lake	4.62E-03	6.32E-05	0.00E+00	3.34E-04	1.52E-02	1.04E-02	1.73E-04	0.00E+00	6.34E-03	1.12E-04	6.16E-02	8.28E-03
		Russell Lake Inlet	4.59E-03	6.31E-05	0.00E+00	3.31E-04	1.52E-02	1.04E-02	1.70E-04	0.00E+00	6.04E-03	1.08E-04	6.15E-02	8.16E-03
	American Robin	Reference (Kratchkowsky Lake)	3.87E-02	3.05E-02	0.00E+00	5.09E-03	3.79E-03	1.38E-01	2.66E-03	0.00E+00	1.09E-01	3.29E-03	7.82E-01	7.91E-02
		Whitefish Lake	3.87E-02	3.05E-02	0.00E+00	5.10E-03	3.79E-03	1.38E-01	2.66E-03	0.00E+00	1.09E-01	4.46E-03	7.82E-01	7.92E-02
		McGowan Lake	3.87E-02	3.05E-02	0.00E+00	5.09E-03	3.79E-03	1.38E-01	2.66E-03	0.00E+00	1.09E-01	3.45E-03	7.82E-01	7.91E-02
		Russell Lake Inlet	3.87E-02	3.05E-02	0.00E+00	5.09E-03	3.79E-03	1.38E-01	2.66E-03	0.00E+00	1.09E-01	3.33E-03	7.82E-01	7.91E-02
	Lesser Scaup	Reference (Kratchkowsky Lake)	7.78E-03	1.15E-04	0.00E+00	7.89E-04	2.54E-02	1.82E-02	2.80E-04	0.00E+00	9.69E-03	1.71E-04	1.15E-01	1.47E-02
		Whitefish Lake	8.08E-03	1.16E-04	0.00E+00	8.31E-04	2.57E-02	1.84E-02	3.05E-04	0.00E+00	1.29E-02	2.09E-04	1.16E-01	1.60E-02
		McGowan Lake	7.91E-03	1.15E-04	0.00E+00	8.21E-04	2.56E-02	1.83E-02	2.99E-04	0.00E+00	1.18E-02	1.97E-04	1.16E-01	1.56E-02
		Russell Lake Inlet	7.86E-03	1.15E-04	0.00E+00	8.13E-04	2.56E-02	1.83E-02	2.94E-04	0.00E+00	1.13E-02	1.90E-04	1.16E-01	1.54E-02

(a) - Aquatic receptor TRVs for copper have been calculated using the FEQG and are included in Section 6.3.2.
n/a = not applicable; HQ = hazard quotient.

5.4.1.2 Radiological Risk

An HQ is not typically calculated for radiological risk; however, a comparison of the total radiological dose (baseline plus Project) against the ecological dose benchmarks is presented.

There were no predicted exceedances of the 2.4 mGy/d radiation dose benchmark for terrestrial and riparian biota or the 9.6 mGy/d radiation dose benchmark for aquatic biota in the Project area, LSA, or RSA during any phase of the Project (Table 5-25) or in the future centuries (Table 5-26). This includes Whitefish Lake, McGowan Lake, and Russell Lake as exposure locations as well as Kratchkowsky Lake as a reference location. All predicted doses are well below the radiation dose benchmarks.

During the Project phases, the maximum predicted total dose for terrestrial and riparian biota is to lichen near Whitefish Lake (0.99 mGy/d), and the main contributors to total dose are from uranium-234 and uranium-238 in air that deposits to lichen. The maximum predicted total dose for aquatic biota is to zooplankton at Whitefish Lake (0.10 mGy/d), and the main contributor to total dose is from polonium-210 in tissue.

During the future centuries, the maximum predicted dose to aquatic biota is to zooplankton (0.08 mG/d) in Whitefish Lake from polonium-210 in water. The maximum predicted dose during the future centuries to terrestrial and riparian biota is to the scaup (0.05 mGy/d) who eats aquatic animals from Whitefish Lake. For terrestrial plants the dose during the future centuries is 0.22 mGy/d for lichen at all locations, due to background concentrations of polonium-210 in the soil.

Overall, it is unlikely that there would be significant adverse effects on terrestrial or aquatic populations or communities as a result of radionuclide releases from the Project.

Table 5-25: Summary of Total Radiation Doses to Limiting Ecological Receptors – Project Phases

Category	Maximum Total Dose [(a)] (mGy/d)	Receptor	Location	Largest Contributor and Pathway to Dose	Dose Benchmark (mGy/d)
Aquatic Plants	0.01	Macrophytes	Whitefish Lake Middle	Ra-226 Water to tissue (internal)	9.6
Aquatic Animals	0.10	Zooplankton	Whitefish Lake South	Po-210 Water to tissue (internal)	9.6
Terrestrial Plants	0.99	Lichen	On-site near Whitefish Lake	U-234 Soil to tissue (internal)	2.4
Terrestrial Animals	0.06	Lesser Scaup	Whitefish Lake	Po-210 Aquatic animals ingestion (internal)	2.4

Note:
(a) Total radiation dose includes the baseline dose and the Project dose combined.

Table 5-26: Summary of Total Radiation Doses to Limiting Ecological Receptors – Future Centuries

Category	Maximum Total Dose [(a)] (mGy/d)	Receptor	Location	Largest Contributor and Pathway to Dose	Dose Benchmark (mGy/d)
Aquatic Plants	0.01	Macrophytes	Whitefish Lake Middle	Ra-226 Water to tissue (internal)	9.6
Aquatic Animals	0.08	Zooplankton	Whitefish Lake Middle	Po-210 Water to tissue (internal)	9.6
Terrestrial Plants	0.22	Lichen	All locations	Po-210 tissue (internal)	2.4
Terrestrial Animals	0.05	Lesser Scaup	Whitefish Lake	Po-210 Aquatic animals ingestion (internal)	2.4

Note:
(a) Total radiation dose includes the baseline dose and the Project dose combined.

5.4.2 Uncertainties in the Risk Characterization

Since the risk characterization is dependent on the problem formulation and the exposure and effects assessments, any uncertainty identified in these assessments propagates uncertainty into the risk estimates. In general, the uncertainties are expected to cause an overestimation, not an underestimation of risk due to the conservative approaches employed in the ERA, including the use of:

- maximum predicted concentrations for COPCs in media for each exposure scenario;
- exposure of ecological receptors to COPCs in the environment for chronic periods of time and during sensitive life stages; and
- effect levels based on low-effect threshold concentrations and doses.

The assumptions to address uncertainties in the ERA are anticipated to produce overly conservative estimates of risk, as discussed below.

For the calculation of risk to environmental receptors, there are uncertainties associated with the use of literature-based TRVs. These uncertainties may include: extrapolation of results from laboratory tests to the field, differences in sensitivity between the test organism and resident organisms, laboratory conditions that are not representative of field conditions, and the form of the COPC used in toxicity testing which may not be representative of the form found at the site.

The use of TRVs from laboratory studies tends to be conservative because these studies are typically chemical-specific and use highly bioavailable forms of the COPC. In field situations, the chemical form of the COPC may be less bioavailable, and toxicity-modifying factors may be present that were not acting in laboratory tests.

There is inherent uncertainty associated with the use of LOAEL values as TRVs as these values are not precisely related to biologically relevant thresholds and do not provide information about the actual magnitude of effects in the reported studies. However, LOAEL values have widespread use in the risk assessment community and the science is not currently available to change this approach to TRVs.

Taken together, these approaches are anticipated to produce a risk characterization that has not underestimated risk; the resulting HQs are either overestimates or realistic estimates of risk, both of which are considered acceptable.

6.0 Quality Assurance and Updated Risk Characterization

6.1 Quality Assurance

Throughout the planning and preparation of the ERA, all staff worked under the Ecometrix ISO 9001:2015 certified Quality Management System. All work was internally reviewed and verified. Reviews included verification of input data in the IMPACT files against the source documents and verification of selected results with independent calculation spreadsheets, as well as review of report content. Comments have been addressed as appropriate by report revisions. The review process has been documented through a paper trail of review comments and responses. Examples of the independent calculation spreadsheets are provided in Appendix B.

The software used for the ERA was IMPACT 5.6.0, a dynamic version of the model and was tailored to align with the guidance in CSA standards N288.6-22 (CSA, 2022) and N288.1-20 (CSA, 2020). It contains differential equations for COPC transport, allowing for non-steady-state conditions, whereas N288.1 contains the corresponding steady-state equations. When utilizing IMPACT for this Project, all inputs to IMPACT were checked, along with an overall verification of IMPACT scenario files. Checks were performed on data and calculations to verify that transcription errors and formula errors, if any, were caught and addressed. Checks of the model structure, algorithms and functions have been made repeatedly throughout the model development history as it has been used in several related applications that underwent multiple layers of review.

The ERICA Tool, version 1.3.1, was used as a source of biota dose coefficients. Its parameters, including dose coefficients, have been subject to validation through numerous intercomparison exercises, as described by Brown et al., (Brown et al., 2016, 2003, 2008) and have generally compared well with other sources. The intercomparisons of dose coefficients are described by Vives I Batlle et al. (Vives i Batlle et al., 2011, 2007). The external dose predictions for small mammals have been validated against dosimetric measurements (Beresford et al., 2008). The code and database are updated from time to time, as described in its documented version history.

The ERA utilized environmental monitoring data collected as part of the baseline monitoring program which followed either Ecometrix' Quality Management System for the monitoring conducted by Ecometrix or the Quality Management System for Denison's other subcontractors. The data collected during the baseline monitoring program was considered valid and appropriate for use in the ERA. The ERA was reviewed and accepted by Denison in accordance with Denison's QA requirements.

6.2 Sensitivity Analysis

A sensitivity analysis of key model parameters was undertaken to understand the degree to which the results or conclusions of the risk assessment would vary if these parameters differed from what was assumed.

6.2.1 Woodland Caribou Diet

The food source for the woodland caribou in the winter is terrestrial or arboreal lichens; terrestrial and aquatic vegetation are also food sources in the remainder of the year. For the ecological risk assessment, a low lichen diet (LLD) comprised of 50% browse, 20% lichen and 30% macrophytes was assumed to represent the year-round diet for woodland caribou (woodland caribou LLD). Research has noted that arboreal lichen could make up 70% of the caribou's winter diet (MNRW, 2006). To ensure that woodland caribou who may have higher consumption rates of lichen remains protected, a high lichen diet (HLD) comprised of 70% lichen, 20% browse and 10% macrophytes was assumed as a sensitivity case for woodland caribou who may have higher consumption rates of lichen (woodland caribou HLD).

The predicted maximum HQs for non-radiological risk and the maximum radiological dose for radiological COPCs for both woodland caribou models are shown in Table 6-1 and Table 6-2. Compared with the woodland caribou LLD, the predicted maximum HQs for the woodland caribou HLD generally increased by 5 to 81% with the exception of copper and molybdenum where the HQ decreased by 4 to 22% due to the copper and molybdenum concentration in lichen being lower than in browse. However, all HQs for woodland caribou HLD are below the benchmark of 1 for all non-radiological COPCs. The predicted maximum total radiological dose for the woodland caribou HLD increased by 65% compared to that for the woodland caribou LLD. However, the total dose for woodland caribou HLD is still far below the radiation dose benchmark of 2.4 mGy/d for terrestrial biota, as recommended in CSA N288.6-22.

Table 6-1: Non-radiological Risk to Woodland Caribou during Project Phases

Biota	Location	Maximum HQs during Project Phases				
		Arsenic	Cadmium	Cobalt	Chromium	Copper
WoodLand Caribou LLD	Reference (Kratchkowsky Lake)	3.70E-04	2.79E-04	1.62E-04	2.30E-04	2.74E-02
	Whitefish Lake	3.85E-04	2.84E-04	1.66E-04	2.33E-04	2.83E-02
WoodLand Caribou HLD	Reference (Kratchkowsky Lake)	3.90E-04	3.28E-04	2.00E-04	3.72E-04	2.15E-02
	Whitefish Lake	4.06E-04	3.33E-04	2.04E-04	3.76E-04	2.29E-02
Biota	**Location**	**Molybdenum**	**Selenium**	**Uranium**	**Vanadium**	**Zinc**
WoodLand Caribou LLD	Reference (Kratchkowsky Lake)	3.30E-04	4.63E-03	3.10E-04	7.79E-03	2.80E-03
	Whitefish Lake	2.54E-03	7.65E-03	9.19E-03	8.98E-03	2.82E-03
WoodLand Caribou HLD	Reference (Kratchkowsky Lake)	4.50E-04	6.41E-03	4.20E-04	9.97E-03	3.53E-03
	Whitefish Lake	2.43E-03	8.40E-03	1.66E-02	1.10E-02	3.54E-03

Table 6-2: Maximum Radiological Doses to Woodland Caribou during Project Phases

Biota	Location	Maximum Radiological Dose During Project Phases (mGy/d)						
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Total Dose
WoodLand Caribou LLD	Reference (Kratchkowsky Lake)	3.34E-06	3.81E-06	6.25E-06	6.81E-04	1.20E-05	6.24E-03	**6.95E-03**
	Whitefish Lake	8.19E-05	9.32E-05	7.30E-06	6.86E-04	1.20E-05	6.26E-03	**7.14E-03**
WoodLand Caribou HLD	Reference (Kratchkowsky Lake)	3.61E-06	4.12E-06	4.44E-06	6.05E-04	1.99E-05	1.09E-02	**1.15E-02**
	Whitefish Lake	1.43E-04	1.62E-04	4.74E-06	6.09E-04	1.99E-05	1.09E-02	**1.18E-02**

6.2.2 Effluent Discharge Rate

One of the key model parameters is the effluent discharge rate. As described in Section 3.1, treated effluent will be released to Whitefish Lake Middle (LA-5) via a discharge line with a diffuser at the end to promote effluent mixing within the lake. Effluent will be released at a discharge rate of 36.5 m^3/hr (10.1 L/s) as the EA case. The maximum upper bound discharge rate is 81 m^3/hr (22.5 L/s). The reasonable upper bound effluent quality during the phases where effluent will be released is summarized in Table 3-2 – effluent quality is assumed to be constant over that time period.

In this ERA, surface water quality modeling was completed using IMPACT version 5.6.0 with treated effluent released to Whitefish Lake Middle at an expected discharge rate of 36.5 m^3/h during the operation and decommissioning phases of the Project. If the effluent was released at the maximum upper bound discharge rate of 81 m^3/hr, the maximum concentrations of COPCs in Whitefish Lake Middle and its downstream waterbodies will increase up to 120%.

*increase (%) = 100 * (modelled max concentration at upper bound discharge rate - modelled max concentration at expected discharge rate) / modelled max concentration at expected discharge rate.*

Figure 6-1 shows the maximum concentrations of COPCs in surface water at the expected and upper bound discharge rate. Compared to the maximum concentrations in surface water at the expected discharge rate, the maximum concentrations of COPCs in surface water at the upper bound discharge rate will increase 10 – 44% for arsenic, 29 – 51% for cadmium, 109 – 113% for chloride, 14 – 26% for cobalt, 20 – 38% for chromium, 17 – 30% for copper, 119 – 120% for molybdenum, 116 – 117% for sulphate, 101 – 111% for selenium, 107 – 113% for uranium, 53 – 95% for vanadium, 24 – 45% for zinc, 107 – 113% for uranium-238 and uranium-234, 36 – 55% for thorium-230, 12 – 24% for radium-226, 12 – 53% for lead-210, and 6 – 13% for polonium-210, respectively. If treated effluent is released at the maximum upper bound discharge rate, cadmium concentration in Whitefish Middle/South and McGowan Lake (LA-1) would exceed its surface water quality guideline of 0.00004 mg/L, and chromium concentration in Whitefish Middle/South would slightly exceed its surface water quality guideline of 0.001 mg/L. The modelled concentrations of other COPCs are expected to be below their corresponding surface water quality guidelines.

Figure 6-2 shows the resulting maximum concentrations of COPCs in sediment at the expected and upper bound discharge rate. Compared to the maximum concentrations in sediment at the expected discharge rate, the maximum concentrations of COPCs in sediment at the upper bound discharge rate will increase –10 - 30% for arsenic, 23 - 38% for cadmium, 13 - 21% for cobalt, 16 - 27% for chromium, 15 - 24% for copper, 119 -120% for molybdenum, 95 - 106% for selenium, 102 - 110% for uranium, 47 -84% for vanadium, 19 - 33% for zinc, 102 -110% for uranium-238 and uranium-234, 32 - 47% for thorium-230, 9 - 17% for radium-226, 12 - 40% for lead-210, and 12 - 39% for polonium-210, respectively. If treated effluent was released at the maximum upper bound discharge rate, the modelled concentrations of all COPCs are expected to be below their corresponding sediment quality guidelines, with the exception of cadmium, molybdenum, selenium and vanadium.

This is a conservative prediction as it assumes effluent is released during decommissioning at the same upper bound flow and quality as during operations. For cadmium, the predicted maximum sediment quality at the expected discharge rate is 0.497 mg/kg dw in Whitefish Lake Middle, which is below the selected interim sediment quality guideline (ISQG) value of 0.6 mg/kg dw. However, the predicted maximum sediment quality at the upper bound discharge rate is 0.688 mg/kg dw in Whitefish Lake Middle and 0.647 mg/kg dw in Whitefish Lake South, which exceeds the ISQG value but is below the probable effect level (PEL) of 3.5 mg/kg dw.

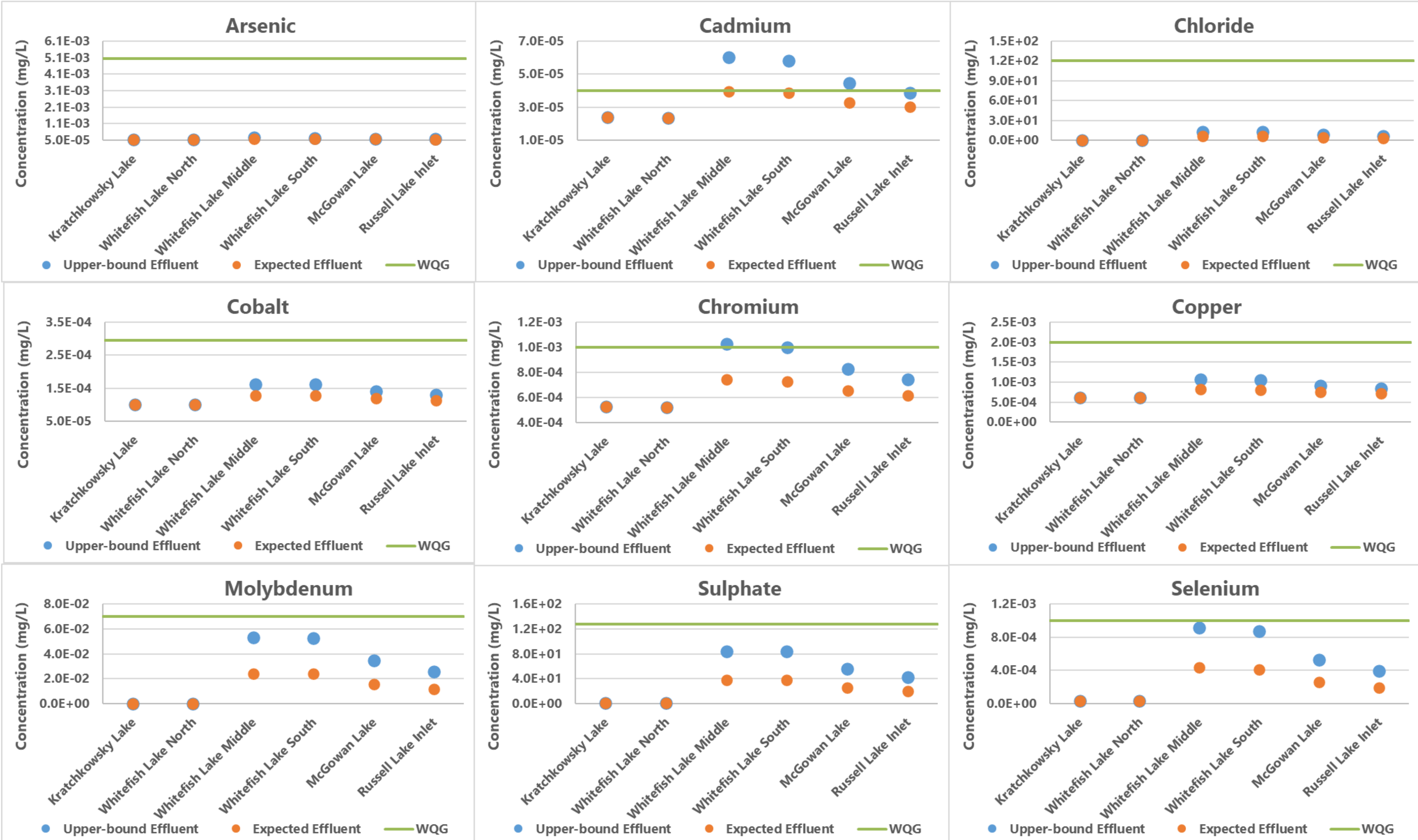
The predicted maximum molybdenum concentration in sediment is predicted to be 57.2 mg/kg dw in Whitefish Lake Middle at the expected discharge rate and 125 mg/kg dw in Whitefish Lake Middle at the upper bound discharge rate. Both values are above its reference (REF) value of 23 mg/kg dw, but below its no-effect (NE2) sediment quality benchmark of 245 mg/kg dw.

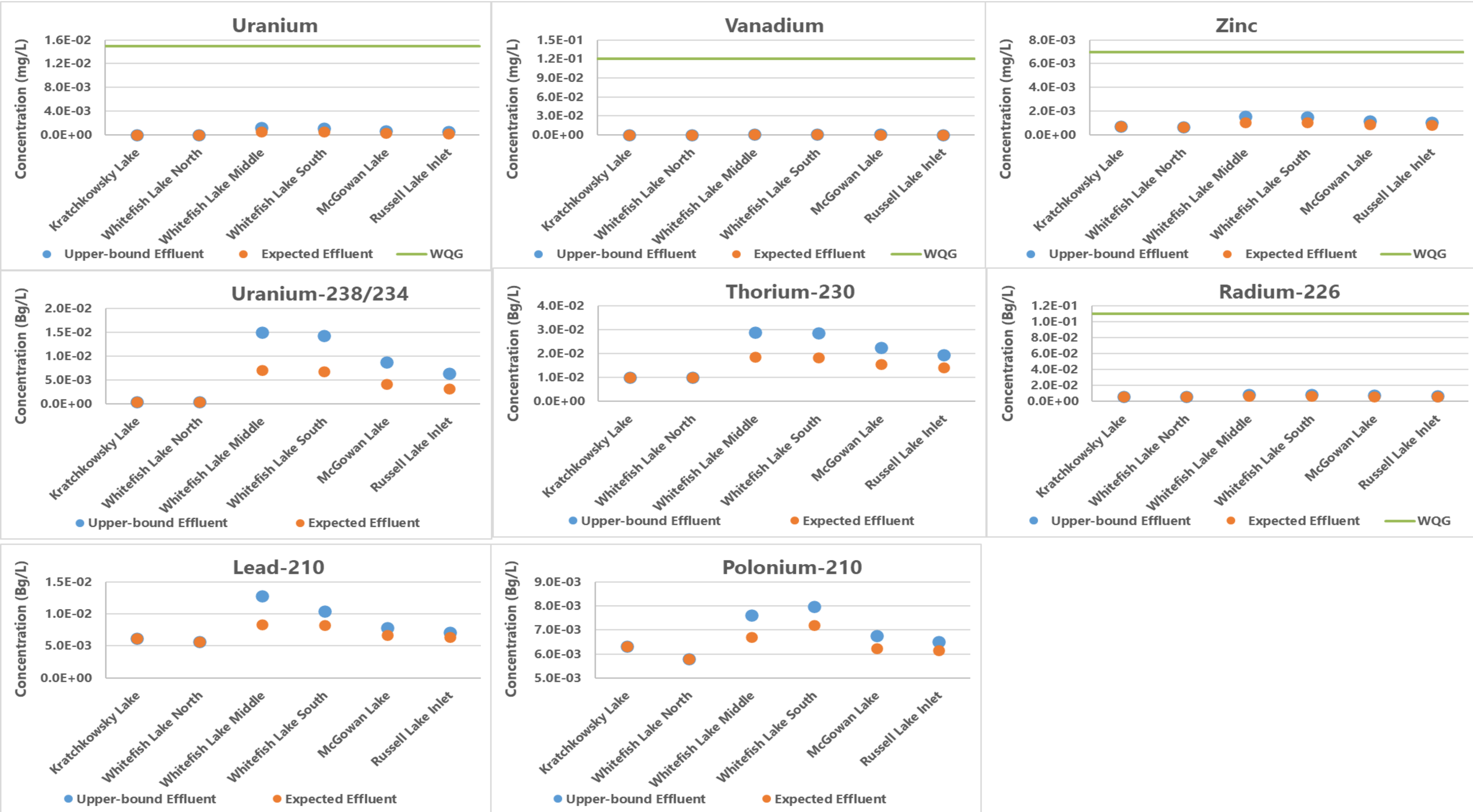
The maximum selenium concentration in sediment is 5.48 mg/kg dw in Whitefish Lake Middle at the expected discharge rate and 11.3 mg/kg dw in Whitefish Lake Middle at the upper bound discharge rate. Both values are above its REF value of 3.6 mg/kg dw, but below its NE2 value of 30 mg/kg dw.

The predicted maximum concentration of vanadium in sediment at the end of decommissioning is 37.2 mg/kg dw in Whitefish Lake Middle at the expected discharge rate and 68.5 mg/kg dw in Whitefish Lake Middle at the upper bound discharge rate. Both values are higher than the REF value of 35.1 mg/kg dw and the lowest effect level (LEL) of 35.2 mg/kg dw but are well below the severe effect level (SEL) of 160 mg/kg dw.

The REF values refer to locations upstream of mining or milling activities or located within separate but nearby drainages. Exceedance of a REF value indicates that sediment downstream of the proposed discharge is elevated compared to natural background (Burnett-Seidel and

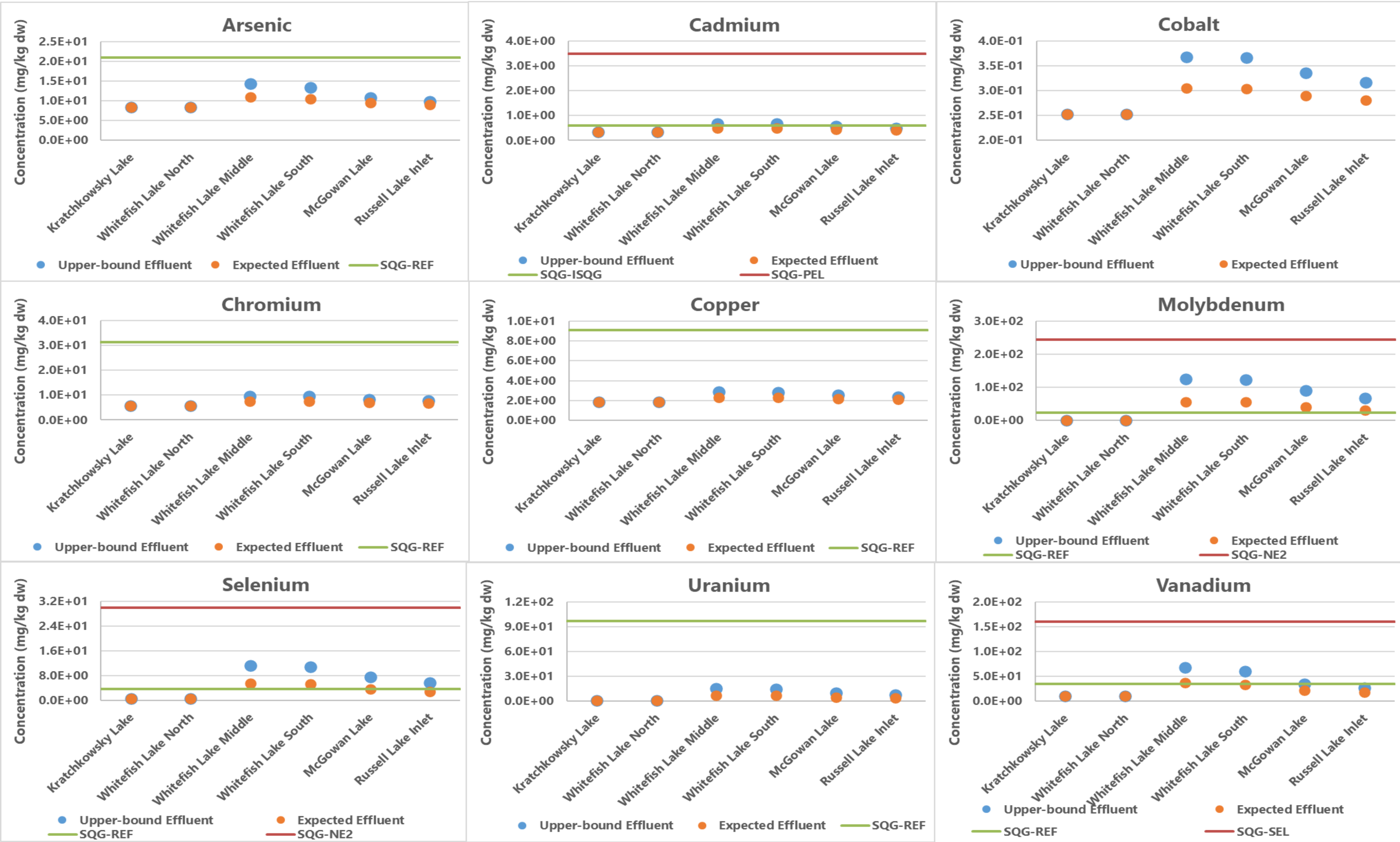
Liber, 2013). The predicted sediment concentration for exceedances of a REF or LEL value are not indicative of adverse effects to benthic communities but do suggest that further investigation may be warranted. The LEL represents a concentration in sediment that the majority of benthic organisms can tolerate, whereas the SEL represents a concentration in sediment that the majority of benthic organisms cannot tolerate (Persaud et al., 1993). The NE2 values refer to exposed (lightly contaminated) areas with elevated concentrations but no significant effect on benthic invertebrate abundance, richness, and evenness. Concentrations below the NE2 values indicate that benthic invertebrate community metrics (abundance, richness, and evenness) downstream of discharges are not expected to differ significantly (less than 20% difference) from those observed at natural background conditions. The predicted exceedances in sediment concentrations for cadmium, molybdenum, selenium and vanadium are all below their PEL or NE2 or SEL values, therefore, adverse effects to benthic communities are not anticipated under the upper bound discharge scenarios.

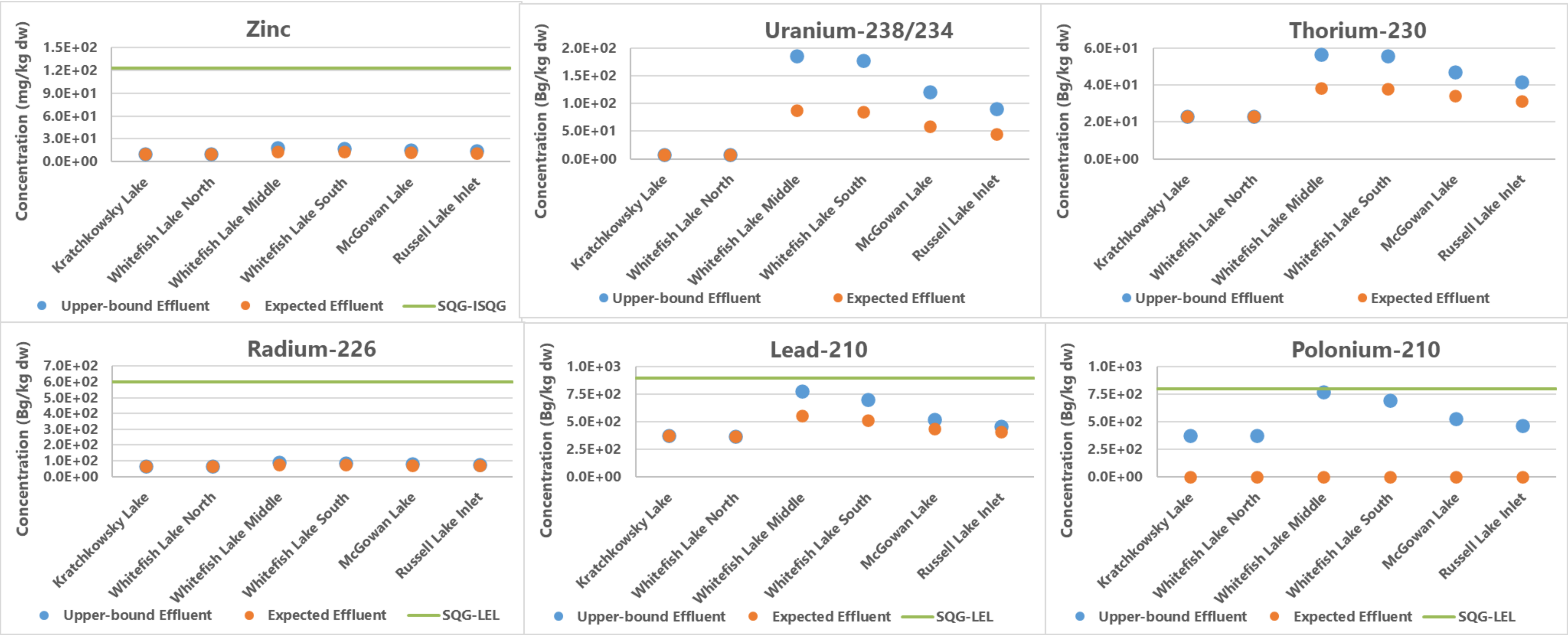

Arsenic
Concentration (mg/L)
6.1E-03
5.1E-03
4.1E-03
3.1E-03
2.1E-03
1.1E-03
5.0E-05
Cadmium
7.0E-05
5.0E-05
3.0E-05
1.0E-05
Chloride
1.5E+02
1.2E+02
9.0E+01
6.0E+01
3.0E+01
0.0E+00
Cobalt
3.5E-04
2.5E-04
1.5E-04
5.0E-05
Chromium
1.2E-03
1.0E-03
8.0E-04
6.0E-04
4.0E-04
Copper
2.5E-03
2.0E-03
1.5E-03
1.0E-03
5.0E-04
0.0E+00
Molybdenum
8.0E-02
6.0E-02
4.0E-02
2.0E-02
0.0E+00
Sulphate
1.6E+02
1.2E+02
8.0E+01
4.0E+01
0.0E+00
Selenium
1.2E-03
8.0E-04
4.0E-04
0.0E+00
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Upper-bound Effluent
Expected Effluent
WQG



WQG = Water Quality Guideline. The WQG is the green line and is consistent with the selected screening values shown in Table 3-1.

Figure 6-1: Comparison of Maximum Concentrations of COPCs in Surface Water at the Expected and Upper Bound Discharge Rate


Arsenic
Concentration (mg/kg dw)
2.5E+01
2.0E+01
1.5E+01
1.0E+01
5.0E+00
0.0E+00
Kratchkowsky Lake
Whitefish Lake North
Whitefish Lake Middle
Whitefish Lake South
McGowan Lake
Russell Lake Inlet
Upper-bound Effluent
Expected Effluent
SQG-REF
Cadmium
Concentration (mg/kg dw)
4.0E+00
3.0E+00
2.0E+00
1.0E+00
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-ISQG
SQG-PEL
Cobalt
Concentration (mg/kg dw)
4.0E-01
3.5E-01
3.0E-01
2.5E-01
2.0E-01
Upper-bound Effluent
Expected Effluent
Chromium
Concentration (mg/kg dw)
4.0E+01
3.0E+01
2.0E+01
1.0E+01
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-REF
Copper
Concentration (mg/kg dw)
1.0E+01
8.0E+00
6.0E+00
4.0E+00
2.0E+00
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-REF
Molybdenum
Concentration (mg/kg dw)
3.0E+02
2.0E+02
1.0E+02
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-REF
SQG-NE2
Selenium
Concentration (mg/kg dw)
3.2E+01
2.4E+01
1.6E+01
8.0E+00
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-REF
SQG-NE2
Uranium
Concentration (mg/kg dw)
1.2E+02
9.0E+01
6.0E+01
3.0E+01
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-REF
Vanadium
Concentration (mg/kg dw)
2.0E+02
1.5E+02
1.0E+02
5.0E+01
0.0E+00
Upper-bound Effluent
Expected Effluent
SQG-REF
SQG-SEL



SQG = Sediment Quality Guideline. The SQG with the green line is consistent with the selected sediment screening values (REF or ISQG or LEL) shown in Table 3-6. The SQG with the red line is the upper sediment quality values (NE2 or SEL or PEL) shown in Table 3-6.

Figure 6-2: Comparison of maximum concentrations of COPCs in sediment at expected and upper bound discharge rate

6.3 Updated Risk Characterization for Selenium and Copper

An updated risk characterization for selenium and copper was undertaken due to additional evaluation criteria being published since the initiation of the ERA.

6.3.1 Selenium in Fish Tissue

The TRV for selenium in fish used in Section 5.3.1 was the US EPA criterion of 11.3 mg/kg dw muscle (US EPA, 2021d). ECCC has published a FEQG for selenium of 6.7 µg/g dw for whole body and 14.7 µg/g dw for egg-ovary. This section re-evaluates the assessment of selenium in fish tissue using the FEQG guidance (ECCC, 2022).

The whole-body concentrations were recalculated from the predicted selenium in muscle tissue concentrations (Appendix B, Table B.5), using site-specific moisture content and the species-specific US EPA (2021d) conversion factors. The values used for moisture content and conversion factors for muscle to whole body and egg-ovary to whole body are shown in Table 6-3 below. The resulting whole-body concentrations (Table 6-4) do not exceed either EPA (2021d) or ECCC (2022) guidelines for whole-body tissue, which are 8.5 µg/g dw and 6.7 µg/g dw, respectively, and therefore the conclusions of the ERA are unchanged.

Table 6-3: Moisture Content and Conversion Factors used for Selenium Calculations

Fish Species	Moisture Content (Aquatic Baseline Studies, Appendix 8-D, Table A-17)	Muscle:Whole Body (Table B-4, B-5, US EPA 2021d)	Egg-Ovary:Muscle (Table B-3, US EPA 2021d)
Northern Pike	77.98	1.27	1.88
White Sucker	76.55	1.34	1

Table 6-4: Calculated Whole Body and Egg-Ovary

			FEQG (µg/g dw)	6.7	14.7
Fish Species	**Lake**	**Muscle µg/g fw**	**Muscle µg/g dw**	**Whole Body µg/g dw**	**Egg-Ovary µg/g dw**
Northern Pike	Reference	1.89E-01	8.58E-01	0.68	1.61
	Whitefish Lake North	1.86E-01	8.45E-01	0.67	1.59
	Whitefish Lake Middle	1.57E+00	7.13E+00	5.61	13.40
	Whitefish Lake South	1.51E+00	6.86E+00	5.40	12.89
	McGowan Lake	1.02E+00	4.63E+00	3.65	8.71
	Russell Lake	8.12E-01	3.69E+00	2.90	6.93
White Sucker	Reference	1.46E-01	6.23E-01	0.46	0.62
	Whitefish Lake North	1.43E-01	6.10E-01	0.46	0.61
	Whitefish Lake Middle	1.74E+00	7.42E+00	5.54	7.42
	Whitefish Lake South	1.66E+00	7.08E+00	5.28	7.08
	McGowan Lake	1.06E+00	4.52E+00	3.37	4.52
	Russell Lake	8.06E-01	3.44E+00	2.57	3.44

6.3.1.1 Uncertainty Evaluation for Northern Pike Bioaccumulation Factor

Selenium BAFs were derived using regional data of measured fish tissue and water concentration data. Using measured fish tissue data and measured water concentrations to develop the BAF incorporates the selenium bioaccumulation through the food chain and would represent the transfer (enrichment function and trophic transfer).

Tissue data were available for northern pike, cisco, lake trout, longnose sucker, lake whitefish, white sucker, lake chub, and spottail shiner. The data comparisons resulted in the following conclusions:

- The same BAF can be applied to a fish species at different lakes;
- The BAF values for longnose sucker, cisco, and lake trout were not significantly different from those for northern pike; therefore; data from these species were combined to derive a BAF for northern pike;
- The BAF values for lake whitefish and white sucker were significantly different ($p<0.05$) from that for northern pike; and
- The BAF values for lake chub and spottail shiner were not significantly different ($p>0.05$) from each other; therefore, data for these two species were combined to derive a BAF for small-bodied fish.

Most of the data from fish species evaluated demonstrated a linear relationship between fish tissue and water concentrations. The linear regression line was shown to underestimate selenium in northern pike tissue at low water concentrations. Therefore, a non-linear relationship was adopted for northern pike, where the BAF = $949x^{0.827}$ (x is in units of µg/L). As shown in Figure 6-3, the linear (dotted line) and power function (solid red curve) are quite similar except where the water concentrations were less than 0.001 mg/L. The R^2 values for the linear and power function are similar but the better fit at the lower water concentration values provided a basis for selecting the power function as the preferred model for the northern pike. Correlation analyses of the tissue and water concentration data for selenium indicated that a significant relationship ($p<0.05$) existed between the water and tissue concentrations in northern pike, white sucker, lake whitefish and small-bodied fish.

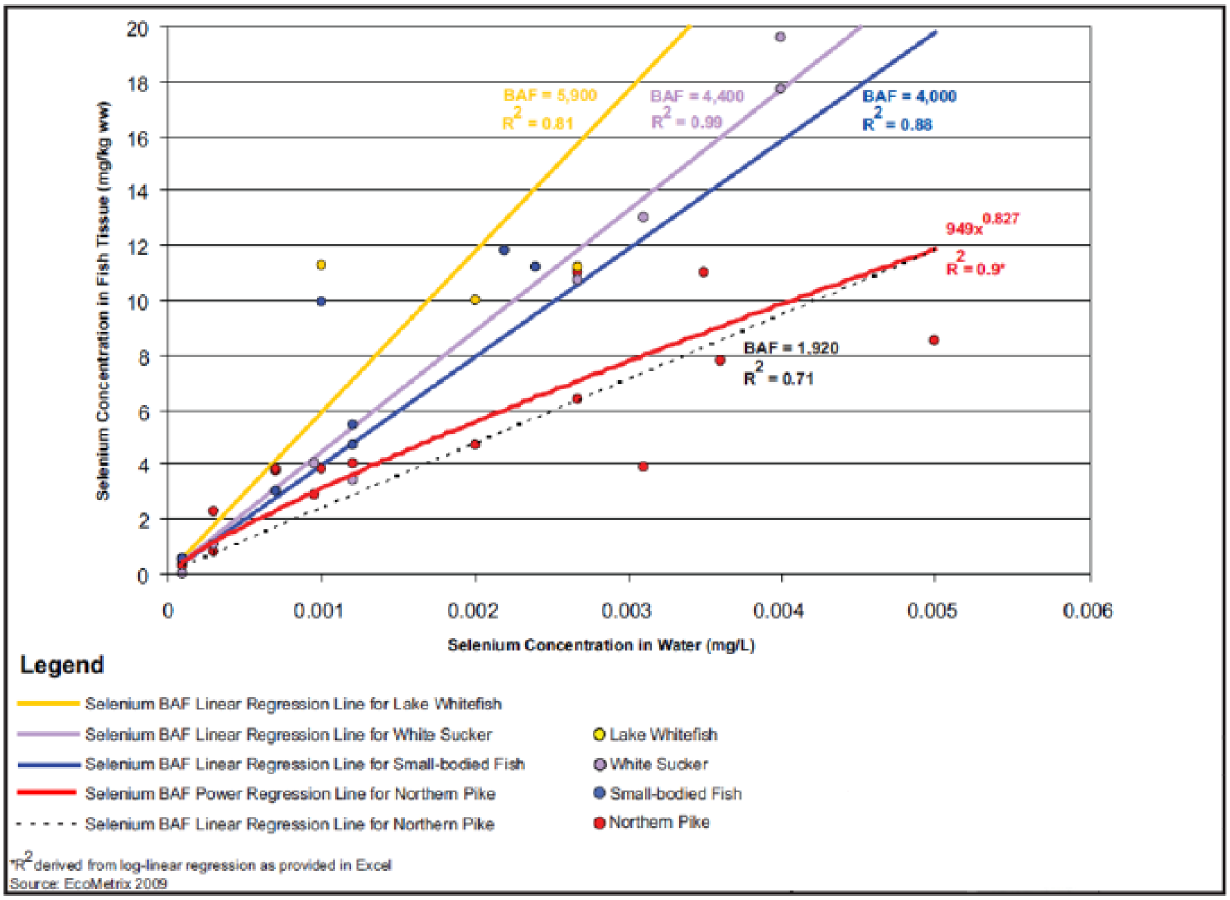


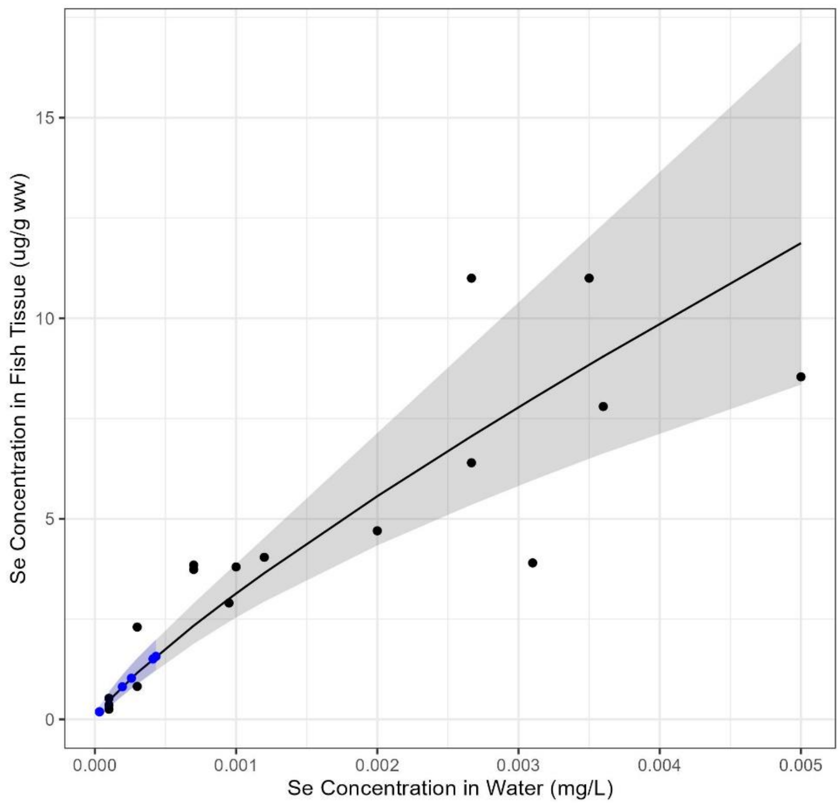
Figure 6-3: Development of Regional Fish BAFs for Selenium in Saskatchewan

To evaluate the range of uncertainty in the northern pike BAF, a power-regression (log-log) of the water and fish tissue selenium data was used to generate the expected relationship between selenium in water and selenium in tissue. The model was a good fit to the data (R^2 = 0.88). The regression equation ($y = ax^b$) was:

$$Se_{[tissue;\ \mu g/g\ ww]} = a \times Se_{[water;\ mg/L]}{}^{b},$$

where the 95% confidence interval for '*a*' was 295–3060 and for '*b*' was 0.66–0.99.

The predicted mean response and confidence ribbon for those values are shown in Figure 6-4 and Table 6-5. Analysis was completed in *R v.* 4.4.4 using base functions (e.g., *lm()* and associated *predict()*). Plots were generated using *ggplot v.* 3.5.5.



Note: Blue dots are Wheeler River predictions, black dots are regional data

Figure 6-4: Predicted Mean Response and Confidence Ribbon – Selenium in Northern Pike

Table 6-5: Predicted Mean Lower and Upper Northern Pike Tissue Selenium Concentrations

	Water Concentration LA-5	Fish Muscle Tissue (Mean Value)	Fish Muscle Tissue (Low Value)	Fish Muscle Tissue (Upper Value)
Lake	**mg/L**	**µg/g fw**	**µg/g fw**	**µg/g fw**
Reference	3.35E-05	1.89E-01	1.06E-01	3.36E-01
Whitefish Lake North	3.28E-05	1.86E-01	1.04E-01	3.31E-01
Whitefish Lake Middle	4.33E-04	1.57E+00	1.23E+00	2.00E+00
Whitefish Lake South	4.12E-04	1.51E+00	1.18E+00	1.93E+00
McGowan Lake	2.59E-04	1.02E+00	7.65E-01	1.37E+00
Russell Lake	1.95E-04	8.12E-01	5.85E-01	1.12E+00

Using the range of the uncertainty in the northern pike BAF (from Table 6-5), fish muscle tissue selenium concentrations were calculated for the various lakes, using site-specific moisture content and the species-specific US EPA (2021d) conversion factors (see Table 6-3).

For reference, as indicated previously the whole body tissue and egg-ovary concentrations do not exceed the FEQGs (ECCC, 2022) for the mean BAF (Table 6-4). As shown in Table 6-6, the resulting whole-body tissue and egg-ovary concentrations do not exceed the FEQGs (ECCC, 2022) for the BAF lower range of uncertainty. At the upper range of the BAF, the egg-ovary concentration in Whitefish Lake exceeds the whole-body guideline of 6.7 µg/g dw and the egg-ovary guideline of 14.7 µg/g dw from ECCC (2022). At all other lakes the predicted whole-body and egg-ovary concentrations are below the selenium guidelines.

The results of the ERA and EIS are interpreted based on the expected mean BAF. Based on the expected selenium BAF, no significant adverse effects are predicted to northern pike from exposure to selenium. The uncertainty results provide a range (lower and upper) around the risk; however, there are numerous conservative assumptions in the overall assessment that would indicate the expected BAF is sufficiently conservative.

Table 6-6: Calculated Whole Body and Egg-Ovary Selenium Concentrations – Range of Uncertainty

FEQG (µg/g dw)						6.7	6.7	14.7	14.7
	Water Concent-ration	Fish Muscle Tissue (Lower Value)	Fish Muscle Tissue (Upper Value)	Fish Muscle Tissue (Lower Value)	Fish Muscle Tissue (Upper Value)	Whole Body (Lower Value) (b)	Whole Body (Upper Value) (b)	Egg-Ovary (Lower Value) (c)	Egg-Ovary (Upper Value) (c)
Lake	**mg/L**	**µg/g fw**	**µg/g fw**	**µg/g dw**	**µg/g dw**	**µg/g dw**	**µg/g dw**	**µg/g dw**	**µg/g dw**
Reference	3.35E-05	1.06E-01	3.36E-01	4.82E-01	1.53E+00	0.38	1.20	0.91	2.87
Whitefish Lake North	3.28E-05	1.04E-01	3.31E-01	4.72E-01	1.50E+00	0.37	1.18	0.89	2.83
Whitefish Lake Middle	4.33E-04	1.23E+00	2.00E+00	5.59E+00	9.07E+00	4.40	**7.14**	10.51	**17.06**
Whitefish Lake South	4.12E-04	1.18E+00	1.93E+00	5.35E+00	8.74E+00	4.21	**6.88**	10.05	**16.44**
McGowan Lake	2.59E-04	7.65E-01	1.37E+00	3.48E+00	6.24E+00	2.74	4.91	6.54	11.73
Russell Lake	1.95E-04	5.85E-01	1.12E+00	2.66E+00	5.10E+00	2.09	4.02	5.00	9.59

Notes:

(a) The site-specific moisture content for northern pike of 77.98% was used to convert from fresh weight to dry weight.

(b) A Muscle:Whole Body ratio of 1.27 was used for northern pike from Table B-4, B-5, US EPA 2021d.

(c) An Egg-Ovary:Muscle ratio of 1.88 was used for northern pike from Table B-3, US EPA 2021d.

Bold indicates exceedance of the selenium guideline.

6.3.2 Copper Aquatic Toxicity Reference Values

Since initiation of the ERA, ECCC has developed an updated FEQG for copper for protection of freshwater aquatic life based on the biotic ligand model (BLM) (ECCC, 2021). The FEQG is calculated based on site-specific concentrations of DOC, hardness, temperature and pH.

As identified in Section 5.3.1.1, TRVs for copper were obtained from the US EPA Ecotoxicology Database (ECOTOX) for aquatic organisms. The selected TRVs were 20% Effect Concentrations (i.e., EC_{20} values), which are concentrations at which only 20% of the test organisms respond. The TRVs used in the ERA for HQ calculations are shown in Table 5-12.

The TRVs for aquatic organisms have been re-evaluated using the FEQG and the BLM. The BLM was run based on baseline site-specific conditions (hardness of 5.26 mg/L, DOC of 2.24 mg/L, pH of 6.61, temperature of 13°C). The test species and concentrations identified as used to generate the BLM were evaluated to develop TRVs for the applicable biotic groups. The most restrictive effect concentration for each biotic group was identified. The test endpoint was either an EC_{10} or an IC_{10}. Based on the protocol identified in Table 5-11, the EC_{10} (or IC_{10}) was multiplied by 2 to obtain an EC_{20}, which was then utilized as the TRV. A summary of the TRVs for baseline conditions is identified in Table 6-7.

Considering that while the facility is in operation and during periods of treated effluent discharge it is expected that hardness in the receiving environment will increase to approximately 9 mg/L and pH will increase to approximately 7, the BLM was re-run under those conditions and the TRVs were re-evaluated based on the test species and concentrations used to generate the BLM. The copper TRVs under site conditions are presented in Table 6-8.

Table 6-7: Copper Toxicity Reference Values from Baseline Conditions BLM

COPC	Biotic Group	TRV	Unit	Rationale	Data Source
Copper	Forage fish	0.00517	mg/L	Fathead minnow, growth (IC_{10} = 0.0026 mg/L)	FEQG BLM
	Predator fish	0.000776	mg/L	White sturgeon, growth (EC_{10} = 0.0004 mg/L)	FEQG BLM
	Zooplankton	0.000886	mg/L	Daphnia magna, reproduction (EC_{10} = 0.0004 mg/L)	FEQG BLM
	Benthic invertebrates	0.000417	mg/L	Pond snail, growth (EC_{10} = 0.0002 mg/L)	FEQG BLM
	Phytoplankton	0.00913	mg/L	Rotifer, intrinsic (EC_{10} = 0.0046 mg/L)	FEQG BLM
	Aquatic plants	0.0212	mg/L	Duckweed, root length (EC_{10} = 0.01 mg/L)	FEQG BLM

Notes:
BLM based on hardness of 5.26 mg/L, DOC of 2.24 mg/L, pH of 6.61, temperature of 13°C.
TRV is an EC_{20}, adjusted from an EC_{10} or IC_{10}.

Table 6-8: Copper Toxicity Reference Values from Site Conditions BLM

COPC	Biotic Group	TRV	Unit	Rationale	Data Source
Copper	Forage fish	0.0104	mg/L	Fathead minnow, growth (IC_{10} = 0.005 mg/L)	FEQG BLM
	Predator fish	0.0018	mg/L	White sturgeon, growth (EC_{10} = 0.001 mg/L)	FEQG BLM
	Zooplankton	0.00205	mg/L	Daphnia magna, reproduction (EC_{10} = 0.001 mg/L)	FEQG BLM
	Benthic invertebrates	0.00098	mg/L	Pond snail, growth (EC_{10} = 0.0005 mg/L)	FEQG BLM
	Phytoplankton	0.0174	mg/L	Rotifer, intrinsic (EC_{10} = 0.009 mg/L)	FEQG BLM
	Aquatic plants	0.0153	mg/L	Duckweed, root length (EC_{10} = 0.008 mg/L)	FEQG BLM

Notes:
BLM based on hardness of 9 mg/L, DOC of 2.24 mg/L, pH of 7, temperature of 13°C.
TRV is an EC_{20}, adjusted from an EC_{10} or IC_{10}.

The hazard quotients (HQs) for aquatic organisms were re-evaluated using both sets of TRVs, baseline conditions and site conditions during operation where hardness and pH are increased (Table 6-9). Consistent with Section 5.4.1, an HQ less than or equal to 1 suggests low risk to the ecological receptor, and an HQ above 1 needs further investigation to determine if adverse effects are possible. Conservatively using baseline conditions, HQs for all aquatic organisms are less than 1 with the exception of predator fish in Whitefish Lake, and benthic invertebrates at all locations where HQs are slightly above 1. As such, further consideration was given to changes in site conditions when the facility is in operation.

Using predicted site conditions for hardness and pH, HQs for all aquatic organisms are less than 1 at all downstream locations, indicating no adverse effects to aquatic organisms from facility related copper during periods of treated effluent discharge. It is relevant to consider all aspects of the receiving environment, and this includes induced hardness and pH since the scenario being evaluated only occurs during periods of effluent discharge. This approach is used in other jurisdictions (e.g., water licences in northern Canada issued through local water boards) and therefore the concept of induced hardness is not unique.

The copper predictions are considered conservative based on the following assumptions:

- Baseline concentrations of copper are predominantly below the detection limit, indicating that baseline concentrations of copper are likely overestimated in the ERA.
- Based on the effluent quality and quantity released to Whitefish Lake, the maximum copper concentration in Whitefish Lake and downstream waterbodies was evaluated as part of the HQ. This is a conservative assumption.
- Once the facility is operational, site conditions will change which includes increased hardness and pH; therefore, the predicated HQs under baseline conditions are considered conservative and overestimate risk.

Table 6-9: Re-Evaluated Hazard Quotients for Copper in Aquatic Organisms

Location	Maximum Copper Concentration in Water (mg/L)	Hazard Quotients (unitless) – Baseline Conditions						Hazard Quotients (unitless) – Site Operation Conditions					
		Forage Fish	Predator Fish	Zooplankton	Benthic Invertebrate	Phyto-plankton	Aquatic Plants	Forage Fish	Predator Fish	Zooplankton	Benthic Invertebrate	Phytoplankton	Aquatic Plants
Kratchkowsky Lake (reference) [1]	6.22E-04	0.12	0.80	0.70	**1.49**	0.07	0.03	0.12	0.80	0.70	**1.49**	0.07	0.03
Whitefish Lake North	6.20E-04	0.12	0.80	0.70	**1.49**	0.07	0.03	0.06	0.34	0.30	0.63	0.04	0.04
Whitefish Lake Middle	8.22E-04	0.16	**1.06**	0.93	**1.97**	0.09	0.04	0.08	0.46	0.40	0.84	0.05	0.05
Whitefish Lake South	8.17E-04	0.16	**1.05**	0.92	**1.96**	0.09	0.04	0.08	0.45	0.40	0.83	0.05	0.05
McGowan Lake	7.50E-04	0.14	0.97	0.85	**1.80**	0.08	0.04	0.07	0.42	0.37	0.76	0.04	0.05
Icelander River	7.49E-04	0.14	0.97	0.84	**1.80**	0.08	0.04	0.07	0.42	0.37	0.76	0.04	0.05
Russell Lake Inlet	7.17E-04	0.14	0.92	0.81	**1.72**	0.08	0.03	0.07	0.40	0.35	0.73	0.04	0.05

Note:

Bold and shaded value indicates hazard quotient greater than 1.

[1] Kratchkowsky Lake is a reference lake located upstream of the effluent discharge point, and as such, the site operation conditions were the same as baseline conditions.

7.0 Conclusions and Recommendations

The selection of human and ecological receptors for inclusion in the ERA was informed by Indigenous and Local Knowledge, information from baseline studies, as well as professional judgement. The assumptions made for the Traditional Foods diet (i.e., amounts consumed and food types) was informed by an existing ERFN country foods study and through engagement with a local fisher/trapper.

The ERA focused on COPCs that exceeded screening values in air and water based on predicted atmospheric releases and aqueous releases (treated effluent) from the Wheeler River Project. The final list of COPCs included: arsenic, cadmium, chromium, cobalt, copper, molybdenum, selenium, uranium, vanadium, zinc, sulphate, chloride, and total dissolved solids.

Radionuclides of the uranium-238 series, including radon, were included as COPCs because these constituents are of public interest.

7.1 Human Health Risk Assessment

The HHRA estimated dose and risk during all Project phases to the following receptors: camp worker, seasonal resident, recreational fisher/hunter, fisher/trapper, and during future centuries to the future permanent resident. The future centuries reflect the time period over which the highest constituent concentrations in groundwater are predicted to migrate towards and interact with surface water post-restoration (i.e. beyond the Project timeline of 0-38 years).

During Post-Decommissioning, the Project area could be accessed intermittently by members of the public for various land use purposes. Any risks to these members of the public would be less than those assessed for the camp work and therefore the Project area would be safe for periodic land use during this period.

7.1.1 Non-radiological Human Health Risk Assessment

For assessment of non-carcinogens, risk was estimated based on Project total HQs (includes the Project risk in addition to the baseline risk) and Project incremental HQs (includes the Project risk only with baseline component removed). Project incremental HQs were compared to a benchmark HQ value of 0.2 because total background exposures (e.g. store-bought foods) were not included in the incremental HQ. This approach is consistent with Health Canada's guidance on human health preliminary quantitative risk assessment (Health Canada, 2021a).

The Project incremental HQ was predicted to remain below 0.2 for human receptors for all non-carcinogens and all pathways during all phases of the Project, with the exception of selenium for the fisher/trapper at Russell Lake from the fish ingestion pathway. The traditional foods diet for the fisher/trapper is conservative as it assumes a high annual fish consumption rate of 183 kg/yr (approximately 1 to 2 servings per day) and assumes that all fish consumed in the diet is obtained from the Project area. The diet of the fisher/trapper is representative of one person, who consumes a unique composition and quantity of traditional foods. Most people fishing, hunting, and trapping in the LSA and RSA would consume traditional foods more consistent with the average traditional foods consumer diet which was developed from the ERFN country foods study (CanNorth, 2017). During the future centuries there are no precited exceedances of the HQ benchmark (HQ<0.2) for human receptors, including the permanent resident, for any non-carcinogens.

The results are also discussed in terms of the total Project HQ (baseline plus Project). Since the Project total HQ includes background contributions from store-bought foods, a benchmark HQ value of 1 was considered. The Project total HQs for the fisher/trapper for selenium are predicted to be equal to or greater than 1. Since the Project incremental HQs for the fish ingestion pathway for selenium are predicted to be above 0.2, this indicates that the Project is expected to contribute to selenium in the environment and the food chain.

For assessment of risk for carcinogens (arsenic), the ILCR was estimated and compared against the cancer risk level of 1 in 100,000 recommended by Health Canada (Health Canada, 2021a). Incremental cancer risk was predicted to remain below the negligible cancer risk level of 1 in 100,000 for the camp worker, recreational fisher/hunter, and seasonal resident during the Project phases. The incremental cancer risk was predicted to be essentially equal to the negligible cancer risk level of 1 in 100,000 for the adult fisher/trapper at Russell Lake. These findings for the fisher/trapper are based on the conservative assumption of high consumption of Traditional Foods including fish and caribou in the LSA and RSA. As indicated above, the diet of the fisher/trapper is representative of one person, who consumes a unique composition and quantity of traditional foods. During the future centuries the cancer risk was not predicted to exceed the negligible cancer risk level of 1 in 100,000 for any human receptors, including the permanent resident.

7.1.2 Radiological Human Health Risk Assessment

The incremental radiation dose to all human receptors during all Project phases is predicted to be below the regulatory public dose limit of 1 mSv/yr and the dose constraint of 0.3 mSv/yr during all Project phases and in the future centuries. The maximum incremental radiological dose is predicted to be 0.06 mSv/yr to the fisher/trapper at Russell Lake. The total incremental dose to the camp worker from all radionuclides in the U-238 decay chain including radon would be 0.16 mSv/year, which is below the dose limit for a non-NEW of 1 mSv/yr.

Overall, since the radiation dose estimates would be below the dose limit, no discernable health effects are anticipated due to exposure of these receptors to radioactive releases from the Project.

7.2 Ecological Risk Assessment

The EcoRA estimated dose and risk to representative aquatic and terrestrial receptors during all Project phases and the future centuries. The future centuries reflect the time period over which the highest constituent concentrations in groundwater are predicted to migrate towards and interact with surface water post-restoration (i.e. beyond the Project timeline of 0-38 years).

Species at risk were either assessed directly or were represented by other more common species that have similar diets and exposure pathways.

7.2.1 Non-radiological Ecological Risk Assessment

The potential for ecological effects was assessed by comparing exposure levels to toxicological benchmarks and was characterized quantitatively in terms of total HQs. A total HQ greater than 1 indicates adverse effects may be possible for a given ecological receptor and further investigation would be warranted.

No significant adverse effect on either aquatic or terrestrial populations or communities, as a result of releases from the Project, are predicted during the Project phases or during the future centuries. All estimated total HQs for all COPCs, except copper, for all ecological receptors are predicted to remain below the HQ benchmark of 1. Under baseline conditions as well as the future centuries, copper HQs for all aquatic organisms are less than 1 with the exception of predator fish in Whitefish Lake, and benthic invertebrates at all locations where HQs are slightly above 1. Using operational site conditions for hardness and pH, copper HQs for all aquatic organisms are less than 1 at all downstream locations, indicating no adverse effects to aquatic organisms from facility related copper (Section 6.3.2). Since there are no total HQs above 1 for birds and mammals, individual species at risk would also be considered protected.

7.2.2 Radiological Ecological Risk Assessment

Radiation dose benchmarks of 9.6 mGy/d and 2.4 mGy/d (UNSCEAR, 2008) were selected for the assessment of effects on aquatic biota and terrestrial biota, respectively, as recommended in CSA N288.6-22.

There were no predicted exceedances of the 9.6 mGy/d radiation dose benchmark for aquatic biota or the 2.4 mGy/d radiation dose benchmark for terrestrial and riparian biota during any Project phase or during the future centuries.

Since there were no predicted exceedances of the respective dose benchmarks for any of the aquatic or terrestrial receptors, individual species at risk would also be considered protected.

Overall, it is unlikely that there would be potential adverse effects on terrestrial or aquatic populations or communities as a result of radionuclide releases from the Project.

7.3 Monitoring and Follow-up

The ERA was developed based on best available information for the Project, including baseline monitoring data, assumptions on source-terms, and Traditional Foods diet (intake rates and food types).

Monitoring should focus on collecting data to verify ERA model predictions, as well as provide data to improve model predictions as the Project begins. Recommended monitoring would support Denison's environmental protection framework with the goal of reducing uncertainty over time through an iterative process:

Air quality: With the exception of uranium, there were no predicted exceedances of annual screening values for any constituents, indicating that unacceptable chronic effects from direct exposure to air are not expected. Uranium exceeded its annual screening value at the on-site ecological receptor location, but not at the camp. Some short-term exceedances, based on maximum predicted concentrations, were predicted to occur at the camp and at the fence line for nitrogen dioxide (1 hour) and particulate matter (24 hour), and for uranium in TSP and PM_{10}. The predicted exceedances would be infrequent, short-term, and limited spatially. Any public visits to these locations would be very infrequent. Unacceptable levels of risk are not expected from infrequent, short-term exposures to these constituents in air. However, it is recommended that these constituents be monitored in accordance with provincial and federal guidelines and standards (i.e., CAAQS) as part of any Air Emissions Monitoring Plan. Additionally, for NO_2, monthly collection of passive samplers will be performed.

Environmental monitoring: Denison is implementing an Environmental Monitoring Program consistent with requirements and guidance in CSA N288.4-19: *Environmental monitoring programs at nuclear facilities and uranium mines and mills* (CSA, 2019). Monitoring would focus on providing data to verify the predictions made by the ERA, to refine the models used in the ERA, and to reduce the uncertainty in the predictions made by the ERA. The Environmental Monitoring Program should include collection of surface water, sediment, and soil samples as well as fish tissue samples, benthic invertebrate tissue samples, and country foods such as blueberries. Monitoring locations would be focused in the area of Whitefish Lake, McGowan Lake and Russell Lake. Monitoring constituents would include those identified as COPCs in the ERA, including metals and uranium-238 series radionuclides, and chloride and sulphate in lake waters. However, monitoring could extend to include other constituents for other purposes, such as meeting regulatory requirements for monitoring, or addressing constituents of public interest based on experience at other uranium mines and process plants.

8.0 References

Alberta, 2021. Alberta Ambient Air Quality Objectives [WWW Document]. Ambient Air Quality Objectives and supporting documents. URL https://www.alberta.ca/ambient-air-quality-objectives.aspx#jumplinks-5

Arrington, L.R., Davis, G.K., 1953. Molybdenum toxicity in the rabbit. J. Nutr. 51, 295–304.

ATSDR, 2007. Toxicological Profile for Arsenic.

ATSDR, 2004. Toxicological Profile for Cobalt [WWW Document]. URL http://www.atsdr.cdc.gov/toxprofiles/tp33.pdf

Bartlett, A., 2009. An assessment of the chronic toxicity of sodium chloride to Hyalella azteca (Unpublished data presented at the 1st International Conference on Urban Drainage and Road Salt Management in Cold Climates: Advances In Best Practices.). University of Waterloo.

BC Conservation Data Centre, 1993. Species Summary: Myodes gapperi [WWW Document]. BC Ministry of Environment.

BC MECCS, 2020. 2020. B.C. Source Drinking Water Quality Guidelines: Guideline Summary.

BC MOE, 2013. Ambient Water Quality Guideline for Sulphate. Technical Appendix. Update. BC Ministry of Environment. Water Protection & Sustainability Branch.

Beak International Inc, 1999. Ecotoxicology test results (Unpublished report for M.S. Evans). Environment Canada, National Water Research Institute.

Beresford, N.A., Gaschak, S., Barnett, C.L., Howard, B.J., Chizhevsky, I., Stromman, G., Oughton, D.H., Wright, S.M., Maksimenko, A., Copplestone, D., 2008. Estimating the exposure of small mammals at three sites within the Chernobyl exclusion zone – a test application of the ERICA Tool. Journal of Environmental Radioactivity. Journal of Environmental Radioactivity 1496–1502.

Beyer, W.N., Connor, E., Gerould, S., 1994. Estimates of Soil Ingestion by Wildlife. J. Wildl. Manage. 58.

Birge, W.J., Black, J.A., Westerman, A.G., Short, T.M., Taylor, S.B., Bruser, D.M., Wallingford, E.D., 1985. Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warm water species of aquatic life in the Commonwealth of Kentucky. Memorandum of Agreement No. 5429. Kentucky Natural Resources and Environmental Protection Cabinet, Lexington.

Birge, W.J., Hudson, J.E., Black, J.A., Wasterman, A.G., 1979. Embryo-larval Bioassays on Inorganic Coal Elements and In Situ Biomonitoring of Coal-waste Effluents, in: Surface Mining and Fish/Wildlife Needs in the Eastern United States. Fish and Wildlife Service, Office of Biological Services, pp. 97–104.

Brown, J., Alfonso, B., Avila, R., Beresford, N.A., Copplestone, N.A., Hosseini, A., 2016. A new version of the ERICA tool to facilitate impact assessments of radioactivity on wild plants and animals. Journal of Environmental Radioactivity 153, 141–148.

Brown, J., Strand, P., Hosseini, A., Borretzen, P., 2003. Handbook for Assessment of the Exposure of Biota to Ionising Radiation from Radionuclides in the Environment.

Brown, J.E., Alfonso, B., Avila, R., Beresford, N.A., Copplestone, D., Prohl, G., Ulanovsky, A., 2008. The ERICA Tool. Journal of Environmental Radioactivity 99, 1371–1383.

Buckley, J.A., Rustagi, K.P., Laughlin, J.D., 1996. Response of Lemna minor to sodium chloride and a statistical analysis of continuous measurements for EC50 and 95% confidence limits calculation. Bulletin of Environmental Contamination and Toxicology 57, 1003–1008.

Burnett-Seidel, C., Liber, K., 2013. Derivation of no-effect and reference-level sediment quality values for application at Saskatchewan uranium operations. Environ. Monit. Assess. 185, 9481–9494.

Cal OEHHA, 2000. Proposed Action Level for Vanadium. California Office of Environmental Health Hazard Assessment.

CanNorth, 2018. Human Health Risk Assessment for the Eastern Athabasca Basin. Final Report. October.

CanNorth, 2017. English River First Nation Country Foods Study – Final Report (No. Project No. 2147). Canada North Environmental Services.

CanNorth, 2000. Hatchet Lake Dietary Survey – Field Report (No. Project No. 2147). Canada North Environmental Services.

CCME, 2020. Guidance Document on Achievement Determination for Canadian Ambient Air Quality Standards for Nitrogen Dioxide. PN 1608.

CCME, 2011a. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Chloride Ion (Scientific Criteria Document No. PN 1460). Canadian Council of Mininsters of the Environment, Winnipeg.

CCME, 2011b. Canadian Water Quality Guideline for the Protection of Aquatic Life. Uranium. Canadian Council of Mininsters of the Environment.

CCME, 2008. Canadian Water Quality Guidelines.

CCME, 2007. A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. Canadian Council of Ministers of the Environment.

CCME, 1999a. Canadian Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life (updated September 2007). Canadian Council of Ministers of the Environment.

CCME, 1999b. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Thallium 1999. Canadian Council of Ministers of the Environment.

CCME, 1995. Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (No. CCME EPC-98E). Canadian Council of Ministers of the Environment.

Chan, L., Receveur, O., Sadik, T., Schwartz, H., Ing, A., Fediuk, K., Tikhonov, C., 2018. First Nations Food, Nutrition and Environment Study (FNFNES): Results from Saskatchewan (2015). University of Ottawa, Ottawa.

Chapman, P.M., Allen, H.E., Z'Graggen, M.N., 1996. Evaluation of bioaccumulation factors in regulating metals. Environ. Sci. Technol. 30, 448A-452A.

Chen, C.J., Chuang, Y.C., Lin, T.M., Wu, H.Y., 1985. Malignant neoplasms among residents of a blackfoot disease-endemic area in Taiwan: High-arsenic artesian well water and cancers. Cancer Research 45, 5895–5899.

CNSC, 2020. Environmental Protection. Environmental Principles, Assessments and Protection Measures. REGDOC-2.9.1, Version 1.2. Canadian Nuclear Safety Commission.

COSEWIC, 2018. Olive-sided Flycatcher (Contopus cooperi): COSEWIC Assessment and Status Report 2018. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Crane, M., Flower, T., Holmes, D., Watson, S., 1992. The toxicity of selenium in experimental freshwater ponds. Arch. Environ. Contam. Toxicol. 23, 440–452.

CSA, 2022. N288.6:22. Environmental risk assessments for nuclear facilities and uranium mines and mills. Canadian Standards Association.

CSA, 2020. Guidelines for modelling radionuclide environmental transport, fate, and exposure associated with the normal operation of nuclear facilities (No. CSA N288.1-20). Canadian Standards Association.

CSA, 2019. Environmental monitoring programs at nuclear facilities and uranium mines and mills. CSA N288.4-19.

CSA, 2012. Environmental risk assessments at Class I nuclear facilities and uranium mines and mills (No. CSA N288.6-12). Canadian Standards Association.
CWF, 2022. Canada Lynx [WWW Document]. The Canadian Wildlife Federation.
Davis, J.E., Fields, J.P., 1958. Experimental production of polycythemia in humans by administration of cobalt chloride. Proc Soc Exp Biol Med 99, 493–495.
Denison, 2019. Wheeler River Project - Provincial Technical Proposal and Federal Project Description. Denison Mines Corp.
DFO, 2018. Northern Pike [WWW Document]. Fisheries and Oceans Canada.
DFO, 2016. White Sucker [WWW Document]. Fisheries and Oceans Canada.
Dodds-Smith, M.E., Johnson, M.S., Thompson, D.J., 1992. Trace metal accumulation by the shrew sorex araneus. ii. tissue distribution in kidney and liver. Ecotoxicol Environ Saf. 24, 118–130.
Domingo, J.L., Paternain, J.L., Llobet, J.M., Corbella, J., 1986. Effects of vanadium on reproduction, gestation, parturition and lactation in rats upon oral administration. Life Sciences 39, 819–824.
Doyle, J.J., Pfander, W.H., Grebing, S.E., Pierce, J.O., 1974. Effect of dietary cadmium on growth, cadmium absorption and cadmium tissue levels in growing lambs. J. Nutr. 104, 160–166.
Durante, M., Pugliese, M., 2002. Estimates of radiological risk from depleted uranium weapons in war scenarios. Health Physics 82, 14–20.
EC and HC, 2003. Priority Substances List Assessment Report: Releases of Radionuclides from Nuclear Facilities (Impact on Non- Human Biota) (PSL2). Environment Canada and Health Canada.
EC and HC, 1993. Priority Substances List Assessment Report for Arsenic and its Compounds. Environment Canada and Health Canada, Ottawa.
ECCC, 2022. Federal Environmental Quality Guidelines Selenium. Environment and Climate Change Canada.
ECCC, 2021. Federal Environmental Quality Guidelines Copper. Environment and Climate Change Canada.
ECCC, 2018. Canada and Cackling Geese: Management and Population Control in Southern Canada. Canadian Wildlife Service, Environment Canada.
Ecometrix, 2022. Numerical Modelling: Post-Decommissioning Evaluation (Report prepared for Denison Mines Corporation). Ecometrix Incorporated.
Ecometrix, 2020. Wheeler River Project: Baseline Aquatic Environment Study (Report prepared for Denison Mines Corporation). Ecometrix Incorporated.
Elbetieha, A., Al-Hamood, M.H., 1997. Long-term exposure of male and female mice to trivalent and hexavalent chromium compounds: effect on fertility. Toxicology 116, 39–47.
Elphick, J.R., Davies, M., Gilron, G., Canaria, E.C., 2011. An aquatic toxicological evaluation of sulfate: The case for considering hardness as a modifying factor in setting water quality guidelines. Environ. Toxicol. Chem. 30, 247–253.
Elphick, J.R.F., Bergh, K.D., Bailey, H.C., 2011. Chronic toxicity of chloride to freshwater species: effects of hardness and implications for water quality guidelines. Environmental Toxicology and Chemistry 30, 239–249.
ERFN, 2011. English River First Nation, Aboriginal Traditional Knowledge Summary Report. Compiled by Environment Canada. English River First Nation.
ERFN, SVS, 2022a. Wheeler River Project – Summary of Health and Socio-Economic Study Results (Prepared for English River First Nation). English River First Nation (ERFN); Shared Value Solutions (SVS).
ERFN, SVS, 2022b. Wheeler River Project – Summary of Traditional Knowledge Study Results (Prepared for English River First Nation No. Project No. 2147). English River First Nation (ERFN); Shared Value Solutions (SVS).

FCSAP, 2012. Ecological Risk Assessment Guidance, Module 3: Standardization of Wildlife Receptor Characteristics. Environment Canada, Vancouver, B.C.

Gilman, A.P., Villeneuve, D.C., Secours, V.E., Yagminas, A.P., Tracy, B.L., Quinn, J.M., Valli, V.E., Wiles, R.J., Moss, M.A., 1998. Uranyl nitrate: 28-day and 91-day toxicity studies in the Sprague-Dawley rat. Toxicological Science 41, 117–128.

Goettl, J.P.Jr., Davies, P.H., Sinley, J.R., 1976. Water Pollution Studies, in: D.B.Cope (Ed.), Colorado Fish.Res.Rev.1972-1975, DOW-R-R-F72-75, Colorado Div.of Wildl. Boulder, pp. 68–75.

Government of Saskatchewan, 2015. Table 20: Saskatchewan Ambient Air Quality Standards.

Grobner, M.A., Cheeke, P.R., Patton, N.M., 1986. Effect of Dietary Copper and Oxytetracycline on Growth and Mortality of Weanling Rabbits. Journal of Applied Rabbit Research 9, 46–53.

Hamilton, S.J., Mehrle, P.M., 1986. Metallothionein in fish: review of its importance in assessing stress from metal contaminants. Transactions of the American Fisheries Society 115, 596–609.

Haseltine, S.D., Sileo, L., 1983. Response of American Black Ducks to Dietary Uranium: A Proposed Substitute for Lead Shot. Journal of Wildlife Management 47, 1124–1129.

Haseltine, S.D., Sileo, L., Hoffman, D.J., Mulhern, B.M., 1986. Effects of chromium on reproduction and growth of black ducks. Unpublished (Cited in Eisler, 1986 & Custer Et Al., 1986).

Health Canada, 2021a. Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 3.0.

Health Canada, 2021b. Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs) Version 3.0.

Health Canada, 2020. Guidelines for Canadian Drinking Water Quality - Summary Table. September 2020.

Health Canada, 2019a. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document—Copper. Health Canada, Ottawa.

Health Canada, 2019b. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document—Uranium. Health Canada, Healthy Environments and Consumer Safety Branch, Ottawa.

Health Canada, 2018. Guidance for Evaluating Human Health Impacts in Environmental Assessments: Country Foods. Report No. H129- 54/5- 2018E-PDF.

Health Canada, 2016a. Guidance for evaluating Human Health Impacts in Environmental Assessment: Air Quality. Health Canada.

Health Canada, 2016b. Human Health Risk Assessment for Ambient Nitrogen Dioxide. Health Canada, Healthy Environments and Consumer Safety Branch.

Health Canada, 2016c. Human Health Risk Assessment for Coarse Particulate Matter. Health Canada. Healthy Environments and Consumer Safety Branch.

Health Canada, 2013. Interim Guidance on Human Health Risk Assessment for Short-Term Exposure to Carcinogens at Contaminated Sites. Federal Contaminated Sites Risk Assessment in Canada.

Health Canada, 2011. Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM). Prepared by the Canadian NORM Working Group of the Federal Provincial Territorial Radiation Protection Committee.

Health Canada, 2010a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. Contaminated Sites Program. Health Canada.

Health Canada, 2010b. Federal Contaminated Site Risk Assessment in Canada. Part VI: Guidance on Human Health Detailed Quantitative Radiological Risk Assessment (DQRARAD). Health Canada.

Health Canada, 2010c. Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0. September.
Health Canada, 2006. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document—Arsenic. Health Canada, Healthy Environments and Consumer Safety Branch, Ottawa.
Health Canada, 2004. Canadian Community Health Survey Cycle 2.2, Nutrition (2004) - A Guide to Accessing and Interpreting the Data (No. No. 4627). Office of Nutrition Policy and Promotion, Health Canada, Ottawa, ON.
Health Canada, 1998. National Ambient Air Quality Objectives for Particulate Matter. Executive Summary. Part 1: Science Assessment Document. Health Canada.
Health Canada, 1991. Guidelines for Canadian Drinking Water Quality: Guideline Technical Document—Total Dissolved Solids (TDS).
Hesterberg TW, Bunn WB, McClellan RO, Hamade AK, Long CM, Valberg PA, 2009. Critical review of the human data on short-term nitrogen dioxide (NO2) exposures: evidence for NO2 no-effect levels. Critical Reviews in Toxicology 39, 743–81.
Howell, G.O., Hill, C.H., 1978. Biological Interaction of Selenium with Other Trace Elements in Chicks. Environ. Health Perspect. 25, 147–150.
Hunder, G., Schaper, J., Ademuyiwa, O., Elsenhans, B., 1999. Species Differences in Arsenic-mediated Renal Copper Accumulation: A Comparison between Rats, Mice and Guinea Pigs. Hum. Exp. Toxicol. 18, 699–705.
ICRP, 2008. Environmental Protection - the Concept and Use of Reference Animals and Plants, ICRP Publication 108. International Commission on Radiological Protection.
ICRP, 2003. Basic Anatomical and Physiological Data for Use in Radiological Protection: Reference Values (No. Publication 89). International Commission on Radiological Protection.
ICRP, 1994. Dose Coefficients for Intakes of Radionuclides by Workers., Publication 68. Annals of the ICRP 24(4). International Commission on Radiological Protection.
IOM, 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Food and Nutrition Board of the Institute of Medicine of the National Academies, Washington, D.C.
IOM, 2000. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium and Carotenoids. Food and Nutrition Board of the Institute of Medicine of the National Academies, Washington, D.C.
Ivankovic, S., Preussmann, R., 1975. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. Food and Cosmetics Toxicology 13, 347351.
Jenkins, K.J., Hidiroglou, M., 1986. Tolerance of the preruminant calf for selenium in milk replacer. J Dairy Sci. 69, 1865–1870.
Jenner, H.A., Janssen-Mommen, J.P.M., 1993. Duckweed Lemna minor as a tool for testing toxicity of coal residues and polluted sediments. Arch. Environ. Contam. Toxicol. 25, 3–11.
Kessler, E., 1974. Physiological and biochemical contributions to the taxonomy of the genus Chlorella. IX: Salt tolerance as a taxonomic character. Archives of Microbiology 100, 51–56.
KML, NVP, 2022a. Kineepik Métis Local #9 Kineepik Valued Ecosystem Components (KML Pre-statement for Denison EIS). Kineepik Métis Local (KML); Northern Village of Pinehouse Lake (NVP).
KML, NVP, 2022b. Response to the Environment Impact Assessment. (For the Proposed Ministry of Highways 914 Extension Project.). Kineepik Métis Local (KML); Northern Village of Pinehouse Lake (NVP).

KPI Program, 2020. Cabin owner survey conducted by Denison Mines. February 14-24, 2020. Key Person Interview Program (KPI Program).
KPI Program, 2019. Interview with the English River First Nation trapper conducted by Denison Mines (Notes finalized January 2, 2020.). Key Person Interview Program (KPI Program).
KPI Program, 2018. ERFN Patuanak Reserve workshop conducted by Denison Mines. Key Person Interview Program (KPI Program).
Laird, B.D., Chan, H.N., 2013. Bioacessibility of metals in fish, shellfish, wild game, and seaweed harvested in British Columbia, Canada. Food and Chemical Toxicology 58, 381–387.
Liber, K.S., deRosemond, S., Budnick, K., 2007. Uranium Toxicity to Regionally-Representative Algae and Invertebrate Species. Toxicology Centre, University of Saskatchewan, for AREVA Resources Inc. and Cameco Corporation.
Lynch, G.P., Smith, D.F., Fisher, M., Pike, T.L., Weinland, B.T., 1976. Physiological responses of calves to cadmium and lead. J. Anim. Sci. 42, 410–421.
May-Passino, D.R.M., Novak, A.J., 1987. Toxicity of arsenate and DDT to the Cladoceran Bosmina longirostris. Bull.Environ.Contam.Toxicol. 33, 325–329.
McConnell, R.P., 1977. Toxicity of molybdenum to rainbow trout under laboratory conditions., in: Chappell, W.R. and K.K. Peterson (Eds.). Molybdenum in the Environment. Volume 2. The Geochemistry, Cycling, and Industrial Uses of Molybdenum. Marcel Dekker, New York.
MECP, 2020. Ontario's Ambient Air Quality Criteria. Ministry of the Environment, Conservation and Parks.
MECP, 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Standards Development Branch. Ontario Ministry of the Environment, Conservation and Parks.
Meluzzi, A., Simoncini, F., Sirri, F., Vandi, L., Giordani, G., 1996. Feeding hens diets supplemented with heavy metals (chromium, nickel and lead). Archiv Fuer Gefluegelkunde 60, 119–125.
Miller, W.J., Amos, H.E., Gentry, R.P., Blackmon, D.M., Durrance, R.M., Crowe, C.T., Fielding, A.S., Neathery, M.W., 1989. Long-term feeding of high zinc sulfate diets to lactating and gestating dairy cows. J. Dairy Sci. 72, 1499–1508.
Morales, K.H., Ryan, L., Kuo, T.L., Wu, M.M., Chen, C.J., 2000. Risk of internal cancers from arsenic in drinking water. Environmental Health Perspectives 108, 655–661.
Morrison, L.L., Chavez, E.R., 1983. Selenium-arsenic Interaction in the Weanling Pig. Canadian Journal of Animal Science 63, 239–246.
NCC, 2022. Moose [WWW Document]. Nature Conservancy Canada.
Nemec, M.D., Holson, J.F., Farr, C.H., Hood, R.D., 1998. Developmental Toxicity Assessment of Arsenic Acid in Mice and Rabbits. Reprod. Toxicol. 12, 647–658.
Newman, M.C., Unger, M.A., 2002. Fundamentals of Ecotoxicology, 2nd ed. CRC/Lewis Press, Boca Raton, FL.
NRC, 2021. Woodland caribou – boreal population [WWW Document]. Natural Resources Canada.
NWF, 2021a. Snowshoe Hare [WWW Document]. The National Wildlife Federation.
NWF, 2021b. Black Bear [WWW Document]. The National Wildlife Federation.
NWF, 2021c. Common Loon [WWW Document]. The National Wildlife Federation.
Olivares, M., Pizarro, F., Speisky, H., Lönnerdal, B., Uauy, R., 1998. Copper in Infant Nutrition: Safety of World Health Organization Provisional Guideline Value for Copper Content of Drinking Water. Journal of Pediatric Gastroenterology and Nutrition 26, 251–257.
Omnia, 2020. Denison Mines Corporation Wheeler River Project - Terrestrial Environment Wildlife and Vegetation Baseline Inventory. Omnia Ecological Services.

Ontario MOE, 2011. Ontario Air Standards for Uranium and Uranium Compounds. Ontario Ministry of Environment. Technical Assessment and Standards Development Branch.

Ortolani, E.L., Machado, C.H., Sucupira, M.C.A., 2003. Assessment of Some Clinical and Laboratory Variables for Early Diagnosis of Cumulative Copper Poisoning in Sheep. Vet. Hum. Toxicol. 45, 289.

Paternain, J.L., Domingo, J.L., Ortega, A., Llobet, J.M., 1989. The Effects of Uranium on Reproduction, Gestation, and Postnatal Survival in Mice. Ecotoxicol. Env. Saf. 17, 291–296.

Persaud, D., Jaagumagi, R., Hayton, A., 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality of Ontario. Ministry of Environment and Energy. Ontario.

Phillips, T.D., Nechay, B.R., Neldon, S.L., Kubena, L.F., Heidelbaugh, N.D., Shepherd, E.C., Stein, A.F., Hayes, A.W., 1982. Vanadium-induced inhibition of renal sodium, potassium adenosinetriphosphatase in the chicken after chronic dietary exposure. J. Toxicol. Environ. Health 9, 651–661.

Raisbeck, M.F., O'toole, D., Schamber, R.A., Belden, E.L., Robinson, L.J., 1996. Toxicologic evaluation of a high-selenium hay diet in captive pronghorn antelope (Antilocapra americana). J. Wild. Dis. 32, 9–16.

Rhian, M., Moxon, A.L., 1943. Chronic selenium poisoning in dogs and its prevention by arsenic. J. Pharmacol. Exp. Ther. 78, 249.

Richardson, G.M., 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. Ottawa: O'Connor Associates Environmental Inc.

Sajwan, K.S., Ornes, W.H., 1994. Phytoavailability and bioaccumulation of cadmium in duckweed plants. J. Environ. Sci. Health. A 29, 1035–1044.

Sample, B.E., Opresko, D.M., Suter, G.W.I., 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. United States Department of Energy.

Sample, B.E., Suter, G.W.I., 1994. Estimating Exposure of Terrestrial Wildlife to Contaminants (No. ES/ER/TM-125). Oak Ridges National Laboratory.

Sauter, S., Buxton, K.S., Macek, K.J., Petrocelli, S.R., 1976. Effects of Exposure to Heavy Metals on Selected Fresh Water Fish. Toxicity of Copper, Cadmium, Chromium and Lead to Eggs and Fry of Seven Fish Species (No. EPA-600/3-76-105). U.S. Environmental Protection Agency, Duluth, Minesota.

Schroeder, H.A., Mitchener, M., 1971. Toxic effects of trace elements on the reproduction of mice and rats. Arch. Environ. Health. 23, 102–106.

Smith, J.S., Heinz, G.H., Hoffman, D.J., Spann, J.W., Krynitsky, A.J., 1988. Reproduction in black-crowned night-herons fed selenium. Lake Reservoir Manage 4, 175–180.

Solaiman, S.G., Maloney, M.A., Qureshi, M.A., Davis, G., D'Andrea, G., 2001. Effects of High Copper Supplements on Performance, Health, Plasma Copper and Enzymes in Goats. Small Ruminant Research 41, 127–139.

Stubblefield, W.A., Van Genderen, E., Cardwell, A.S., Heijerick, D.G., Janssen, C.R., De Schamphelaere, A.C., 2020. Acute and Chronic Toxicity of Cobalt to Freshwater Organisms: Using a Species Sensitivity Distribution Approach to Establish International Water Quality Standards. Environmental Toxicology and Chemistry 39, 799–811.

Suter, G.W., Tsao, C.L., 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota (No. ES/ER/TM-96/R2).

Suter, G.W.I., 1996. Risk Characterization for Ecological Risk Assessment of Contaminated Sites. Oak Ridge National Laboratory, Oak Ridge.

Swiergosz, R., Zakrzewska, M., Sawicka Kapusta, K., Bacia, K., Janowska, I., 1998. Accumulation of cadmium in and its effect on bank vole tissues after chronic exposure. Ecotoxicol. Environ. Saf. 41, 130–136.

TCEQ, 2016. Effects Screening Levels (ESLs) Used in the Review of Air Permitting Data [WWW Document]. Texas Commission on Environmental Quality. URL https://www.tceq.texas.gov/toxicology/esl/list_main.html (accessed 10.28.20).

Tetra Tech Inc., 2008. Aquatic Life Water Quality Criteria for Molybdenum, July 9, 2008. Prepared for Nevada Division of Environmental Protection. Bureau of Water Quality Planning.

Thomas, J.W., Moss, S., 1951. The effect of orally administered molybdenum on growth, spermatogenesis and testes histology of young dairy bulls. J. Dairy Sci. 34, 929–934.

Thompson, P.A., Kurias, J., Mihok, S., 2005. Derivation and use of sediment quality guidelines for ecological risk assessment of metals and radionuclides released to the environment from uranium mining and milling activities in Canada. Environ. Monit. Assess. 110, 71–85.

Trabalka, J.R., Gehrs, C.W., 1977. An observation on the toxicity of hexavalent chromium to Daphnia magna. Toxicol. Lett. 1, 131–134.

Underwood, E.J., 1971. Trace elements in human and animal nutrition, in: Molybdenum. Academic Press, New York, pp. 116–140.

UNSCEAR, 2008. Sources and Effects of Ionizing Radiation. Annex E. Effects of Ionizing Radiation on Non-human Biota., Report to the General Assembly with Scientific Annexes. United Nations Scientific Committee on Effects of Ionizing Radiation.

US EPA, 2021a. Indicators: Zooplankton [WWW Document]. National Aquatic Resource Surveys.

US EPA, 2021b. Indicators: Macrophytes [WWW Document]. National Aquatic Resource Surveys.

US EPA, 2021c. Indicators: Phytoplankton [WWW Document]. National Aquatic Resource Surveys.

US EPA, 2021d. 2021 Revision* to: Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2016 (No. EPA 822-R-21-006). United States Environmental Protection Agency.

US EPA, 2007a. Aquatic Life Ambient Freshwater Quality Criteria – Copper. United States Environmental Protection Agency.

US EPA, 2007b. Ecological Soil Screening Levels for Copper (Interim Final). United States Environmental Protection Agency.

US EPA, 2007c. Ecological Soil Screening Levels for Selenium– Interim Final. U.S. Environmental Protection Agency.

US EPA, 2007d. Ecological Soil Screening Levels for Zinc – Interim Final. U.S. Environmental Protection Agency.

US EPA, 2005a. Guidance for Developing Ecological Soil Screening Levels. OSWER Directive 9285.7-55 (Revised). United States Environmental Protection Agency.

US EPA, 2005b. Ecological Soil Screening Levels for Arsenic – Interim Final.

US EPA, 2005c. Ecological Soil Screening Levels for Cadmium – Interim Final. U.S. Environmental Protection Agency.

US EPA, 2005d. Ecological Soil Screening Levels for Chromium - Interim Final (No. OSWER Directive 9285.7-66). U.S. Environmental Protection Agency.

US EPA, 2005e. Ecological Soil Screening Levels for Cobalt– Interim Final (Interim Final).

US EPA, 2005f. Ecological Soil Screening Levels for Vanadium - Interim Final (No. OSWER Directive 9285.7-75). U.S. Environmental Protection Agency.

US EPA, 1998. Toxicological Review of Trivalent Chromium in Support of Summary Information on the Integrated Risk Information System (IRIS). Washington, DC.

US EPA, 1993. Wildlife Exposure Factors Handbook (No. EPA/600/R-93/187). Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, D.C.

US EPA, 1985. Ambient Water Quality Criteria for Chromium - 1984 (No. EPA-440/5-84-029). Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, D.C.

US EPA, 1980. Particle Size Distribution of Yellowcake Emissions at the United Nuclear-Churchrock Uranium Mill (No. ORP/LV-80-1). Office of Radiation Programs, U.S. Environmental Protection Agency, Las Vegas, NV.

USFS, 2021. About Lichens [WWW Document]. United States Forest Service.

USGS, 2006. Cadmium Risks to Freshwater Life: Derivation and Validation of Low-Effect Criteria Values using Laboratory and Field Studies. Scientific Investigations Report 2006-5245. U.S. Geological Survey, Department of the Interior.

Vives i Batlle, J., Balonov, M., Beaugelin-Seiller, K., Beresford, N.A., Brown, J., Cheng, J.-J., Copplestone, D., Doi, M., Filistovic, V., Golikov, V., Horyna, J., Hosseini, A., Howard, B.J., Jones, S.R., Kamboj, S., Kryshev, A., Nedvecaite, T., Olyslaegers, G., Prohl, G., Ulanovsky, A., Vives Lynch, S., Yankovic, T., Yu, C., 2007. Inter-comparison of absorbed dose rates for non-human biota 349–373.

Vives i Batlle, J., Beaugelin-Seiller, K., Beresford, N.A., Copplestone, D., 2011. The estimation of absorbed dose rates for non-human biota: an extended intercomparison. Radiation Environ. Biophys. 50, 231–251.

Vocke, R.W., Sears, K.L., O'Toole, J.J., Wildman, R.B., 1980. Growth responses of selected freshwater algae to trace elements and scrubber ash slurry generated by coal-fired power plants. Water. Res. 14, 141–150.

Vohra, P., Kratzer, F.H., 1968. Zinc, copper and manganese toxicities in turkey poults and their alleviation by EDTA. Poult. Sci. 47, 699.

VST, 2004. Final Report on the Toxicity Investigation of Uranium to Aquatic Organisms. Vizon SciTech Inc., for the Canadian Nuclear Safety Commission.

WHO, 2017. Guidelines for drinking-water quality. World Health Organization.

WHO, 2011. Evaluation of certain food additives and contaminants: seventy-third [73rd] report of the Joint FAO/WHO Expert Committee on Food Additives (No. No. 960), WHO Technical Report Series. World Health Organization, Food and Agriculture Organization of the United Nations & Joint FAO/WHO Expert Committee on Food Additives.

WHO, 2006. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Global update 2005, Summary of risk assessment.

Wiemeyer, S.N., Hoffman, D.J., 1996. Reproduction in eastern screech-owls fed selenium. Journal of Wildlife Management 60, 332–341.

Wood, C.M., Port, P., 2000. Intracellular pH regulation and buffer capacity in CO2/HCO3-buffered media in cultured epithelial cells from rainbow trout gills. J. Comp. Physiol. B. 170, 175–184.

WSA, 2017. Saskatchewan Water Quality Objective for the Protection of Aquatic Life – Molybdenum. Fact Sheet. (No. WSA 514). Saskatchewan Water Security Agency.

Wu, M.M., Kuo, T.L., Hwang, Y.H., Chen, C.J., 1989. Dose–response relation between arsenic concentration in well water and mortality from cancers and vascular diseases. American Journal of Epidemiology 130, 1123–1132.

YNLRO, 2022. An Exploration of Recorded Athabasca Denesųłiné Traditional Knowledge, Land Use and Occupancy Information in the Vicinity of Denison Mines Wheeler River Project. Ya'thi Néné Lands and Resources Office.

Zarafonetis, J.H., Hampton, R.E., 1974. Some effects of small concentrations of chromium on growth and photosynthesis in algae. Mich. Acad. 6, 417–421.

Appendix A Wheeler River Project IMPACT Model

WHEELER RIVER PROJECT - IMPACT MODEL

MODELLING REPORT

REPORT PREPARED FOR:

Denison Mines Corp.
www.denisonmines.com

REPORT PREPARED BY:

Ecometrix Incorporated
www.ecometrix.ca
Mississauga, ON

Ref. 19-2638
1 October 2024

WHEELER RIVER PROJECT - IMPACT MODEL

MODELLING REPORT

DRAFT

Langping Wu, Ph.D.
Environmental Scientist
Technical Lead

DRAFT

Rina Parker, M.A.Sc., P.Eng.
Environmental Risk Assessment Specialist
Project Manager

DRAFT

Don Hart, Ph.D.
Senior Ecotoxicologist
Project Principal and Reviewer

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

BAF	bioaccumulation factor
CNSC	Canadian Nuclear Safety Commission
COPC	constituent of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CSA	Canadian Standards Association
DCF	dose coefficient
dw	dry weight
ERA	environmental risk assessment
fw	fresh weight
HQ	hazard quotient
IMPACT	Integrated Model for the Probabilistic Assessment of Contaminant Transport
TF	transfer factor
USEPA	United States Environmental Protection Agency

Units of Measure

%	percent
µGy/h	micrograys per hour
Bq/kg	becquerels per kilogram
Bq/L	becquerels per litre
Bq/m^2	becquerels per square metre
Bq/m^3	becquerels per cubic metre
cm/h	centimetres per hour
d	day
h	hour
ha	hectare
kg	kilogram
kg/L	kilograms per litre
$kg/m^2/s$	kilograms per square metre per second
kg/yr	kilograms per year
km	kilometre
km^2	square kilometre
L	litre
L/d	litres per day
L/kg	litres per kilogram
$L/m^2/s$	litres per square metre per second
L/m^3	litres per cubic metre
L/s	litres per second
m	metre
m/s	metres per second

m^2	square metre
m^3	cubic metre
m^3/d	cubic metres per day
m^3/kg	cubic metres per kilogram
m^3/yr	cubic metres per year
mg	milligram
mg/kg	milligrams per kilogram
mg/kg/d	milligrams per kilogram per day
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
mg/s	milligrams per second
mSv/yr	millisieverts per year
s	second
Sv/Bq	sieverts per becquerel
Sv/yr	sieverts per year
yr	year

1.0 Introduction

1.1 Overview of the IMPACT Model

The environmental transport and pathways model, IMPACT (Integrated Model for the Probabilistic Assessment of Contaminant Transport), is used to evaluate the transport and effects of constituents of potential concern (COPCs) on the local environment and receptors, including humans and non-human biota. The model represents a convenient platform and powerful tool to complete systematic evaluations of the risks to ecological and human receptors associated with releases of constituents to water and air from proposed or existing anthropogenic (i.e., human) activities. The scope of this appendix is to provide further detail on the modelling approach followed to calculate dose and risk to ecological and human receptors, as reported in the main body of the Wheeler River Environmental Risk Assessment (ERA).

IMPACT is a modelling tool, the current version of which was created, and is maintained and supported, by Ecometrix Incorporated (Ecometrix). The IMPACT model was originally developed by BEAK Consultants Ltd. in 1993 as part of a research initiative partially funded by the Atomic Energy Control Board (now the Canadian Nuclear Safety Commission, CNSC). Since the initial development, IMPACT has been continuously updated to improve the interface, to integrate various operating systems, and most importantly, to embody an up-to-date understanding of the fate, transport, and toxicity of metals, radionuclides, and other constituents released to the environment.

IMPACT updates have been funded by the CANDU Owners Group to ensure that it is continually aligned with the Canadian Standards Association (CSA) relevant standards. The CSA standard N288.1 presents analytical equations and parameters for radiological pathways analysis, developed with the participation of experts from the nuclear industry, government agencies and consultants, including the CNSC and Ecometrix. The CSA standard N288.6-22 provides guidance for environmental risk assessment at nuclear facilities, and references N288.1 for radiological risk assessment.

The IMPACT 5.6.0 is a dynamic version of the model and was tailored to align with the guidance in CSA standards N288.6-22 (CSA Group, 2022) and N288.1-20 (CSA Group, 2020). It contains differential equations for COPC transport, allowing for non-steady-state conditions, whereas N288.1 contains the corresponding steady-state equations.

The IMPACT model is a customizable tool that allows the user to assess the transport and fate of COPCs through a user-specified environment. The model is used to estimate concentrations of COPCs in a range of environmental media, based on releases and environmental features. The IMPACT model enables the quantification of potential doses and hazard quotients (HQs) for aquatic and terrestrial ecological receptors, as well as humans. The graphical user interface features make it possible to create or modify scenarios quickly and without the need to change the programming code. Thus, users can construct complex models to predict potential environmental effects in a wide variety of natural environments without the need for programming skills or the use of multiple, complex model interfaces.

The IMPACT model has been applied to ecological and human health risk assessments at several proposed and operating uranium mines and mills including Cigar Lake Mine (Cameco, 2004), Key Lake Mine (Ecometrix, 2005, 2012, 2013a) and Millennium Mine (Ecometrix, 2013b, c). This model has also been used extensively by other nuclear facilities for ecological and human health risk assessments, to support preparation of derived release limits and for annual public dose calculations. The extensive environmental database developed for northern Saskatchewan since the 1970s to present day has gone through numerous updates as a larger available database of environmental data became available over time. This has helped develop more statistically rigorous relationships for COPC transfer among various environmental compartments. Substantial effort was made during this assessment to review parameters in the model and compare to the existing baseline dataset for the Wheeler River Project, which is further discussed in Section 3.0, Development of Model Parameters.

1.2 Objective of this Document

The objective of this document is to present the structure and functioning of the IMPACT model as implemented for the Wheeler River Project (the Project). The Project is a proposed uranium mine and processing plant in northern Saskatchewan, Canada. It is located in a relatively undisturbed area of the boreal forest about 4 km off of Highway 914 and approximately 35 km north-northeast of the Key Lake uranium operation. Denison is proposing to apply an innovative approach to uranium mining called In-Situ Recovery (ISR), which eliminates the need for large open pits, shafts, and underground mine workings. The Project site and surrounding local and regional study areas are shown in Figure 1-1.

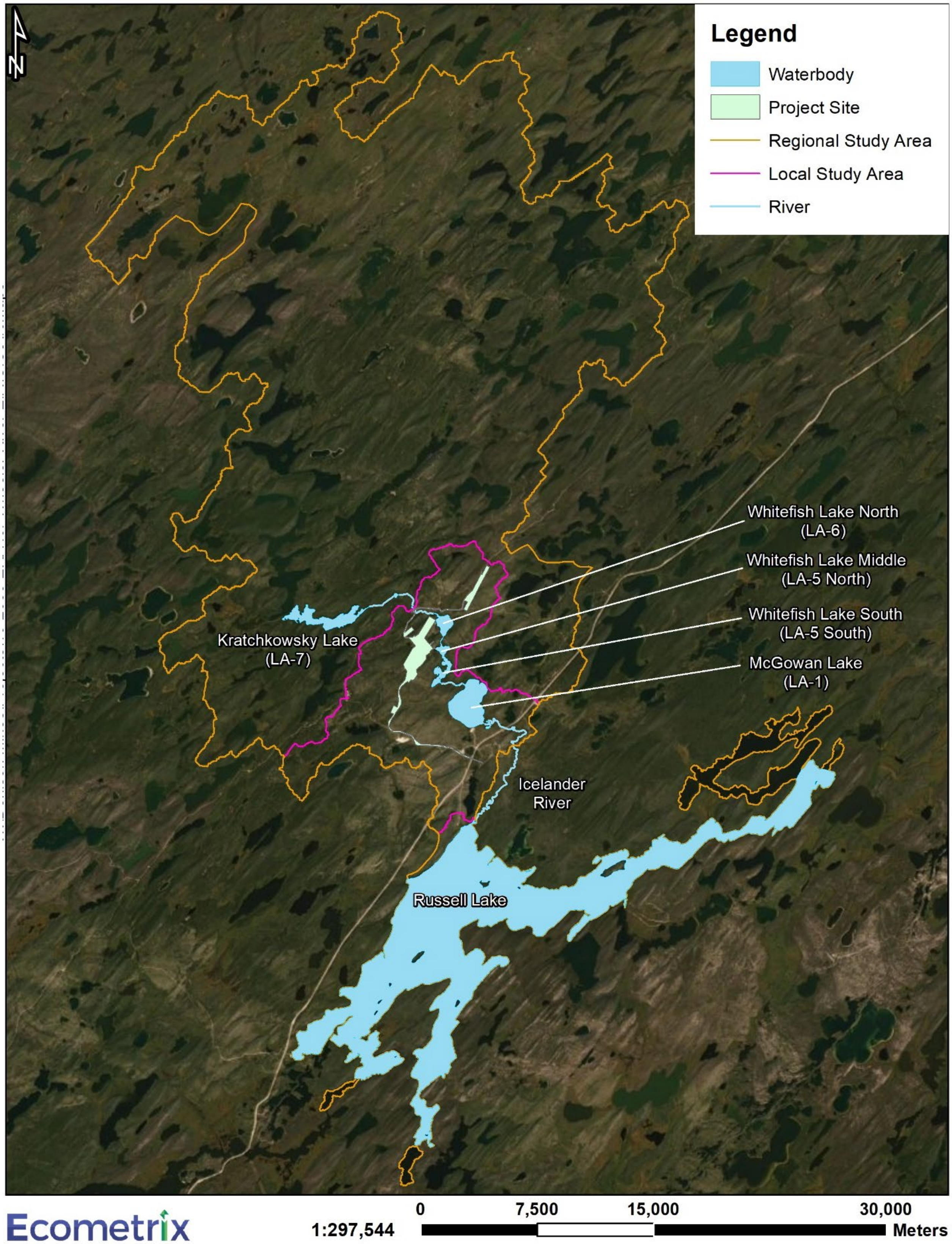


Figure 1-1: Wheeler River Project Site and Study Areas

This document discusses the inputs and assumptions used in the IMPACT model, including receptor characteristics, exposure pathways, and the derivation and identification of site-specific information.

1.3 Structure of this Document

The document contains the following sections and content:

Section 2: Describes the model structure for ecological and human receptor assessment, specific assumptions made for the Project, and the generic equations used to calculate the transfer of constituents between environmental media and the receptors.

Section 3: Presents the development of project-specific input parameters and describes the approach used for calibration and validation based on regional monitoring data.

2.0 The IMPACT Model

The IMPACT model simulates the transport of constituents from sources through various environmental media such as air, water, soil, and sediment, to receptors. The model estimates the resulting concentration of constituents in environmental media, potential uptake (i.e., absorption) by aquatic and terrestrial vegetation and animals, and potential intake (i.e., ingestion) by and dose to animals and humans.

Environmental pathways are the transport, transformation, and transfer mechanisms by which COPCs travel from sources to receptors. A pathway exists when there is a point at which COPC uptake or external exposure by an ecological or human receptor may occur, following COPC transport from the source through environmental media. If a complete transport pathway does not exist between the source of a COPC and an ecological or human receptor, then no exposure is expected to occur.

The links within a pathway represent different processes of COPC transfer, which depend on the receptors and environmental conditions. These processes can include intake, transfer, and accumulation of constituents.

IMPACT is consistent with the calculations outlined in CSA N288.1-20 and CSA N288.6-22. As such the default model parameters are consistent with these publications. All environmental parameters including bioaccumulation factors, transfer factors and other constants can be adjusted to site or regional data as these are available. In general, it is preferable to use regional values and this approach was followed in this assessment, where regional values were available. Values for water-sediment transfer as well as aquatic animals and plants were based on regional datasets which have been developed using extensive environmental data collected over many years (Ecometrix 2005, 2012, 2013). These values will be identified as regional data. For the remaining factors, literature values were selected. In this selection process the CSA standards were preferred to other available literature.

This IMPACT model was set up to be representative of the environment it models and the transfer processes between environmental components. Where deemed applicable, field measurements were used either as inputs or as a validation of modelled values. Some model parameters were selected based on regional monitoring data and previous model calibrations to regional data for northern Saskatchewan. Model predicted COPC concentrations for the Wheeler River baseline condition were compared to measured Wheeler River baseline data to ensure that model predictions were not underestimating as compared to measurements. This is discussed in detail in Section 3.0, Development of Model Parameters.

2.1 The IMPACT Model Structure

The basic units of assessment in IMPACT are "polygons". IMPACT supports two types of polygons, aquatic and terrestrial, which represent aquatic and terrestrial environments respectively. Ecological and human receptors inhabit polygons. Polygons represent zones of surface water or land that have similar physical, chemical, biological, and/or hydrological characteristics. Individual polygons are given specific attributes, such as topography for land polygons and water depth and flow for water polygons, which can be based on site-specific information. Each polygon is given a specific spatial extent that is defined by a centroid point (with X and Y coordinates) and a surface area. Polygons can be connected by water or air pathways. A number of receptors may reside within each polygon and may have exposure connections to other polygons.

The transfer of constituents between environmental media, receptors, and polygons is conceptualized by links (i.e., arrows indicating direction of transfer). The links represent different transfer processes depending on the context. For example, a link between two waterbodies may represent flow of water, and a link between water and sediment may represent sedimentation. Each transfer process is represented by a differential equation.

Transfer of constituents is modelled iteratively with a constant user-selected time step. IMPACT uses the Euler Method to numerically solve the set of ordinary differential equations at each time step. The modelling time step for this Project was selected to optimize computing time and produce a convergent solution in a dynamic system. The modelling simulation time step chosen was 0.0025 years. Results were monitored at intervals of 0.083 years (monthly) during the Project phases and 2 years for the scenario of future centuries.

2.2 Water Polygons

Lakes and streams are defined within IMPACT as water polygons, which are distinct from land polygons. Water polygons can be inhabited by aquatic receptors and provide exposure pathways for terrestrial and human receptors.

The IMPACT model includes flow and mass balance in lakes and streams. Constituents enter the aquatic environment from a source and travel through various waterbodies. Atmospheric deposition to Whitefish Lake is considered negligible relative to direct input from effluent. This is consistent with the COG DRL guidance (COG, 2019) which shows that the transfer of constituents from the atmosphere to large bodies of water (including lakes and rivers) is negligible if emissions to water approximate those to air.

A sample calculation for uranium is provided below to illustrate that for the Project the atmospheric input of uranium to Whitefish Lake (LA-5) is very small relative to the direct input to water via effluent.

The transfer from air source to air (P_{01}) is estimated by dividing the air concentration (X_1) by the atmospheric release rate ($X_{0(a)}$), as shown below.

$P_{01}=X_1/X_{0(a)}$

X_1	Air Concentration (LA-5) U	3.45E-05	mg/m^3	EIS Appendix 6
$X_{0(a)}$	Atmospheric Release Rate	6.83E+01	mg/s	EIS Appendix 6
P_{01}	Transfer source to air	5.05E-07	s/m^3	calculated

The transfer from water source to water (P_{02}) is estimated by dividing the water concentration (X_2) by the effluent release rate ($X_{0(w)}$).

$P_{02}=X_2/X_{0(w)}$

X_2	Water Concentration (LA-5) U	5.74E-04	mg/L	From IMPACT Model
$X_{0(w)}$	Effluent Release Rate (U)	5.78E-01	mg/s	U Effluent Concentration x Effluent Flowrate
P_{02}	Transfer source to water	9.93E-04	s/L	calculated

The transfer from air to water (P_{12}) is estimated below.

$P_{12} = V_g (A/V)10^{-3}/(\lambda_s+\lambda_w)$

V_g	Atmospheric deposition velocity	0.003	m/s	N288.1
Area	LA-5	96940	m^2	site-specific (Appendix A)
Volume	LA-5	106634	m	site-specific (Appendix A) (Area*Depth)

$\lambda_s = DR \cdot \rho \cdot K_d \cdot (A/V)$

DR	Sediment deposition rate	6.34E-08	mm/s	Assumption (2mm/yr)
P	sediment dry bulk density	0.11	kg/L	N288.1
K_d	partition coefficient	20000	L/kg	N288.1
λ_s	sedimentation loss rate constant	1.27E-07	s^{-1}	calculated

$\lambda_w = U \cdot CA/V = Q/V$

Q	Inflow into LA-5	1.379	m^3/s	site-specific (Appendix A)
V	Volume of LA-5	106634	m^3	Area*Depth
λ_w	loss via water flow rate constant	1.29E-05	s^{-1}	calculated
P_{12}	Transfer from air to water	2.09E-01	m^3/L	calculated

Water concentration from air = $X_{0(a)}*P_{01}*P_{12}$	7.20E-06	mg/L
Water concentration from effluent = $X_{0(w)}*P_{02}$	5.74E-04	mg/L
Percent contribution to Water from Air	1%	

As constituents travel through a series of connected waterbodies such as lakes, concentrations in water can decrease as a result of mixing with natural inflows from the surrounding watershed and interactions with lake sediment. The sediment-water exchange of constituents is estimated using chemical-specific partitioning coefficients. The water and sediment pathways involve the exchange of constituents between surface water and sediment through the following processes:

- sorption and desorption between dissolved and particulate forms in water and sediment;
- settling of particulates from water to sediment;
- diffusive exchange between sediment porewater and the water column; and
- loss to deeper sediments through accumulation and burial.

The model estimates concentrations in water and sediment using the advection dispersion equation (detailed below), which is essentially a mass conservation equation. The partial differential equations are solved iteratively. The model estimates change in concentrations in water and sediment through each downstream waterbody, over time.

Aquatic receptors reside in water polygons. Terrestrial receptors (e.g., moose, humans) reside in land polygons and can be linked to aquatic receptors from water polygons.

The IMPACT model included the following distinct water polygons: LA-7 South (Kratchkowsky Lake – reference lake), LA-6 (Whitefish Lake North), LA-5 North (Whitefish Lake Middle), LA-5 South (Whitefish Lake South), LA-1 (McGowan Lake), Russell Lake (exposed area). The lakes were connected by creeks which were considered as a flow-through channel, in the same way as the Icelander River connecting LA-1 and Russell Lake. This is discussed in more detail in Section 3.1.1.

2.2.1 Ecological Receptors Residing in Water Polygons

Aquatic plants and animals are assigned to water polygons. The aquatic ecological receptors that were considered in this iteration of the IMPACT model include aquatic macrophytes (i.e., plants), phytoplankton, zooplankton, benthic invertebrates, and fish.

Macrophytes

Aquatic macrophytes are primary producers that occupy the lowest level in the food chain and are exposed to constituents in surface water. Macrophytes can potentially uptake metals in their roots and shoots and are modelled accordingly. Macrophytes provide a pathway for the introduction of bioavailable constituents and their compounds into the food chain through direct consumption by terrestrial herbivores (e.g., moose [*Alces alces*] and woodland caribou [*Rangifer tarandus caribou*]).

Phytoplankton

Phytoplankton are primary producers that occupy the lowest level in the food chain and are assessed for exposure to constituents in surface water.

Zooplankton

Zooplankton are primary consumers that occupy the second lowest level in the food chain and are assessed for exposure to constituents in surface water.

Benthic Invertebrates

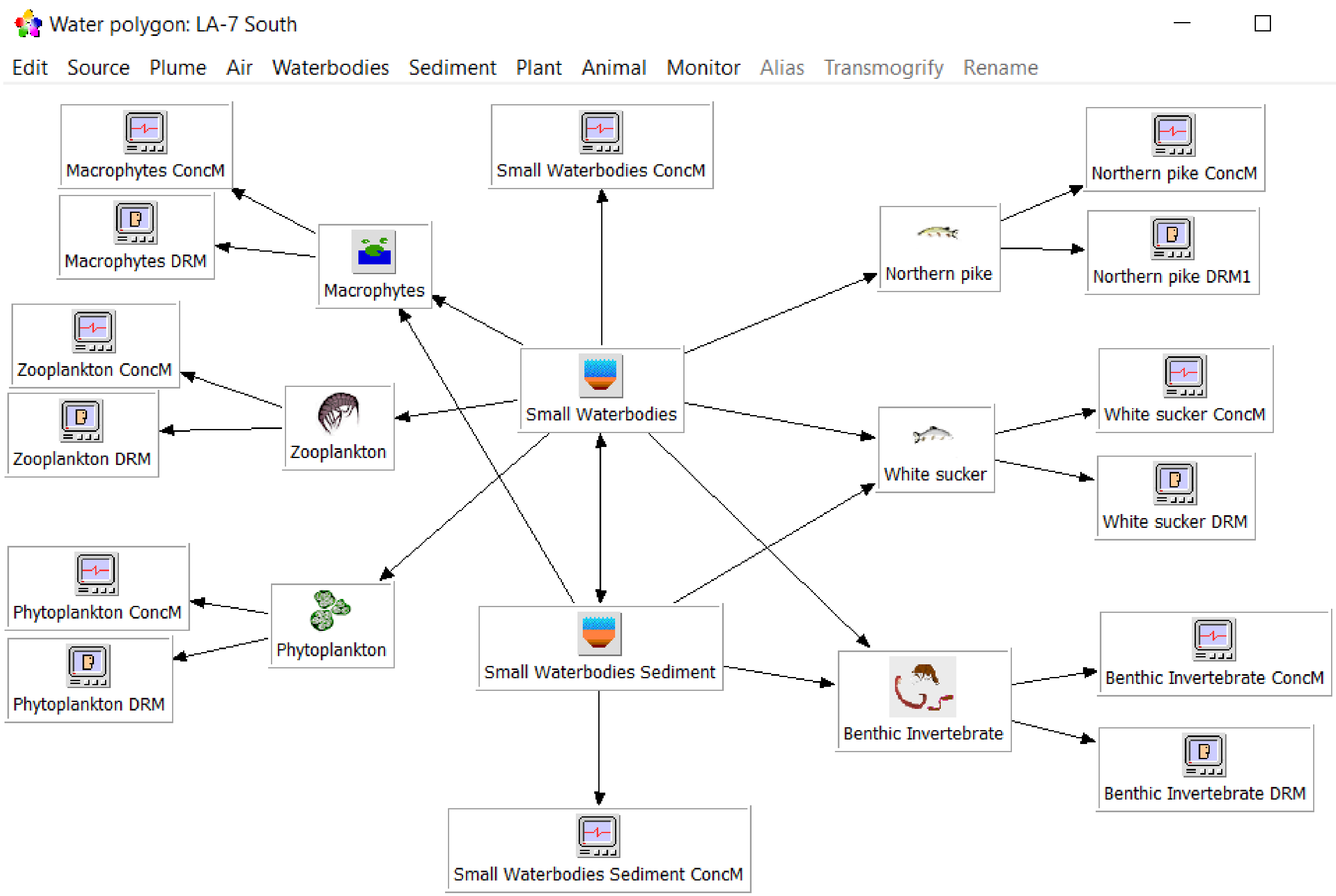
Benthic invertebrates are primary consumers. These organisms are important food sources for aquatic and semi-aquatic animals. In the IMPACT model, benthic invertebrates are assumed to be exposed to COPCs in the aquatic environment directly through contact with water and sediment.

Fish

Fish were collected from waterbodies within the vicinity of the Project local and regional study areas to provide data on baseline COPC concentrations in muscle and bone tissues in large-bodied fish (Ecometrix, 2020a). Fish species observed and sampled included northern pike (*Esox lucius*) and white sucker (*Catostomus commersonii*). Northern pike was selected for IMPACT modelling purposes to represent a piscivorous (i.e., fish-eating) top carnivore. White sucker was selected for IMPACT modelling to represent a bottom-feeding fish. Northern pike and white sucker represent different trophic levels. Although there may be other fish species that are not included explicitly in the model, northern pike and white sucker are assumed to be representative of other similar species. Since baseline data are available for these species, model predictions can be validated against measured data (see Section 3.6.2).

2.2.2 Aquatic Pathways

Aquatic pathways include the transfer of COPCs between water, sediment, aquatic animals, and aquatic plants. Environmental media (i.e., water and sediment) and aquatic ecological receptors (i.e., macrophytes, phytoplankton, zooplankton, benthic invertebrates, and fish) are connected by arrows in the IMPACT model (Figure 2-1). The arrows represent equations listed below the figure. Model outputs include concentrations in environmental media and receptors, and dose and risk values for aquatic ecological receptors.



DRM = Dose-Risk Monitor; ConcM = Concentration Monitor.

Figure 2-1: Representation of Transfer between Aquatic Media in the IMPACT Model

The equations for concentrations in water and sediment are partial differential equations that are solved numerically within IMPACT. Each of these equations is characterized by a series of parameters that describe the physical and biochemical environment of each lake and stream represented by the model. These parameters can be divided into general categories to represent the following components and processes:

- physical environment;
- natural background conditions;
- project-related constituent loadings; and
- biochemical exchange processes.

There are four basic equations that describe the concentrations in the aquatic environment for water and sediment.

Water column concentration (C_{wc}):

$$\frac{dC_{wc}}{dt} = \frac{W_w + Q_{in} \cdot C_{in} + Q_{gw} \cdot C_{gw}}{V_w} + \lambda_{parent} \cdot C_{parent} - \frac{k_s}{z_w}\left[(1 - f_w) \cdot C_{wc} - C_{pw}\right] - C_{wc} \cdot \left[\lambda_T + \frac{g_w \cdot f_w}{z_w} + \frac{Q_{out} + (1 - f_w) \cdot Q_{gw\leftrightarrow out}}{V_w}\right]$$

Sediment layer concentration (C_s):

$$\frac{dC_s}{dt} = \frac{g_w \cdot f_w \cdot C_{wc}}{z_s} + \lambda_{parent} \cdot C_{parent} + \frac{k_s}{z_s}\left[(1 - f_w) \cdot C_{wc} - C_{pw}\right] + \frac{Q_{gw} \cdot C_{gw}}{V_s} - C_s \cdot \left[\lambda_T + \frac{g_b}{z_s} + \frac{(1 - f_s) \cdot Q_{gw\leftrightarrow out}}{\varepsilon_s \cdot V_s}\right]$$

The fraction of a constituent that is particulate in the water column (f_w) defined as:

$$f_w = \frac{K_d \cdot \frac{\rho_s}{\varepsilon_s}}{1 + K_d \cdot \frac{\rho_s}{\varepsilon_s}}$$

The sediment-water transport coefficient (k_s) defined as:

$$k_s = \frac{D^*}{z_i}$$

The burial rate of sediments (g_b) defined as:

$$g_b = \frac{g_w \cdot SS}{\rho_s}$$

<u>Aquatic animal concentrations (C_{aa}) are calculated as:</u>

$$C_{aa} = C_{wc} \cdot BAF_{aa} \cdot \alpha \cdot (1 - OF_s) + C_{pw} \cdot BAF_{aa} \cdot \alpha \cdot OF_s$$

<u>Aquatic plant concentrations (C_{ap}) are calculated as:</u>

$$C_{ap} = C_{wc} \cdot BAF_{ap}$$

where:

α	=	food web multiplier(s) (unitless)
BAF_{aa}	=	bioaccumulation factor for aquatic animal L/kg)
BAF_{ap}	=	bioaccumulation factor for aquatic plants L/kg)
C_{in}	=	concentration of constituent entering water column (mg/L, Bq/L)
C_{gw}	=	concentration of constituent in seepage (input) groundwater (mg/L, Bq/L)
C_{parent}	=	concentration of parent constituent (mg/L, Bq/L)
C_{pw}	=	concentration in the surficial sediment pore water (mg/L, Bq/L)
C_s	=	concentration of constituent in surficial sediments (mg/kg, Bq/kg)
C_{wc}	=	concentration of constituent in water column (mg/L, Bq/L)
D^*	=	sediment-water column diffusion coefficient (m^2/s)
ε_s	=	porosity of surficial sediment (unitless)
f_s	=	fraction of a constituent that is particulate in the sediment layer (unitless)
f_w	=	fraction of a constituent that is particulate in the water column (unitless)
g_b	=	burial rate of sediments (m/s)
g_w	=	settling rate of particulates in water column (m/s)
K_d	=	water-to-sediment partitioning coefficient (L/kg)
k_s	=	sediment-water transport coefficient (m/s)
λ_{parent}	=	first-order decay constant for parent constituent (1/s)
λ_T	=	total first-order decay constant for constituent (1/s), which is the sum of the universal decay constant and the media-specific decay constant
OF_S	=	sediment occupancy factor (unitless)
Q_{in}	=	inflow rate from upstream surface water (L/s)
Q_{gw}	=	inflow rate from groundwater (L/s)
Q_{out}	=	net outflow rate to downstream surface water (L/s)
$Q_{gw\leftrightarrow out}$	=	outflow rate to groundwater (L/s)
ρ_s	=	bulk density of surficial sediment (kg dw/L)
SS	=	suspended solids concentration (mg/L)
V_s	=	volume of surficial sediment layer (L)
V_w	=	volume of surface waterbody (L)
W_w	=	total effluent emission rate from all sub-sources (mg/s, Bq/s)
z_i	=	sediment-water column diffusion interface thickness (mm)
z_s	=	thickness of sediment layer (m)
z_w	=	mean lake depth (m)

Many parameters representing the physical environment were derived from baseline hydrology studies (Ecometrix, 2020b) including waterbody surface areas and volumes. Information from published literature and from experience with similar environments was used to quantify physical parameters that are conceptual or that were not observed directly (e.g., sediment interface thickness). A summary of these parameters used as inputs for the above transport equations is presented in Table 2-1. It should be noted here that the underlying assumption for water-sediment transport in IMPACT is that minimal suspended solids will be introduced through the effluent.

Table 2-1: Water-Sediment Transport Modelling Parameters

Model Parameter		Value	Unit
Mixing depth (thickness of sediment layer)	z_s	0.03	m
Dry bulk density	ρ_s	0.11	kg dw/L
Water content (porosity)	ε_s	0.96	unitless
Diffusion coefficient	D*	3.16×10^{-10}	m^2/s
Interface thickness	z_i	0.01	m
Settling rate	g_w	2	mm/yr
Suspended solids	SS	2	mg/L

dw = dry weight.
Note: Values calibrated based on regional data.

The natural background conditions represent the quality of water and sediment within the watershed prior to mining. Where possible, field data were used to quantify natural background conditions (Section 3.2.1, Background Water Quality and Section, 3.3.1, Background Sediment Quality). Monitoring data indicated that concentrations of some constituents in water were below analytical detection limits. Concentrations in the sediments from lakes were generally measurable. Water-sediment partitioning coefficients were selected based on the available data (Section 3.3.2, Water to Sediment Partitioning Coefficients).

The source loads of constituents from natural and Project-related sources represent the boundary conditions of the model. Natural sources are represented by the chemical influx from natural groundwater discharge, overland runoff, and stream inflows from the surrounding landscape. These natural loadings were estimated from natural background water quality and inflow rates for site-specific conditions.

2.2.3 Radiological Dose to Aquatic Ecological Receptors

Radiological dose to an aquatic receptor is the radiation energy absorbed due to radiation emissions from radionuclides present in the environment (water or sediment) or in the tissues of the organism. Through comparison with dose benchmarks, the risk to the organism can be quantified. This model characterizes dose resulting from both background and project exposure.

The total dose (D_{total}) to an aquatic ecological receptor from each constituent is:

$$D_{total} = D_{int} + D_{ext}$$

The internal dose of COPCs to an aquatic ecological receptor due to incorporated radioactivity (D_{int}) is:

$$D_{int} \quad = \quad C_t \cdot DCF_{int}$$

The external dose to an aquatic ecological receptor from radioactivity in water and sediment (D_{ext}) is:

$$D_{ext} \quad = \quad [C_w \cdot (OF_w + 0.5OF_{ws} + 0.5OF_{ss}) + C_s \cdot (OF_s + 0.5OF_{ss})] \cdot DCF_{ext}$$

where:

C_t	=	whole body tissue concentration from water (becquerels per kilogram fresh weight (Bq/kg fw))
C_w	=	water concentration (becquerels per litre (Bq/L))
C_s	=	sediment concentration (Bq/kg fw)
D_{int}	=	internal radiation dose (micrograys per hour (μGy/h))
D_{ext}	=	external radiation dose (μGy/h)
DCF_{int}	=	dose coefficient for radionuclide in tissue ([μGy/h])/[Bq/kg fw])
DCF_{ext}	=	external dose coefficient for water ([μGy/h]/[Bq/kg fw sediment] or [μGy/h]/[Bq/L water])
OF_s	=	fraction of time spent immersed in sediment (unitless). Assumption based on characteristics of the organism; see Table 2-5
OF_{ss}	=	fraction of time spent on the sediment surface (unitless). Assumption based on characteristics of the organism; see Table 2-5
OF_w	=	fraction of time spent immersed in the water column (unitless). Assumption based on characteristics of the organism; see Table 2-5
OF_{ws}	=	fraction of time spent on the water surface (unitless). Assumption based on characteristics of the organism; see Table 2-5

2.2.4 Non-radiological Risk to Aquatic Receptors

Risk to aquatic receptors from exposure to non-radionuclide COPCs is expressed as a Hazard Quotient (HQ). For aquatic receptors, it is characterized through comparison of the exposure concentration with a reference toxicity concentration. This model calculates the risk from both background and project exposure. The HQ for aquatic ecological receptors due to exposure to COPCs in water is estimated as:

$$HQ \quad = \quad \frac{1}{RC_{wc}} \cdot \left[C_{wc} \cdot (1 - OF_s) + C_{pw} \cdot OF_s\right]$$

where:

C_{pw}	=	concentration of constituent in the surficial sediment pore water (mg/L)
C_{wc}	=	concentration of constituent in water column (mg/L)

OF_s	=	sediment occupancy factor (unitless). Assumption based on characteristics of the organism; see Table 2-5
RC_{wc}	=	reference toxic concentration – water column (mg/L)

2.3 Land Polygons

Terrestrial receptors are modelled as residing in land polygons. Land polygons provide exposure pathways for terrestrial and human receptors. Land polygons are populated by one or more terrestrial receptors that are expected to occupy the habitat represented by the prevailing vegetation community and physical characteristics of the surrounding environment.

IMPACT models both terrestrial and aquatic dietary components for terrestrial receptors. Terrestrial pathways include the transfer of constituents between air, soil, water, plants, and animals.

2.3.1 Terrestrial Ecological Receptors

Terrestrial receptors are divided into ecological receptors and human receptors. Ecological receptors typically are selected to include representative species of terrestrial plants, small and large mammals, invertebrates, birds, and riparian animals. Human receptors can be modelled to represent the habits of population groups and ages that are expected to reside in the area of interest (Section 2.4, Exposure of Human Receptors).

Terrestrial ecological receptors are assigned to a land polygon. The terrestrial ecological receptors that were selected include primary producers (plants) and consumers (invertebrates and animals). Primary consumers (herbivores) and secondary consumers (omnivores and carnivores) were selected from among mammals and birds that are known to be present in the vicinity of the Project and are known to be of value to Indigenous groups and local communities. Documented rationale for receptor selection is provided in the Wheeler River ERA Report. The terrestrial ecological receptors considered in the IMPACT model include terrestrial plants, terrestrial invertebrates, terrestrial and riparian mammals, and terrestrial and riparian birds.

Terrestrial Vegetation

Terrestrial vegetation types are dietary components for terrestrial animals and humans. They are represented by browse (shrubs and grasses), lichen (*Cladonia* spp., *Cladina* spp.), blueberry (*Vaccinium mytilloides*), and Labrador tea (*Rhododendron groenlandicum)*. Plants are exposed to constituents in soil through contact with soil and contaminant uptake from soil via bioaccumulation. Lichen is exposed to constituents depositing from air. Berries and Labrador tea represent plants used in the Traditional Foods diet (i.e., diet made up of plants and animals fished, hunted, or gathered from the land).

Terrestrial Invertebrates

Terrestrial invertebrates are considered to be primary consumers. They are represented by earthworms, which live in soil and are therefore exposed to constituents in soil layers through direct contact. Earthworms acquire nutrition through organic matter in soil and decomposing remains of other animals. Terrestrial invertebrates are part of the diet for the American robin (*Turdus migratorius*).

Terrestrial and Riparian Mammals

Mammalian herbivores are represented by woodland caribou, snowshoe hare (*Lepus americanus*), moose, and southern red-backed vole (*Myodes gapperi*). Herbivores convert vegetable matter to animal protein, and in turn are consumed by omnivores and carnivores. Snowshoe hare and southern red-backed vole are small mammals that consume berries and browse. These species are important prey for larger terrestrial predators such as Canada lynx (*Lynx canadensis*). The southern red-backed vole is very abundant in the vicinity of the Project based on the local terrestrial environment wildlife and vegetation baseline inventory (Omnia, 2019). Woodland caribou and moose are large ungulates with distinct home ranges and linkages to aquatic environments during the summer period. The primary food sources for woodland caribou are lichen in the winter and terrestrial vegetation (browse) and aquatic vegetation (macrophytes) in the summer. Moose consumes terrestrial and aquatic vegetation. Moose is part of the Traditional Foods diet and is assumed to be representative for other ungulate species such as white-tailed deer (*Odocoileus virginianus*).

Black bear (*Ursus americanus*) is a terrestrial omnivore that is opportunistic and relies on readily available and easily accessed foods. Black bears consume berries and fish, and therefore have a dietary link to the aquatic environment.

Muskrat (*Ondatra zibethicus*) is riparian mammal that is exposed to constituents in both aquatic and terrestrial environments. The muskrat's diet is fully aquatic, and muskrats are assumed to consume a combination of aquatic plants and benthic invertebrates.

Mink (*Neovison vison*) and Canada lynx are terrestrial predators representing the top level of the food chain. The mink's diet has linkages to both land and water polygons through the consumption of fish, benthic invertebrates, riparian mammals, and birds.

Terrestrial and Riparian Birds

Canada goose (*Branta canadensis*) is terrestrial herbivore. It is part of the traditional food diet and is assumed to be representative for other birds with similar dietary characteristics.

Olive-Sided Flycatcher (*Contopus cooperi*) is an aerial insectivore which has a varied diet but feeds primarily on terrestrial and benthic invertebrates. The olive-sided flycatcher is a Species of Special Concern under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is threatened under the *Species at Risk Act (SARA)*. It can be considered representative for other small birds and at-risk species, such as barn swallow and common nighthawk.

American robin (*Turdus migratorius*) is a terrestrial omnivore and can be representative of other insectivores and ground-feeding birds which were commonly found within the Wheeler River project area (Omnia, 2019), such as ruby-crowned kinglet, dark-eyed junco, hermit thrush, and yellow-rumped warbler. The American robin feeds on fruit and soil invertebrates.

Bald eagle (*Haliaeetus leucocephalus*) is a terrestrial carnivore, which was observed in the study area and is representative for other raptors. Bald eagles consume fish and other riparian birds.

Mallard (*Anas platyrhynchos*), lesser scaup (*Aythya affinis*) and common loon (*Gavia immer*) are migratory water birds that are common to northern Saskatchewan. These riparian birds have a primarily aquatic diet; the mallard and lesser scaup consume macrophytes and benthic invertebrates, and the common loon consumes fish and benthic invertebrates.

2.3.2 Home Ranges and Residency Factors

Home range is defined as the geographic area encompassed by an animal's activities, excluding migration, over a specific time (USEPA 1993). The home range size is used to determine the portion of time that an individual animal is expected to be exposed to COPCs through contact with environmental media. Small mammals such as muskrat and vole have small home ranges that are represented by small polygons with similar vegetation communities.

The residency factor represents the fraction of time an animal is expected to be exposed to a location and the proportion of the animal's intake (i.e., food, water) that is taken from each location. Animals are given a residency factor of one if they receive 100% of their exposures from one polygon location. The IMPACT model looked at three polygon locations where potential exposures to Project emissions could occur (LA-5 (Whitefish Lake), LA-1 (McGowan Lake), Russell Lake) and one reference location that is unexposed (upstream) to Project emissions (Reference Lake represented by LA-7 South). Each polygon location includes both water and land polygons.

Animals with large home ranges (i.e., greater than 10 km^2), such as the woodland caribou, black bear and bald eagle, interact with several different exposed polygon locations for feeding and water intake. All other receptors have relatively small home ranges (i.e., less than 10 km^2) and were assumed to reside in the same polygon year-round. The estimated home ranges of selected mammalian receptors with potentially larger home ranges are presented in Table 2-2. The woodland caribou and black bear have home ranges of approximately 80 km^2 and the bald eagle has a home range of approximately 314 km^2. Therefore, these animals have the potential to be present at more than one polygon location to obtain their food. Home ranges are generally conservatively selected based on the expected home range during sensitive life stages.

Animals that are migratory are unlikely to have 100% residency at one polygon location for the entire year. However, because toxicity reference values that are used to establish potential risk are typically based on sensitive life stages such as reproduction, a 100% residency can be conservatively assumed for a specific life stage to capture the risk from exposure for the life stage of interest. For instance, mallards are not present in the vicinity of the Project for over half the year due to migration but have a small home range during the nesting and rearing of their young. Therefore, it was conservatively assumed that the mallard has a 100% residency factor at one polygon location where the young are hatched and reared.

Similarly, moose can move to different geographical locations between seasons, but generally remain within small seasonal home ranges of 5 km^2 to 10 km^2 during the summer and winter. Mink remains within small seasonal home ranges of 0.06 km^2 to 16.3 km^2. For modelling purposes, these animals (with local home ranges or migratory patterns) are associated with one polygon location (100% residency).

Table 2-2: Estimated Home Ranges of Selected Terrestrial Ecological Receptors

Ecological Receptor	Home Range (km^2)			Comment	Reference
	Expected	Minimum	Maximum		
Woodland Caribou	80[a]	67[b]	267[c]	Female home ranges from GPS tracking data in the Saskatchewan Boreal Shield. The expected home range used for assessment is based on an average female range during the most sensitive life stage of the woodland caribou (i.e., calving/post-calving).	McLoughlin et al, 2016.
Moose	10	5	10	Moose are essentially solitary and have one or several distinct home ranges to which they are strongly attached. Movements between seasonal home ranges may be extensive but home ranges are generally small. The same home ranges are generally returned to year after year.	Wilson and Ruff 1999; Franzmann 1981
Black Bear	80	40	130	Female home ranges from GPS tracking data in the Saskatchewan Boreal Shield.	McLoughlin et al, 2019.
Mink	7.7	0.06	16.3	Expected value based on a study in southern Manitoba	Arnold and Fritzell 1987, FCSAP 2012
Bald Eagle	314	7	452	Eagles tend to nest closer to suitable fishing habitat, forage from the nest, and avoid areas of human disturbance.	Livingston et al . 1990 as cited in US FWS 2002

Notes:

[a] Represents the mean range size pooled over the two study years for calving/post-calving stage.

[b] Represents the mean range size for autumn/rut.

[c] Represents the mean range size for early winter.

Residency factors for receptors with large home ranges (i.e., woodland caribou, black bear, and bald eagle) were estimated based on the relative sizes of waterbodies (surface areas) that are located within an area consistent with the receptor's expected home range size. The objective is to determine the time spent at exposure locations and reference locations.

The woodland caribou or black bear receptor at LA-5 (Table 2-3) was assumed to spend time at LA-5, LA-1, and Russell Lake (i.e., exposed locations). The woodland caribou or black bear receptor at either location is likely to overlap with the others due to the size of their expected home range of 80 km^2 and therefore exposures to these locations were assessed together as one location at LA-5. It was also assumed that the woodland caribou or black bear spends a proportion of time at unexposed locations within its home range (i.e., lakes upstream of future water discharge points). One lake northeast of LA-5 and other unnamed lakes near LA-5 were included as an unexposed location for the woodland caribou and black bear for their residency factor calculation. As a result, the LA-5 woodland caribou or black bear receptor was assumed to spend 6% of its time at LA-5 (59 ha), 13% of its time at LA-1 (149 ha), 46% of its time at Russell Lake (512 ha) and 35% of its time at unexposed locations (392 ha).

Due to its large home range of 314 km^2, the bald eagle located near LA-5 was also assumed to spend only a portion of its time at exposed locations. The exposed locations for determining residency factors include LA-5, LA-1, and Russell Lake (exposed area). The unexposed locations for determining residency factors include LA-7 South, Russell Lake (unexposed area), and other unnamed lakes near LA-5. The sum of the surface areas of these water bodies was used to determine the proportion of time the bald eagle near LA-5 spends at the reference (unexposed) locations, adding up to 5,153 ha. Therefore, the bald eagle located near LA-5 was assumed to spend 1% of its time at LA-5, 2.5% of its time at LA-1, 8.7% of its time at Russell Lake (exposed area) and 87.8% of its time at unexposed locations.

Due to the relatively small seasonal home ranges of moose and mink (Table 2-2), they were assumed to have 100% residency at each home polygon (i.e., residency factor of 1).

Table 2-3 presents the residency factors that were applied in the model for each terrestrial ecological receptor. The exposed lakes are shown on Figure 1-1.

Table 2-3: Residency Factors for Terrestrial Ecological Receptors with Potentially Larger Home Ranges

Ecological Receptors	Home Polygon	Waterbody Surface Area (ha)	Total Waterbody Surface Area (ha)	Residency Factor	Water and Feed Source Polygon
Woodland Caribou	LA-7 South	323	323	1	LA-7 South
	LA-5	59	1111	0.06	LA-5
		149		0.13	LA-1
		512		0.46	Russell Lake
		392		0.35	Unexposed Locations
Moose	LA-7 South	-	-	1	LA-7 South
	LA-5	-	-	1	LA-5
	LA-1	-	-	1	LA-1

Ecological Receptors	Home Polygon	Waterbody Surface Area (ha)	Total Waterbody Surface Area (ha)	Residency Factor	Water and Feed Source Polygon
	Russell Lake	-	-	1	Russell Lake
Black Bear	LA-7 South	323	323	1	LA-7 South
	LA-5	59	1111	0.06	LA-5
		149		0.13	LA-1
		512		0.46	Russell Lake
		392		0.35	Unexposed Locations
Mink	LA-7 South	-	-	1	LA-7 South
	LA-5			1	LA-5
	LA-1	-	-	1	LA-1
	Russell Lake	-	-	1	Russell Lake
Bald Eagle	LA-7 South	323	323	1	LA-7 South
	LA-5	59	5872	0.010	LA-5
		149		0.025	LA-1
		512		0.087	Russell Lake
		5153		0.878	Unexposed Locations

2.3.3 Exposure Assumptions for Terrestrial Ecological Receptors

2.3.3.1 Body Weight and Intake Rates

The body weight and intake rates are required for the calculation of exposure to birds and mammals (Table 2-4). Body weights and intake rates were obtained, in order of preference, from CSA N288.1-20, the US Environmental Protection Agency (USEPA) *Wildlife Exposure Factors Handbook* (USEPA 1993), and the Federal Contaminated Sites Action Plan *Module 3: Standardization of Wildlife Receptor Characteristics* (FCSAP 2012). For species not represented in the above sources, additional sources as identified in Table 2-4 were consulted to identify representative body weights, and then feed intake rates were calculated using allometric equations from the USEPA (1993).

Water intake and inhalation rates were determined using allometric equations from the USEPA (1993) for birds and mammals. The incidental ingestion of soil and/or sediment was estimated from feed intake. Incidental ingestion varied from 2% to 10.4% of food intake as dry weight, depending on the biota (Beyer et al. 1994). However, no incidental soil or sediment ingestion was assumed for the common loon, which feeds from the water column.

Table 2-4: Bird and Mammal Body Weights and Intake Rates

Receptor	Body Weight		Total Feed Intake				Dietary Components	Feed Type Fraction		Feed Intake Rate		Dry Weight Fraction [g]	IMPACT Intake Group	Feed Intake by Group		Intake of Soil [m]	Intake of Sediment [m]	Intake of Soil & Sediment [j]	Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment Intake [k]	Water Intake [l]	Inhalation Rate	
	kg	Source	kg dw/d	Source	kg fw/d	Source		fw	dw	kg dw/d	kg fw/d	unitless		kg dw/d	kg fw/d	%	%	%		kg dw/d	L/d	m^3/d	source
Woodland Caribou	180.0	e	3.817	l	11.327	-	Browse	0.50	0.30	1.133	5.664	0.20	Terrestrial Plants	2.968	7.929	5.3	1.5	6.8	Bison	0.260	10.602	34.774	l
							Lichen	0.20	0.48	1.835	2.265	0.81											
							Macrophytes	0.30	0.22	0.850	3.398	0.25	Aquatic Plants	0.850	3.398								
Snowshoe Hare	1.8	c	0.110	c	0.475	-	Browse	0.90	0.78	0.086	0.428	0.20	Terrestrial Plants	0.110	0.475	3.7	0	3.7	Average of small mammals	0.004	0.168	0.900	c,l
							Berries (Blueberry)	0.10	0.22	0.024	0.048	0.52											
Moose	400.0	b	8.000	b	38.095	-	Browse	0.80	0.76	6.095	30.476	0.20	Terrestrial Plants	6.095	30.476	1.5	0.5	2.0	Moose	0.160	21.751	65.869	l
							Macrophytes	0.20	0.24	1.905	7.619	0.25	Aquatic Plants	1.905	7.619								
Southern Red-Backed Vole	0.03	a, i	0.004	-	0.012	a, i	Berries (Blueberry)	0.60	0.79	0.004	0.007	0.52	Terrestrial Plants	0.004	0.012	2.4	0	2.4	Meadow vole	0.0001	0.005	0.048	a
							Browse	0.40	0.21	0.001	0.005	0.20											
Black Bear	102.5	f	3.075	b	7.053	-	Berries (Blueberry)	0.70	0.83	2.546	4.937	0.52	Terrestrial Plants	2.546	4.937	2.9	0	2.9	Average of large mammals	0.090	6.387	22.162	l
							Fish (Northern Pike)	0.30	0.17	0.529	2.116	0.25	Aquatic Animals	0.529	2.116								
Canada Lynx	14.0	n	0.601	l	2.038	-	Showshoe hare	0.80	0.81	0.489	1.630	0.30	Terrestrial Animals	0.601	2.038	2.8	0	2.8	Red fox	0.017	1.065	4.508	l
							Small Mammals (represented by Vole)	0.15	0.14	0.082	0.306	0.27											
							Terrestrial Birds (Goose)	0.05	0.05	0.031	0.102	0.30											
Muskrat	1.2	a	0.088	-	0.352	a	Macrophytes	0.80	0.80	0.070	0.282	0.25	Aquatic Plants	0.070	0.282	0	3.3	3.3	Mallard	0.003	0.114	0.590	a
							Benthic Invertebrates	0.20	0.20	0.018	0.070	0.25	Aquatic Animals	0.018	0.070								
Mink	1.0	a	0.045	-	0.161	a	Fish (Northern Pike)	0.30	0.27	0.012	0.048	0.25	Aquatic Animals	0.018	0.072	2.6	0.4	3.1	Average of mallard and Lynx	0.001	0.101	0.440	a
							Benthic Invertebrates	0.15	0.14	0.006	0.024	0.25											
							Small Mammals (Muskrat)	0.45	0.49	0.022	0.072	0.30	Terrestrial Animals	0.026	0.088								
							Birds (Mallard)	0.10	0.11	0.005	0.016	0.30											
Canada Goose	3.7	c	0.023	-	0.115	a	Browse	1.00	1.00	0.023	0.115	0.20	Terrestrial Plants	0.023	0.115	8.2	0	8.2	Canada goose	0.002	0.142	0.082	c
Olive-Sided Flycatcher	0.03	d	0.008	-			Soil Invertebrates (Earthworms)	0.90	0.86	0.007	0.039	0.17	Terrestrial Plants	0.007	0.039	8.9	1.5	10.4	American woodcock	0.001	0.006	0.058	l
							Benthic Invertebrates	0.10	0.14	0.001	0.004	0.25	Aquatic Animals	0.001	0.004								
Bald Eagle	5.8	a		-	0.691	a	Fish (Northern Pike)	0.80	0.77	0.138	0.553	0.25	Aquatic Animals	0.138	0.553	9.3	0	9.3	Wild turkey	0.051	0.191	1.310	a
							Riparian birds (Mallard)	0.20	0.23	0.041	0.138	0.30	Terrestrial Animals	0.041	0.138								
American Robin	0.1	a			0.202	a, h	Fruit (Berries)	0.60	0.82	0.062	0.121	0.52	Terrestrial Plants	0.076	0.202	10.4	0	10.4	American woodcock	0.008	0.013	0.142	l
							Soil Invertebrates (Earthworms)	0.40	0.18	0.014	0.081	0.17											
Lesser Scaup	0.8	a	0.063	a			Benthic Invertebrates	0.90	0.90	0.056	0.226	0.25	Aquatic Animals	0.056	0.226	0	3.3	3.3	Mallard	0.002	0.051	0.350	a
							Macrophytes	0.10	0.10	0.006	0.025	0.25	Aquatic Plants	0.006	0.250								
Mallard	1.1	c	0.060	c	0.240	-	Macrophytes	0.25	0.25	0.015	0.060	0.25	Aquatic Plants	0.015	0.060	0	3.3	3.3	Mallard	0.002	0.064	0.020	c
							Benthic Invertebrates	0.75	0.75	0.045	0.180	0.25	Aquatic Animals	0.045	0.180								
Common Loon	5.3	b	0.159	b	0.636	-	Fish (Northern Pike)	0.90	0.90	0.143	0.572	0.25	Aquatic Animals	0.159	0.636	0	0	0	negligible	0	0.180	1.477	l
							Benthic Invertebrates	0.10	0.10	0.016	0.064	0.25											

Notes:

[a] USEPA (1993). Body weights, ingestion rates and inhalation rates of adults or all groups (adults and juveniles) are an average of the listed values. If only a range is given, the upper limit of the range is used. Values for the southern red-backed vole was based on the meadow vole

[b] FCSAP Ecological Risk Assessment Guidance, Module 3: Standardization of Wildlife Receptor Characteristics (March 2012)

[c] CSA Standard N288.1-20 (March 2020), Clause 7.7.4.2, and Table A.5d

[d] Environment Canada. 2015. Recovery Strategy for Olive-sided Flycatcher (*Contopus cooperi*) in Canada; average for adult male/female weight range of 31 to 34 g.

[e] COSEWIC Assessment and Update Status Report on the Woodland Caribou (2002). Body weight calculated as a mean of the male and female upper range.

[f] Hinterland Who's Who. 2007. Average of males and females from http://www.hww.ca/en/wildlife/mammals/black-bear.html

[g] Moisture/dry weight fraction values are based on Beresford *et al,* 2008 (soil invertebrate - assume earthworm); Omnia 2019 (blueberries, lichen and small mammal - assuming vole); and CSA Standard N288.1-20 (all other receptors). The blueberry value is based on the fruit only.

[h] The total feed intake for the American Robin was used in the absence of a species-specific value.

[i] The body weight and total feed intake for the Meadow Vole was used in the absence of a species-specific value.

[j] Beyer *et al* , 1994

[k] Intake of Soil & Sediment (kg dw/d) = Total Feed Intake (kg dw/d) x Intake of Soil & Sediment (%)/100.

[l] Calculated using allometric equations in USEPA (1993)

[m] The % intake of soil or sediment is calculated from the combined % intake of soil and sediment, weighted to the relative proportions of terrestrial vs. aquatic dietary components for each receptor, based on the following equations.
Intake of Soil (%) = Total Intake of Soil & Sediment (%) x Feed Type Fraction Terrestrial. Intake of Sediment (%) = Total Intake of Soil & Sediment (%) x Feed Type Fraction Aquatic.

[n] U.S.FWS (Fish and Wildlife Service), 2017. Species Status Assessment for the Canada Lynx (Lynxcanadensis), Contiguous United States Distinct Population Segment. Version 1.0 - Final, October 2017. Lakewood, Colorado.

fw = fresh weight; dw = dry weight

2.3.3.2 Occupancy Factors

An occupancy factor is defined as the fraction of time the receptor species spend in or on various media. The occupancy factors are based on the experience and judgment of the risk assessor and the known behaviour of the receptor. The occupancy factors used in the IMPACT model are presented in Table 2-5. The riparian biota spends half of its time on soil/sediment surface and the other half in water. However, the water immersion dose to riparian receptors, as for all terrestrial receptors, is considered minor, therefore, only the occupancy factors on soil/sediment surface (OF_{ss}) are applied in dose calculation.

Table 2-5: Receptor Occupancy Factors

Aquatic Biota	OF_a	OF_S	OF_{SS}	OF_W	Terrestrial and Riparian Biota	OF_a	OF_S	OF_{SS}
Macrophytes	-	-	0.1	0.9	Lichen	-	-	1
Phytoplankton	-	-	-	1	Blueberry	-	0.5	0.5
Zooplankton	-	-	-	1	Terrestrial Invertebrates	-	1	-
Benthic Invertebrates	-	1	-	-	Labrador Tea	-	0.5	0.5
White Sucker	-	-	0.5	0.5	Browse	-	0.5	0.5
Northern Pike	-	-	-	1	Woodland Caribou	1	-	1
					Snowshoe Hare	1	-	1
					Moose	1	-	1
					Southern Red-Backed Vole	1	-	1
					Black Bear	1	-	1
					Canada Lynx	1	-	1
					Olive-Sided Flycatcher	1	-	0
					American Robbin	1	-	1
					Canada Goose	1	-	1
					Bald Eagle	1	-	0
					Muskrat	1	-	0.5
					Mink	1	-	0.5
					Mallard	1	-	0.5
					Common Loon	1	-	0.5
					Lesser Scaup	1	-	0.5

Notes

OF_a = occupancy factor in contaminated air
OF_s = occupancy factor in soil/sediment
OF_{ss} = occupancy factor on soil/sediment surface
OF_w = occupancy factor in water
- = not applicable.

2.3.4 Terrestrial Pathways

Terrestrial pathways include the transfer of COPCs between air, soil, terrestrial plants, and terrestrial animals. The specific equations that consider the concentrations of COPCs in soil, terrestrial plants, and terrestrial animals along each of these pathways are listed below.

Concentration in soil (C_{soil}):

$$\frac{dC_{soil}}{dt} = \frac{C_{air} \cdot (V_g + W_r \cdot P_{pt}) \cdot D_f}{\rho_b \cdot z_{soil}} + \lambda_{parent} \cdot C_{parent} + \frac{C_{irr} \cdot Q_{irr}}{\rho_b \cdot z_{soil}} - C_{soil} \cdot \left[\lambda_T + \frac{L \cdot f_{soil}}{\rho_b \cdot z_{soil}} + \frac{v_i \cdot (1 - f_{soil})}{z_{soil} \cdot \varphi}\right]$$

where:

C_{soil}	=	concentration in soil (Bq/kg dw, mg/kg dw)
C_{air}	=	concentration in air (becquerels per cubic metre (Bq/m^3, mg/m^3)
C_{irr}	=	concentration of constituent in irrigation water (Bq/L, mg/L)
C_{parent}	=	concentration of parent constituent (Bq/kg, mg/kg)
D_f	=	deposition fraction for airborne constituents (unitless)
f_{soil}	=	fraction of constituent that is sorbed to solids in soil (unitless)
φ	=	volumetric water content (unitless)
λ_{parent}	=	first order decay constant for parent constituent (1/s)
λ_T	=	sum of the rate constants for all significant loss processes (1/s)
L	=	erosion loss rate in soil block (kg/m^2/s)
P_{pt}	=	precipitation rate (m/s)
Q_{irr}	=	irrigation rate (L/m^2/s)
ρ_b	=	bulk density of soil (kg/L)
v_i	=	infiltration rate (m/s)
V_g	=	atmospheric deposition velocity (m/s)
W_r	=	wet deposition washout ratio (unitless)
Z_{soil}	=	thickness of soil mixing layer (m)

Table 2-6: Modelling Parameters for the Soil Model

Model Parameter		Value	Unit
Mixing depth (thickness of soil layer)	Z_{soil}	0.2	m
Dry bulk density	ρ_b	1.5	kg dw/L
Water content (porosity)	φ	0.1	unitless
Infiltration rate	v_i	1.205E-8	m^3/m^2/s
Erosion rate	L	1.5E-8	kg dw/m^2/s
Precipitation rate	P_{pt}	800	mm/yr
Wet deposition washout ratio (metals)	W_r	5.5E+6	unitless
Dry Deposition velocity (metals)	V_g	0.0014	m/s

Note: All values for the soil model are the default parameters specified in CSA N288.1-20, assuming sandy soil based on the soil type described in the Wheeler River Project - Terrestrial Environment Wildlife and Vegetation Baseline Inventory report (Omnia, 2019).

Concentration in terrestrial plants (C_{tp}):

$$C_{tp} = C_{int} + C_{ext}$$

$$C_{int} = C_{soil} \cdot B_v + C_{air} \cdot T_f$$

$$\frac{dC_{ext}}{dt} = \frac{C_{air} \cdot (V_g + W_r \cdot P_{pt}) \cdot f_a}{Y} + \lambda_{parent} \cdot C_{parent} + \frac{C_{irr} \cdot Q_{irr} \cdot f_{irr}}{Y \cdot A} - C_{ext} \cdot [\lambda_T + \lambda_e]$$

where:

A	=	Area of polygon (m^2)
B_v	=	bioaccumulation factor for soil-to-plant transfer (dw unitless)
C_{tp}	=	concentration in terrestrial plants (Bq/kg fw, mg/kg dw)
C_{int}	=	internal concentration in plant from soil uptake (Bq/kg fw, mg/kg dw)
C_{ext}	=	external concentration in plant from dust and irrigation (Bq/kg fw, mg/kg fw)
C_{soil}	=	concentration in soil (Bq/kg dw, mg/kg dw)
C_{air}	=	concentration in air (Bq/m^3, mg/m^3]
C_{irr}	=	concentration of constituent in irrigation water (Bq/L, mg/L)
C_{parent}	=	concentration of parent constituent (Bq/kg)
f_{irr}	=	irrigation fraction retained on irrigation (unitless)
λ_{Parent}	=	first order decay constant for parent constituent (1/s)
λ_T	=	sum of the rate constants for all significant loss processes (1/s)
λ_e	=	effective removal decay constant (1/s)
P_{pt}	=	precipitation rate (m/s)
Q_{irr}	=	irrigation rate (L/m^2/s)
T_f	=	air-to-plant transfer factor (m^3/kg)
V_g	=	atmospheric deposition velocity (m/s)
W_r	=	wet deposition washout ratio (unitless)
Y	=	vegetation yield (kg dw/m^2)

Concentration in terrestrial animals (C_{ta}):

$$C_{ta} = C_{air} \cdot I_a \cdot F_{inh} + F_{ing} \cdot \begin{bmatrix} I_w \cdot \sum (C_{wc} \cdot k_w) + I_s \cdot \sum (C_s \cdot k_{sed}) + I_{soil} \cdot \sum (C_{soil} \cdot k_{soil}) + \\ I_{tp} \cdot \sum (C_{tp} \cdot k_{tp}) + I_{ta} \cdot \sum (C_{ta} \cdot k_{ta}) + \\ I_{ap} \cdot \sum (C_{ap} \cdot k_{ap}) + I_{aa} \cdot \sum (C_{aa} \cdot k_{aa}) \end{bmatrix}$$

Where:

C_{ta}	=	concentration in ingested terrestrial animals (Bq/kg fw, mg/kg fw)
C_{wc}	=	concentration in water column (Bq/L, mg/L)
C_s	=	concentration in surficial sediment (Bq/kg dw, mg/kg dw)
C_{soil}	=	concentration in soil (Bq/kg dw, mg/kg dw)
C_{tp}	=	concentration in ingested terrestrial plants (Bq/kg dw, mg/kg dw)
C_{ap}	=	concentration in ingested aquatic plants (Bq/kg fw, mg/kg fw)
C_{aa}	=	concentration in ingested aquatic animals (Bq/kg fw, mg/kg fw)
F_{inh}	=	inhalation transfer factor (d/kg fw)
F_{ing}	=	ingestion transfer factor (d/kg fw)
I_w	=	water ingestion rate (L/d)
I_a	=	inhalation rate (m^3/d)
I_s	=	sediment ingestion rate (kg dw/d)
I_{soil}	=	soil ingestion rate (kg dw/d)
I_{tp}	=	terrestrial plants ingestion rate (kg dw/d)
I_{ta}	=	terrestrial animals ingestion rate (kg fw/d)
I_{ap}	=	aquatic plants ingestion rate (kg fw/d)
I_{aa}	=	aquatic animals ingestion rate (kg fw/d)
k_w	=	fraction of water intake from contaminated sources (unitless)
k_{sed}	=	fraction of sediment intake from contaminated sources (unitless)
k_{soil}	=	fraction of soil intake from contaminated sources (unitless)
k_{ta}	=	fraction of terrestrial animal intake from contaminated sources (unitless)
k_{tp}	=	fraction of terrestrial plant intake from contaminated sources (unitless)
k_{aa}	=	fraction of aquatic animal intake from contaminated sources (unitless)
k_{ap}	=	fraction of aquatic plant intake from contaminated sources (unitless)

2.3.5 Radiological Dose to Terrestrial Ecological Receptors

Radiological dose to a terrestrial receptor is the radiation energy absorbed due to radiation emissions from radionuclides present in the environment (air or soil/sediment) or in the tissues of the organism. Through comparison with dose benchmarks, the risk to the organism can be quantified. This model characterizes dose and risk from both background and project exposure.

The total dose to terrestrial animals from each radionuclide is:

$$D_{total} = D_{int} + D_{ext}$$

The internal dose of COPCs to terrestrial animals due to internal radioactivity (D_{int}) is estimated using the equation shown below.

$$D_{int} = C_t \cdot DC_{int}$$

The external dose to terrestrial animals from radioactivity in sediment and soil (D_{ext}) is:

$$D_{ext} = D_{ext,s} + D_{ext,ss}$$

$$D_{ext,s} = C_{soil} \cdot DC_{ext,s} \cdot OF_s$$

$$D_{ext,ss} \quad = \quad C_{ss} \cdot DC_{ext,ss} \cdot OF_{ss}$$

The external dose from noble gases (naturally occurring gases with very low chemical reactivity [e.g., helium]) to terrestrial animals is calculated in IMPACT from outdoor air; however, there are no noble gases in the Wheeler River model applicable to ecological receptors, so the equation is not provided.

Where:

C_t	=	whole body tissue concentration (Bq/kg fw)
C_{soil}	=	soil concentration (Bq/kg dw)
C_{ss}	=	surface soil concentration (Bq/m^2)
D_{int}	=	internal radiation dose (µGy/h)
DC_{int}	=	dose coefficient for radionuclide in tissue ([µGy/h]/[Bq/kg fw])
$D_{ext,s}$	=	external radiation dose in soil (µGy/h)
$D_{ext,ss}$	=	external radiation dose on soil surface (µGy/h)
$DC_{ext,s}$	=	dose coefficient for radionuclide in soil ([µGy/h]/[Bq/kg dw])
$DC_{ext,ss}$	=	dose coefficient for radionuclide on soil surface([µGy/h]/[Bq/m^2])
OF_s	=	fraction of time spent immersed in soil (unitless)
OF_{ss}	=	fraction of time spent on the soil (unitless)

For animals with large home ranges (Section 2.3.2), the total dose is the combined exposure from several locations (Table 2-3), where the residency factors are used as weighting factors to calculate the total dose.

2.3.6 Non-radiological Risk to Terrestrial Ecological Receptors

The IMPACT model provides a means of evaluating the potential effects on environmental components by comparing the non-radiological exposures of receptors to recognized benchmarks, usually a concentration or dose-based toxicity reference values in the same units, for each COPC. This measure of potential risk is known as an HQ. This model calculates the risk from both background and project exposure.

The HQ for terrestrial animals due to ingestion of non-radiological constituents is estimated as:

$$\mathrm{HQ} \quad = \quad \frac{1}{\mathrm{RD} \cdot \mathrm{BM}} \cdot \begin{bmatrix} I_w \cdot \sum (C_{wc} \cdot k_w) + I_s \cdot \sum (C_s \cdot k_{sed}) + \\ I_{soil} \cdot \sum (C_{soil} \cdot k_{soil}) + I_{tp} \cdot \sum \left(C_{tp} \cdot k_{tp}\right) + I_{ta} \cdot \sum (C_{ta} \cdot k_{ta}) + \\ I_{ap} \cdot \sum \left(C_{ap} \cdot k_{ap}\right) + I_{aa} \cdot \sum (C_{aa} \cdot k_{aa}) \end{bmatrix}$$

Where:

BM	=	body mass (kg)
C_{ap}	=	concentration in ingested aquatic plants (mq/kg fw)

C_{aa}	=	concentration in ingested aquatic animals (mq/kg fw)
C_s	=	concentration in surficial sediment (mg/kg dw)
C_{soil}	=	concentration in soil (mg/kg dw)
C_{ta}	=	concentration in ingested terrestrial animals (mg/kg fw)
C_{tp}	=	concentration in ingested terrestrial plants (mq/kg dw)
C_{wc}	=	concentration in water column (mg/L)
I_{aa}	=	aquatic animals ingestion rate (kg fw/d)
I_{ap}	=	aquatic plants ingestion rate (kg fw/d)
I_s	=	sediment ingestion rate (kg dw/d)
I_{soil}	=	soil ingestion rate (kg dw/d)
I_{tp}	=	terrestrial plants ingestion rate (kg dw/d)
I_{ta}	=	terrestrial animals ingestion rate (kg fw/d)
I_w	=	water ingestion rate (L/d)
k_{aa}	=	fraction of aquatic animal intake from contaminated sources (unitless)
k_{ap}	=	fraction of aquatic plant intake from contaminated sources (unitless)
k_{sed}	=	fraction of sediment intake from contaminated sources (unitless)
k_{soil}	=	fraction of soil intake from contaminated sources (unitless)
k_{ta}	=	fraction of terrestrial animal intake from contaminated sources (unitless)
k_{tp}	=	fraction of terrestrial plant intake from contaminated sources (unitless)
k_w	=	fraction of water intake from contaminated sources (unitless)
RD	=	reference toxic dose (mg/kg/d)

2.4 Exposure of Human Receptors

2.4.1 Exposure Assumptions for Human Receptors

The human receptor groups selected for the human health risk assessment are based on the current understanding of how people use the area in the vicinity of the Project and their potential for exposure to Project-related media concentrations during one or more Project phases (i.e., Construction, Operation, Decommissioning and Post-decommissioning). The selected human receptor groups are a camp worker, seasonal resident, recreational fisher/hunter, fisher/trapper and future permanent resident (as shown on Figure 2-2), with rationale for receptor selection provided in the Wheeler River ERA report.
Adult and one-year-old receptors were used to assess potential risk to human health. The exposure factors for these two age groups are summarized in Table 2-7. The selection process and further characteristics of the human receptors are discussed in the ERA report.

The primary exposure routes for human health include ingestion (i.e., food, water, incidental amounts of soil and/or sediment), inhalation (i.e., vapours and/or particulates), dermal absorption (non-radiological), and external exposure to radiation (radiological). The potential exposure pathways are expected to be the same for all human receptors assessed.

Table 2-7: Summary of Receptor Characteristics for the Human Health Risk Assessment

Receptor Characteristic	Unit	Adult [(a)]	One-year-old [(b)]	Reference
Air inhalation (mean)	m^3/yr	5,950	1,830	CSA N288.1-20; Table 19
Water ingestion (mean)	L/yr	379.6	98.92	CSA N288.1-20; Table 21
Soil ingestion (mean) [(c)]	kg dw/d	4.00×10^{-06}	6.10×10^{-05}	CSA N288.1-20; Table 20
Sediment ingestion [(c)]	kg dw/d	4.00×10^{-06}	6.10×10^{-05}	CSA N288.1-20; Table 20
Exposed surface area - water (whole body)	m^2	2.19	0.72	CSA N288.1-20; Table 22
Total food ingestion [(d)]	kg fw/yr	706	410	CSA N288.1-20; Annex G

a) Adult applies to both male and female receptors.
b) The one-year-old is equivalent to the CSA N288.1-20 age class “infant”.
c) Incidental ingestion rate for soil/sediment is apportioned to soil and sediment according to time spent at beach.
d) The higher total food ingestion for the adult male (from CSA N288.1-20) is used to represent both male and female human receptors, which is a conservative assumption for females.
dw = dry weight; fw = fresh weight.

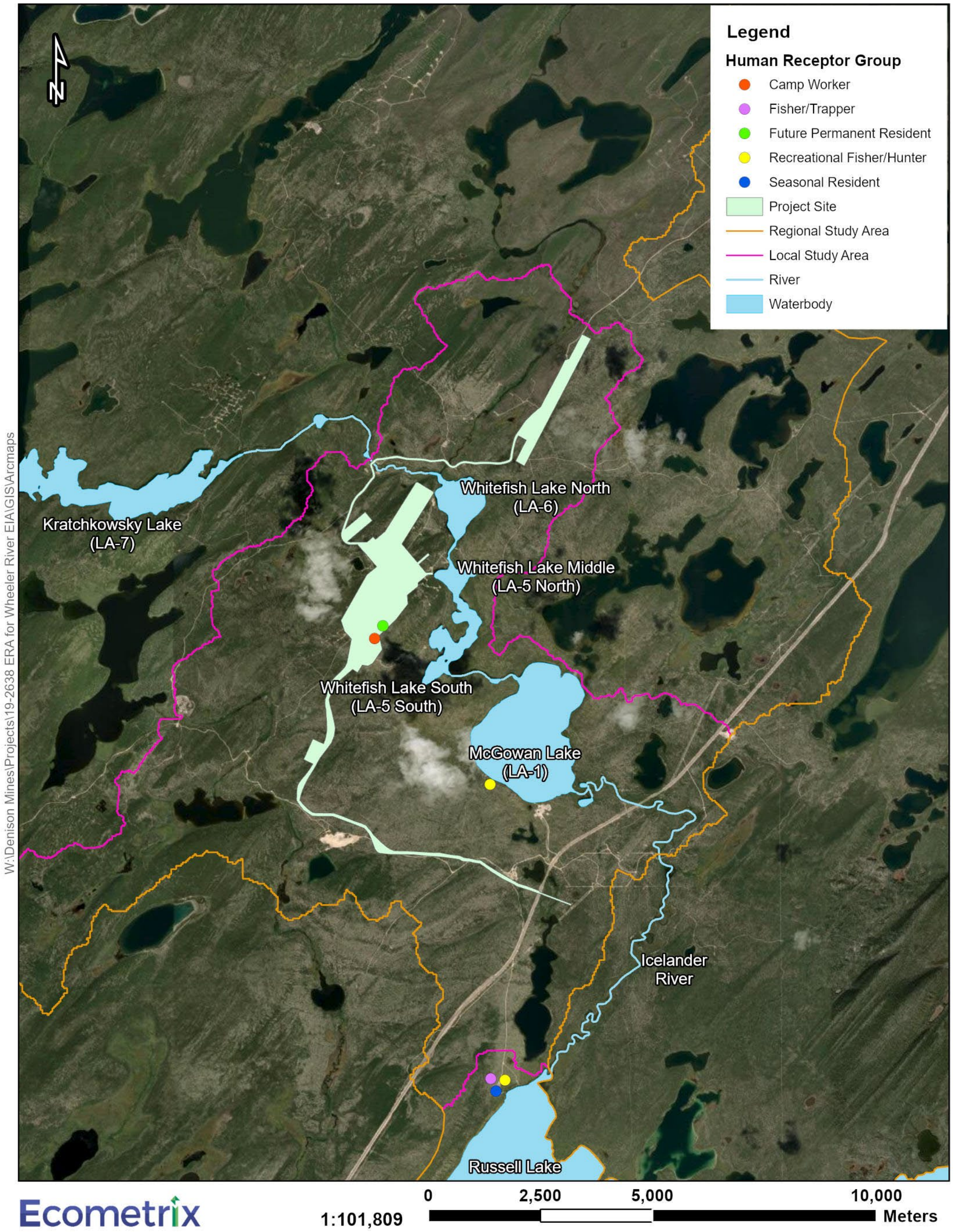


Figure 2-2: Human Receptor Locations for the Wheeler River Model

2.4.1.1 Dietary Assumptions

Each of the human health receptors described in Section 2.4.1, Exposure Assumptions for Human Receptors consumes locally sourced Traditional Foods to an extent that is consistent with either an average or a high consumer. Where possible, the total of Traditional Foods derived was obtained from pertinent Traditional Foods surveys and engagement with Indigenous Groups and local communities. Traditional Foods are those animals and plants that are fished, hunted, or gathered from the land and consumed as food (Health Canada 2018). The remainder of the total food diet is assumed to be from store-bought foods (i.e., store foods). Store foods include grain and other agricultural products of a typical diet that are not available locally.

The camp worker is assumed to work and reside at the Denison camp for half of the year and does not consume any Traditional Foods while at the site. During the other times of the year, the camp worker is assumed to be an average Traditional Foods consumer. The fisher/trapper are assumed to be high Traditional Foods consumers. The future permanent resident, the seasonal resident and the recreational fisher/hunter are assumed to be average Traditional Foods consumers.

<u>Adult Diet</u>

As stated in Table 2-7, the initial assumptions for ingestion rates and components of the total foods diet for the human health risk assessment were taken from CSA N288.1-20 Adult (Table G.9b – Central) total diet.

The human diet provided in CSA N288.1-20 was derived from the 2004 food basket survey results for an adult male. The CSA N288.1-20 human diet was selected over the Health Canada (2010a) human diet. Health Canada (2010a) references Richardson (1997), which used survey results from the late 1970s. The Richardson (1997) diet was also a combined adult male/female diet. The CSA N288.1-20 total adult diet is a smaller overall diet (706 kg/yr) than the Richardson diet (808 kg/yr) by about 100 kg/yr and is based on more recent data.

The total food diet is the sum of Traditional Foods and store foods. Its dietary components, expressed in kilograms per year (kg/yr) of food consumed, are shown in Table 2-8 for average consumers, and high consumers of Traditional Foods.

The store food intakes in each food category were estimated from the total diet intakes provided in CSA N288.1-20, minus the Traditional Foods intakes. If the Traditional Foods intakes were higher than the total intake for the same CSA N288.1-20 food category, the store food intake was set to zero, and then the values for other store food categories were reduced as needed to obtain total dietary intakes equal to those in CSA N288.1-20.

<u>One-Year-Old Diet</u>

Annual food consumption rates for the "one-year-old" were calculated using “adult-to-one-year-old” ratios from CSA N288.1-20 for each of the selected food categories. Annual ingestion rates for individual food items were combined into relevant food categories and the adult-to-one-year-old ratios were determined for each of these food categories.

<u>Representative Ecological Receptors Used in the IMPACT Model</u>

The concentrations of COPCs in Traditional Foods used in the exposure assessment were estimated using the IMPACT model and the modelled concentrations are shown in Appendix B of the Wheeler River ERA report. Based on the descriptions of the different human receptor groups and their Traditional Foods diets, representative ecological receptors were selected for the IMPACT model to represent each Traditional Foods group. The final selection of representative ecological receptors for the Traditional Foods diet is shown in Table 2-9. The local food intake fractions as implemented in IMPACT for the human diet are shown in Table 2-10.

Table 2-8: Annual Food Intakes (kg/yr) for Components of the Human Receptors' Diets

Food Components	Unit	Average Traditional Foods Consumer				High Traditional Foods Consumer			
		Adult [1]		One-year-old [2]		Adult [1]		One-year-old [2]	
Total Food Intake [3] (fresh weight)	**kg/yr**	**706.01**		**409.45**		**706.01**		**409.45**	
Country Meat and Fish	**kg/yr**	**52.82**		**9.34**		**366.88**		**63.50**	
Caribou	kg/yr		2.63		0.33		175.28		21.79
Moose	kg/yr		11.75		1.46		4.65		0.58
Moose (organs)	kg/yr		4.49		0.56				0
Small Mammals [4]	kg/yr		2.45		0.23		0.87		0.08
Mallard [5]	kg/yr		2.99		0.53		1.55		0.28
Canada Goose [6]	kg/yr		1.86		0.33		1.09		0.19
Fish [7]	kg/yr		26.65		5.89		183.44		40.58
Country Plants [8]	**kg/yr**	**19.82**		**10.83**		**0**		**0**	
Blueberries	kg/yr		19.64		10.79		0		0
Labrador Tea	kg/yr		0.18		0.04		0		0
Store Foods	**kg/yr**	**633.38**		**389.28**		**339.13**		**345.95**	

Notes:

[1] Food intake for human receptors that are average Traditional Foods consumers were developed from the results of a dietary survey of the English River First Nation (CanNorth 2017).

[2] CanNorth (2017) provides survey results for adults. Food intake for one-year-olds was proportioned from the adult receptor group using Central Adult - to Central 1-Year-Old derived from the N288.1-20 Human Diet (Table G.9b).

[3] The total food intake is from Table G.9b in CSA N288.1-20 (2020) which represents the central dietary intake based on reference energy intakes.

[4] While ERFN predominantly eat hare, modelling for small mammals is represented by muskrat to have a stronger link to the aquatic environment.

[5] Mallard was selected to represent all waterbirds in the country food diet.

[6] Canada goose was selected to represent upland birds in the country food diet.

[7] Assumed to include 50% predator fish (northern pike) and 50% forage fish (white sucker) based on ERFN dietary survey (CanNorth 2017).

[8] Blueberries include edible fruits and berries. Labrador Tea includes edible plants other than fruits and berries.

Table 2-9: Representative Ecological Receptors Used in the Traditional Foods Diet

Traditional Foods Category	Representative Ecological Receptor	Traditional Foods Diet Components	Rationale[a]
Fish			
Fish	Northern Pike	Lake Trout Northern Pike Walleye Yellow Perch	Predator species and forage species represent two ecological trophic levels. Both are present in most area lakes and surrounding surface water bodies. Spawning habitat of both has also been identified within the study area. Fish flesh and bone of both were analyzed for metal and radionuclides. Age determination has also been done. Both are important reginal traditional foods components. Recreational and commercial fishing documented at Russell Lake.
	White Sucker	Arctic Grayling Burbot Lake Whitefish Longnose Sucker White sucker	
Game Meat/Organs			
Large mammal	Woodland Caribou	Caribou meat	Large herbivore with linkages to the aquatic environment. Generally present in the vicinity of the Project according to baseline studies. Important regional traditional food items. Woodland Caribou has threatened status under COSEWIC and SARA for broader regional study area.
	Moose	Moose meat	
	Moose organs	Moose kidney Moose liver Caribou kidney	
Small mammal	Muskrat	Muskrat meat Rabbit meat	Small herbivore with linkages to the aquatic environment. Generally present in the vicinity of the Project according to baseline studies. Surrogate for other riparian herbivores such as the beaver. Important regional traditional food items. Harvested regionally for fur.
Birds			
Aquatic bird	Mallard	Mallard Common Loon	Omnivorous bird with linkages to the aquatic environment. Observed in the vicinity of the Project according to baseline studies. Important regional traditional food items.
Terrestrial bird	Canada Goose	Grouse Canada Goose	Ground feeding herbivore bird. Observed in the vicinity of the Project according to baseline studies. Important regional traditional food items.
Berries/Plants			
Berries	Blueberry	Blueberry	Observed in the study area. Fruit, leaves and stems collected and analyzed for metals and radionuclides. Important regional traditional food item.

Traditional Foods Category	Representative Ecological Receptor	Traditional Foods Diet Components	Rationale[a]
Plants	Labrador tea	Labrador Tea	Generally present in the vicinity of the Project according to baseline studies. Harvested regionally for medicinal use (tea).

a) The selection of representative ecological receptors to represent Traditional Foods diet components was informed by feedback received from local Indigenous Groups during engagement activities.

Table 2-10: Local Food Intake Fractions for Human Diet

		Camp Worker	Recreational Fisher/Hunter		Seasonal Resident				Fisher/ Trapper	Future Permanent Resident	
		(Adult)	(Adult)	(One-Year-Old)	(Adult)		(One-Year-Old)		(Adult)	(Adult)	(One-Year-Old)
Food Category	**Food Type**	**Exposure %**	**Exposure %**	**Exposure %**	**Reference %**	**Exposure %**	**Reference %**	**Exposure %**	**Exposure %**	**Exposure %**	**Exposure %**
Aquatic Animals	Northern Pike	50	50	50	35	15	35	15	50	50	50
	White Sucker	50	50	50	35	15	35	15	50	50	50
Terrestrial Animals	Store Foods	98.08	96.03	99.12	67.22	28.81	69.38	29.74	64.90	96.03	99.12
	Woodland Caribou	0.19	0.40	0.08	0.28	0.12	0.06	0.02	33.54	0.40	0.08
	Moose	0.86	1.78	0.37	1.25	0.53	0.26	0.11	0.89	1.78	0.37
	Moose Organs	0.33	0.68	0.14	0.48	0.20	0.10	0.04	-	0.68	0.14
	Muskrat	0.18	0.37	0.06	0.26	0.11	0.04	0.02	0.16	0.37	0.06
	Mallard	0.22	0.46	0.14	0.32	0.14	0.10	0.04	0.30	0.46	0.14
	Canada Goose	0.14	0.28	0.09	0.20	0.08	0.06	0.03	0.21	0.28	0.09
Terrestrial Plants	Labrador Tea	0.92	0.92	0.34	0.64	0.28	0.24	0.10	-	0.92	0.34
	Blueberry	99.08	99.08	99.66	69.36	29.72	69.76	29.90	-	99.08	99.66

Note:

\- = value not available, or not applicable.

The concentrations of COPCs in store foods (Table 2-11) used in the exposure assessment are consistent with other recent human health risk assessments conducted for uranium mine and mill projects in Saskatchewan. The proportions of different food items in store foods for the Hatchet Lake Band (CanNorth 2000) were used to derive weighted average concentrations of constituents in the store food diet of human receptors based on Health Canada data (2000 to 2011) for non-radiological constituents (except for chromium, molybdenum and vanadium) in foods for all Canadian cities (Health Canada 2011) and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2000) for radiological constituents. Chromium and vanadium concentrations in store food were calculated from Canadian Total Diet Study - Trace Elements 1993-2018 (Health Canada 2020). Molybdenum concentration was obtained from Health Canada data on trace elements in foods from the Total Diet Study (1993 to 1999) for all Canadian cities (Health Canada 2000).

Table 2-11: Concentrations of Constituents of Potential Concern in Store Foods

Constituents of Potential Concern	Concentration [a]
Non-radionuclides [b]	**mg/kg fw**
Arsenic	0.0066
Cadmium	0.0077
Chromium [c]	0.0416
Cobalt	0.0055
Copper	0.57
Molybdenum [d]	0.097
Selenium	0.063
Uranium	0.0014
Vanadium [c]	0.0133
Zinc	3.98
Radionuclides [e]	**Bq/kg fw**
Lead-210	0.039
Polonium-210	0.048
Radium-226	0.042
Thorium-230	0.0058
Uranium-234	0.0097
Uranium-238	0.0097

a) For the estimation of constituents of potential concern in store foods, proportions of food types in the store food diet were aligned with regional data from CanNorth (2000) for the Hatchet Lake First Nation.

b) Non-radionuclides in store foods were calculated from Canadian Total Diet Study on trace elements in foods (2000 to 2011) for all Canadian cities (Health Canada 2011).

c) Chromium and vanadium values were the average values calculated from Canadian Total Diet Study - Trace Elements 1993-2018 (Health Canada 2020). For those values below the limit of detection (LOD), half of their LOD values were used for calculating average concentrations.

d) Molybdenum value from Health Canada data on trace elements in foods from the Total Diet Study (1993 to 1999) for all Canadian cities (Health Canada 2000).

e) Calculated from UNSCEAR (2000).

Bq = becquerel; fw = fresh weight.

2.4.2 Exposure Duration and Frequency

The residency assumptions for human receptors used for the human health risk assessment are summarized in Table 2-12. This includes the fraction of time the receptor spends at a given location as well as the exposure frequency (which refers to the frequency at which the activity causing the exposure occurs). The exposure duration (which refers to the length of time the receptor engages in the activity causing the exposure) was either the duration of the Project phases (30 years) for non-carcinogens, or the lifetime of the receptor (80 years) for carcinogens except for the camp worker, where only the adult life stage would be relevant for carcinogens.

Table 2-12: Summary of Residency Assumptions for Human Health Receptor Groups

<table>
<tr><th>Human Health Receptor Group</th><th>Age Group(s)</th><th>Residence within Study Area</th><th>Project Phases</th><th>Fraction of Time at Residence/ Reference Location</th><th>Exposure Frequency at Residence/Refence Location (months/year)</th></tr>
<tr><td>Camp Worker
(such as a cook)</td><td>Adult</td><td>Whitefish Lake (LA-5)</td><td>Construction
Operation
Decommissioning
Post-decommissioning</td><td>0.5/0.5</td><td>6/6</td></tr>
<tr><td>Recreational Fisher/Hunter</td><td>Adult and one-year-old</td><td>McGowan Lake (LA-1)
Russell Lake</td><td rowspan="3">Construction
Operation
Decommissioning
Post-decommissioning
Future centuries</td><td rowspan="2">0.3/0.7</td><td rowspan="2">4/8</td></tr>
<tr><td>Seasonal Resident</td><td>Adult and one-year-old</td><td>Russell Lake</td></tr>
<tr><td>Fisher/Trapper</td><td>Adult</td><td>Russell Lake</td><td>0.5/0.5</td><td>6/6</td></tr>
<tr><td>Future Permanent Resident</td><td>Adult and one-year-old</td><td>Whitefish Lake (LA-5)</td><td>Future centuries</td><td>1</td><td>12</td></tr>
</table>

2.4.3 Radiological Dose

The dose to human receptors from all radioactive isotopes except radon-222 is estimated using the equations listed below.

Radiological dose due to ingestion (D_f):

$$D_f = DCF_f \Big[\cdot I_w \cdot \sum C_{wc} \cdot k_w \cdot rf \cdot + I_s \cdot \sum C_{soil} \cdot EF_{soil} + I_{sed} \cdot \sum C_s \cdot EF_s \cdot DF_s + I_{tp} \cdot \sum C_{tp} \cdot k_{tp} \cdot \rho_f + I_{ta} \cdot \sum C_{ta} \cdot k_{ta} \cdot \rho_f + I_{ap} \cdot \sum C_{ap} \cdot k_{ap} \cdot \rho_f + I_{aa} \cdot \sum C_{aa} \cdot k_{aa} \cdot \rho_f \Big]$$

Radiological dose due to external exposure to water (D_w):

$$D_w = C_{wc} \cdot [k_w \cdot OF_w + k_w^S \cdot rf \cdot OF_w^S + k_w^B \cdot rf \cdot D_c \cdot OF_w^B] \cdot DCF_w$$

Radiological dose due to external exposure to soil (D_g):

$$D_g = C_{soil} \cdot f_o \cdot f_r \cdot \left[f_u + (1 - f_u) \cdot S_g\right] \cdot DCF_g \cdot \rho_b \cdot z_{soil}$$

Radiological dose due to external exposure to shoreline sediment (D_s):

$$D_s = C_s \cdot OF_s \cdot W \cdot DF_s \cdot DCF_s$$

Radiological dose due to inhalation in air (D_i):

$$D_i = I_a \cdot OF_i \cdot C_a \cdot DCF_{inh}$$

Radiological dose due to immersion in air (D_a):

$$D_a = f_o \cdot [f_u + (1 - f_u) \cdot S_b] \cdot C_a \cdot DCF_a$$

Total dose (D_{total}) to a human receptor from all pathways of exposure:

$$D_{total} = D_f + D_w + D_g + D_s + D_i + D_a$$

where:

C_{aa}	=	aquatic animal concentration (Bq/kg fw)
C_{ap}	=	aquatic plant concentration (Bq/kg fw)
C_s	=	sediment concentration (Bq/kg dw)
C_{soil}	=	surficial soil concentration (Bq/kg dw)
C_{tp}	=	terrestrial plant concentration (Bq/kg dw)
C_{ta}	=	terrestrial animal concentration (Bq/kg fw)
C_{wc}	=	water column concentration (Bq/L)
D_a	=	dose due to external exposure in air (mSv/yr)
D_f	=	dose due to ingestion (millisieverts per year (mSv/yr)
D_g	=	dose due to external exposure to soil/sediment (mSv/yr)
D_i	=	dose due to inhalation (mSv/yr)
D_w	=	dose due to external exposure in water (mSv/yr)
D_{total}	=	total dose (mSv/yr)
DCF_a	=	dose coefficient for external exposure in air ([Sv/yr]/[Bq/m^3])
DCF_f	=	dose coefficient for ingestion (sieverts per becquerel [Sv/Bq])
DCF_g	=	dose coefficient for external exposure to soil ([Sv/yr]/[Bq/m^2])
DCF_{inh}	=	dose coefficient for inhalation (Sv/Bq)
DCF_s	=	dose coefficient for external exposure to sediment ([Sv/yr]/[Bq/kg])
DCF_w	=	dose coefficient for external exposure in water ([Sv/yr]/[Bq/L])
DF_s	=	dilution factor for shoreline deposits (unitless)
EF_{soil}	=	number of days per year in which soil ingestion occurs (d/yr)
EF_s	=	number of days per year in which sediment ingestion occurs (d/yr)
f_o	=	fraction of total time spent by the individual at the particular location (unitless)
f_r	=	dose reduction factor for non-uniformity of ground surface (unitless)

f_u	=	time spent outdoors at a particular location as a fraction of total time spent at that location (unitless)
I_a	=	inhalation rate (m^3/yr)
I_{aa}	=	aquatic animals' ingestion rate (kg fw/yr)
I_{ap}	=	aquatic plants ingestion rate (kg fw/yr)
I_s	=	sediment ingestion rate (kg dw/d)
I_{soil}	=	soil ingestion rate (kg dw/d)
I_{ta}	=	terrestrial animal ingestion rate (kg fw/yr)
I_{tp}	=	terrestrial plant ingestion rate (kg dw/yr)
I_w	=	water ingestion rate (L/yr)
k_a	=	fraction of air inhalation intake from contaminated source (unitless)
k_{aa}	=	fraction of aquatic animal intake from contaminated source (unitless)
k_{ap}	=	fraction of aquatic plant intake from contaminated source (unitless)
k_{ta}	=	fraction of terrestrial animal intake from contaminated source (unitless)
k_{tp}	=	fraction of terrestrial plant intake from contaminated source (unitless)
k_w	=	fraction of water intake from contaminated source (unitless)
k_w^B	=	fraction of bathing in contaminated water (unitless)
k_w^S	=	fraction of beach swimming in contaminated water (unitless)
OF_i	=	occupancy factor for inhalation (unitless)
OF_s	=	occupancy factor for sediment (unitless)
OF_w	=	occupancy factor for swimming in a surface water body (unitless)
OF_W^B	=	occupancy factor in bath water (unitless)
OF_W^S	=	occupancy factor in swimming water (unitless)
ρ_b	=	dry bulk density of the soil (kg dry soil per m^3)
ρ_f	=	adjustment factor for food processing (unitless)
rf	=	dose reduction factor for water treatment (unitless)
S_b	=	building shielding factor (unitless)
S_g	=	groundshine dose reduction factor for indoor shielding (unitless)
W	=	shore-width factor that describes the shoreline exposure geometry (unitless)
z_{soil}	=	soil mixing depth (m)

Dose from Radon

Consistent with recommendations in CSA N288.6-22 and Health Canada (2010b), the dose from radon in air is calculated according to the following equation:

$$Dose_{Rn} = \left[\frac{C_{Rn}}{3700\frac{Bq}{m^3}} \times F \times \frac{ET}{170h}\right] \times 4mSv$$

Radon typically dissipates quickly outdoors and is usually not a human health issue. However, dose from exposure to radon indoors should be quantified. The outdoor equilibrium fraction is needed to estimate the indoor equilibrium fraction. The equilibrium fraction for radon in outdoor air was estimated as a function of the travel time from the radon source using guidance from Health Canada and the USEPA according to the following equation (Health Canada 2010b; USEPA 1986):

$$F_{out} = 1.0 - 0.0479e^{-\frac{t}{4.39}} - 2.1963e^{-\frac{t}{38.6}} + 1.2442e^{-\frac{t}{28.4}}$$

The equilibrium fraction for radon in indoor air (F_{in}) was estimated as a function of the outdoor equilibrium fraction (F_{out}) using guidance from Health Canada (2010b) and the USEPA (1986) according to the following equation:

$$F_{in} = 0.35(1 + F_{out})$$

where:

C_{Rn}	=	concentration of radon in air (Bq/m^3)
$Dose_{Rn}$	=	incremental dose from radon (mSv/yr)
ET	=	exposure time (h/yr)
F	=	degree of equilibrium between radon and decay products (unitless)
F_{in}	=	indoor equilibrium fraction (unitless)
F_{out}	=	outdoors equilibrium fraction (unitless)
t	=	travel time from source to receptor (minutes) (distance from source to receptor divided by mean wind speed)

2.4.4 Non-radiological Dose

The human receptor exposure to non-radiological COPCs is estimated from the following equations:

Non-radiological intake due to inhalation (D_i):

$$D_i = \frac{C_{air} \cdot I_a \cdot k_a \cdot OF_i}{BM}$$

Non-radiological dose due to ingestion (D_f):

$$D_f = \frac{1}{BM \cdot C} \cdot \Big[I_w \cdot \sum(C_{wc} \cdot k_w \cdot rf) + I_s \cdot \sum\left(C_s \cdot EF_s \cdot DF_s \cdot RAF_{ing}\right) + I_{soil} \cdot \sum\left(C_{soil} \cdot EF_{soil} \cdot RAF_{ing}\right) + I_{tp} \cdot \sum\left(C_{tp} \cdot k_{tp} \cdot \rho_f\right) + I_{ta} \cdot \sum\left(C_{ta} \cdot k_{ta} \cdot \rho_f\right) + I_{ap} \cdot \sum\left(C_{ap} \cdot k_{ap} \cdot \rho_f\right) + I_{aa} \cdot \sum\left(C_{aa} \cdot k_{aa} \cdot \rho_f\right)\Big]$$

Non-radiological external exposure to water (dermal absorption) (D_w):

$$D_w = \frac{k_p \cdot SA_w}{BM} \cdot [C_w^S \cdot OF_w^S + C_w^B \cdot rf \cdot OF_w^B + C_w^P \cdot rf \cdot OF_w^P]$$

Non-radiological external exposure to soil and/or sediment (dermal absorption) ($D_{s,d}$):

$$D_{s,d} = \frac{[C_{soil} * (SA_{hands} * AF_{hands} + SA_{other} * AF_{other}) * RAF_{derm} * EF_{soil}]}{BM * C}$$

where:

AF_{hands}	=	soil adherence factor to hands (kg/m² d)
AF_{other}	=	soil adherence factor to skin other than hands (kg/m² d)
BM	=	body mass (kg)
C	=	conversion factor (365 days per year)
C_{aa}	=	aquatic animal concentration (mg/kg fw)
C_{air}	=	air concentration (mg/m³)
C_{ap}	=	aquatic plant concentration (mg/kg fw)
C_s	=	sediment concentration (mg/kg dw)
C_{soil}	=	surficial soil concentration (mg/kg dw)
C_{tp}	=	terrestrial plant concentration (mg/kg dw)
C_{ta}	=	terrestrial animal concentration (mg/kg fw)
C_w^S	=	water concentration at the beach (mg/L)
C_w^B	=	water concentration in the bath (mg/L)
C_w^P	=	water concentration in the pool (mg/L)
C_{wc}	=	water column concentration (mg/L)
D_f	=	dose due to ingestion (mg/kg d)
D_i	=	dose due to inhalation (mg/kg d)
$D_{s,d}$	=	dose due to dermal contact with soil (mg/kg d)
EF_s	=	days per year exposed to sediment (d/yr)
EF_{soil}	=	days per year exposed to soil (d/yr)
I_a	=	inhalation rate (m³/yr)
I_{aa}	=	aquatic animals' ingestion rate (kg fw/yr)
I_{ap}	=	aquatic plants ingestion rate (kg fw/yr)
I_s	=	sediment ingestion rate (kg dw/d)
I_{soil}	=	soil ingestion rate (kg dw/d)
I_{ta}	=	terrestrial animal ingestion rate (kg fw/yr)
I_{tp}	=	terrestrial plant ingestion rate (kg dw/yr)
I_w	=	water ingestion rate (L/yr)
k_a	=	fraction of air inhalation intake from contaminated source (unitless)
k_{aa}	=	fraction of aquatic animal intake from contaminated source (unitless)
k_{ap}	=	fraction of aquatic plant intake from contaminated source (unitless)
k_p	=	chemical specific permeability coefficient (cm/h)
k_{ta}	=	fraction of terrestrial animal intake from contaminated source (unitless)
k_{tp}	=	fraction of terrestrial plant intake from contaminated source (unitless)
OF_i	=	occupancy factor for inhalation (unitless)

OF_W^B	=	occupancy factor in bath water (unitless)
OF_W^P	=	occupancy factor in pool water (unitless)
OF_W^S	=	occupancy factor at the beach (unitless)
ρ_f	=	adjustment factor for food processing (unitless)
RAF_{derm}	=	relative absorption factor for soil dermal contact (unitless)
RAF_{ing}	=	relative absorption factor for ingestion (unitless)
rf	=	dose reduction factor for water treatment (unitless)
SA_w	=	surface area of exposed skin (m^2)
SA_{hands}	=	surface area of hands (m^2)
SA_{other}	=	surface area of exposed skin other than hands (m^2)

Potential non-cancer effects are evaluated using HQ values estimated as described in Section 2.3.6 for ecological receptors. Potential cancer risks from exposure to carcinogenic constituents are evaluated as incremental lifetime cancer risks.

3.0 Development of Model Parameters

3.1 Ambient Hydrology

A baseline sampling program is fundamental to the development and application of an ecological model for Environmental Assessment. In addition to data on environmental media, many other parameters are required to quantify the transport and fate of constituents in the environment. Many of those parameters are not typically measured and are therefore estimated in the modelling process.

3.1.1 Lake Morphometry

Waterbodies from Whitefish Lake to the Russell Lake inlet were modelled to assess the effects of the Project on the downstream environment. Kratchkowsky Lake and Whitefish Lake North were modelled as reference locations. The lakes were modelled based on characteristics consistent with measured values as presented in Table 3-1. All values are based on the baseline aquatic environment study report (Ecometrix, 2020a).

Table 3-1: Lake Morphometry for all Modelled Lakes in the IMPACT Model

Lake Modelled	Average Depth (m)	Area (km^2)	Average Outflow (L/s)	Retention Time (day)
Reference Kratchkowsky Lake (LA-7 South)	2.9	0.80	331.2	80.66
Whitefish Lake North (LA-6)	1.6	0.26	1379.3	3.53
Whitefish Lake Middle (LA-5 North)	1.1	0.10	1398.5	0.88
Whitefish Lake South (LA-5 South)	1.0	0.32	1414.3	2.65
McGowan Lake (LA-1)	5.5	1.49	1832.3	51.61
Russell Lake Inlet	3.0	0.75	2390.3	10.92

The stream model in IMPACT was used to model rivers and streams to connect McGowan Lake and Russell Lake. As such, the Icelander River acts as a flow-through channel, and no sediment interaction was modelled here. The three basins of Whitefish Lake were modelled as separate waterbodies: Whitefish Lake North, Whitefish Lake Middle and Whitefish Lake South. Part of Russell Lake was modelled, as a conservative representation of the exposure area on Russell Lake.

3.1.2 Surface Water Flows

Watersheds and yields were implemented consistent with the hydrological effect assessment report (NewFields, 2021). Average monthly flows are shown in Table 3-2, and Figure 3-1 shows the flow direction through the modelled environment as implemented in IMPACT. The outflow in IMPACT is calculated as the sum of the upstream flow entering a body of water and the local inflow, defined as any inflow from the contributing watershed and tributaries. The local inflow was calculated based on watershed yield and area. Based on this, inputs for the local inflows were calculated for input into the IMPACT model (Table 3-3).

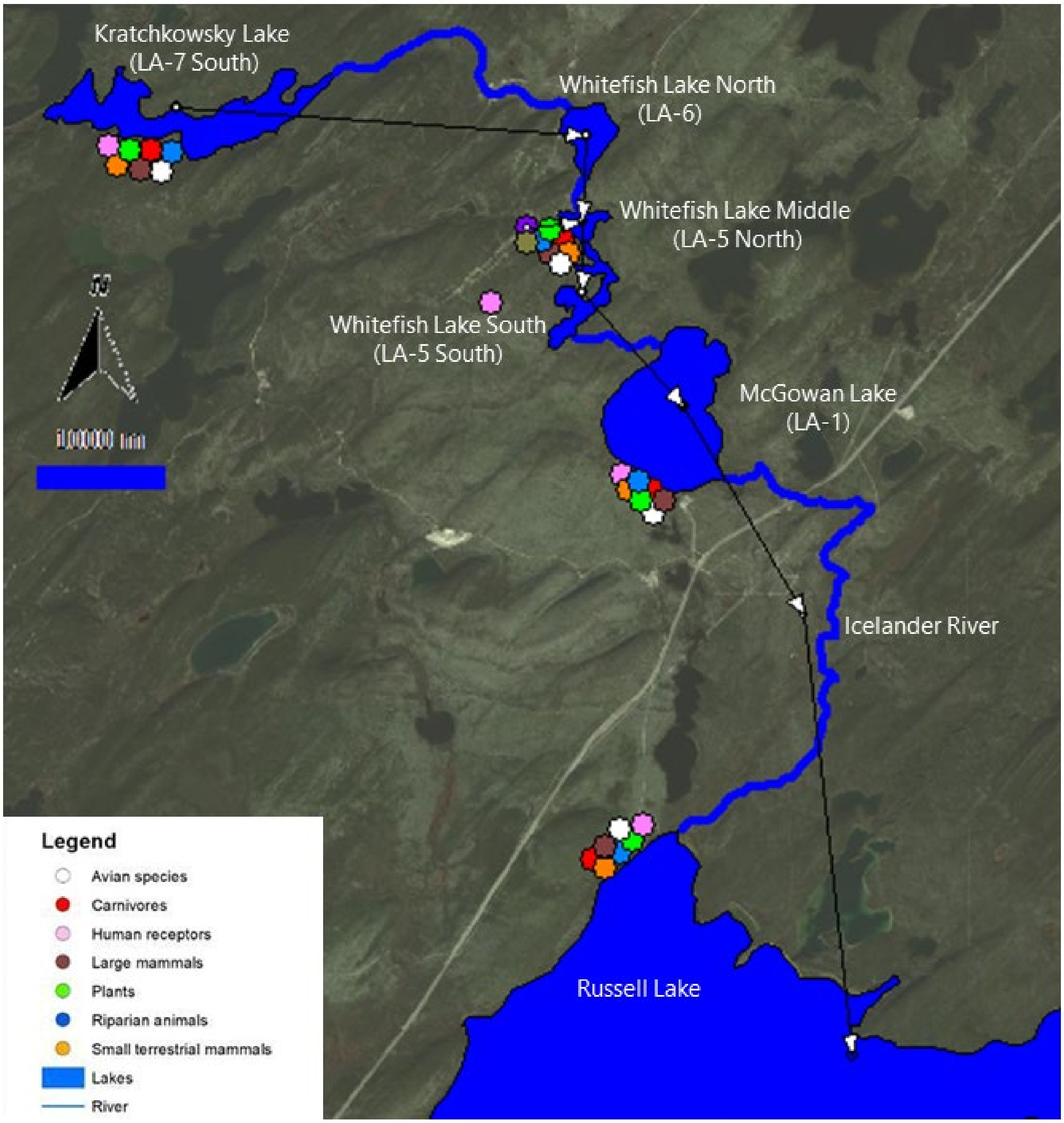


Figure 3-1: Waterbodies and Flow Direction as Implemented in the IMPACT Model

Table 3-2: Average Monthly Flows

Lake Name	Outflow (L/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Kratchkowsky Lake	276.8	264.7	254.9	292.9	444.4	443.8	380.9	337.1	326.7	340.6	323.7	288.1	331.2
Whitefish Lake North	1129.2	1075.4	1029.4	1198.7	1900.0	1900.2	1607.0	1405.0	1360.1	1425.1	1343.4	1178.0	1379.3
Whitefish Lake Middle	1138.7	1082.8	1035.1	1210.9	1939.4	1939.5	1634.9	1425.2	1378.5	1446.1	1361.2	1189.4	1398.5
Whitefish Lake South	1146.6	1088.9	1039.7	1221.0	1971.9	1972.0	1658.1	1441.9	1393.8	1463.4	1375.9	1198.8	1414.3
McGowan Lake	1571.7	1501.6	1458.0	1673.7	2371.9	2356.3	2077.7	1868.0	1800.0	1863.4	1803.5	1641.2	1832.3
Icelander River	1588.9	1517.9	1473.9	1692.0	2397.8	2382.0	2100.4	1888.4	1819.7	1883.7	1823.2	1659.1	1852.3
Russell Lake Inlet	2050.4	1958.9	1902.0	2183.4	3094.3	3073.9	2710.5	2436.9	2348.2	2430.9	2352.7	2141.0	2390.3

Table 3-3: Mean Monthly Local Inflows for All Waterbodies Modelled in IMPACT

Lake Name	Mean Monthly Local Inflow (L/s)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Kratchkowsky Lake	276.8	264.7	254.9	292.9	444.4	443.8	380.9	337.1	326.7	340.6	323.7	288.1	331.2
Whitefish Lake North	852.4	810.7	774.5	905.8	1455.6	1456.4	1226.1	1067.9	1033.4	1084.5	1019.7	889.9	1048.1
Whitefish Lake Middle	9.5	7.4	5.7	12.2	39.4	39.3	27.9	20.2	18.4	21.0	17.8	11.4	19.2
Whitefish Lake South	7.8	6.1	4.6	10.1	32.5	32.5	23.2	16.7	15.2	17.3	14.7	9.4	15.9
McGowan Lake	425.1	412.7	418.3	452.7	400.0	384.3	419.6	426.1	406.2	400.0	427.6	442.4	417.9
Icelander River	17.2	16.3	15.9	18.3	25.9	25.7	22.7	20.4	19.7	20.3	19.7	17.9	20.0
Russell Lake Inlet	461.5	441.0	428.1	491.4	696.5	691.9	610.1	548.5	528.5	547.2	529.5	481.9	538.0

3.2 Water Quality

3.2.1 Background Water Quality

To characterize regional background water quality, a database of baseline water and sediment quality data was compiled from baseline studies performed between 2011 and 2019 (Ecometrix, 2020a). The water and sediment quality data included in the calculation of the regional baseline were obtained from 32 water measurement stations and 35 sediment measurement stations along the five modelled lakes and nearby waterbodies from Kratchkowsky Lake to Russell Lake. The geometric mean of all data in a series of lakes from Kratchkowsky Lake to Russell Lake was selected as the baseline concentration for constituents that had measured data over the detection limit. In the case of constituents for which most or all measured values in water were under the detection limit, but sediment concentration measurements were over the detection limit, the baseline water concentration was calculated from the geometric mean of the sediment measurements using the partitioning coefficients (K_d) (Section 3.3.2). This was the case for cadmium, chromium, copper, selenium, uranium, and vanadium. The geomean is generally more representative of the central value of the data distribution; however, considering the data represents baseline conditions with many values below the detection limit, there is limited difference between the geomean and the arithmetic mean for the majority of constituents.

Lead-210 and its daughter polonium-210 were assumed to be in transient equilibrium. Activity concentrations of a parent and daughter nuclide in transient equilibrium are governed by the following relationship:

$$Q_B = \frac{\lambda_B}{\lambda_B - \lambda_A} \cdot Q_A$$

where:

Q_A	=	activity of the parent
Q_B	=	activity of the daughter
λ_A	=	half life of the parent
λ_B	=	half life of the daughter

Polonium-210 and lead-210 were balanced to remain in transient equilibrium. Sediment concentration of polonium-210 was calculated from the measured values of its water concentration using the distribution coefficient (K_d). The transient equilibrium assumption was used to calculate the sediment concentration of lead-210 from the polonium-210 sediment concentration, and the calculated lead-210 sediment concentration was used to model water concentration of lead-210 using the K_d.

The inflow concentrations for each waterbody were assigned slightly higher values than the background concentrations since sedimentation processes remove metals and radionuclides from the inflow. Inflow concentrations were calculated from the background concentration, the residence time within each respective waterbody, the sedimentation rate, and the COPC-specific partitioning coefficient. The slightly higher inflow values were used in the model to predict stable concentrations in water and sediment within the range of observed values of background conditions. Those concentrations are presented in Table 3-4.

Table 3-4: Calibrated Local Inflow Concentrations for each Water Polygon modelled in IMPACT

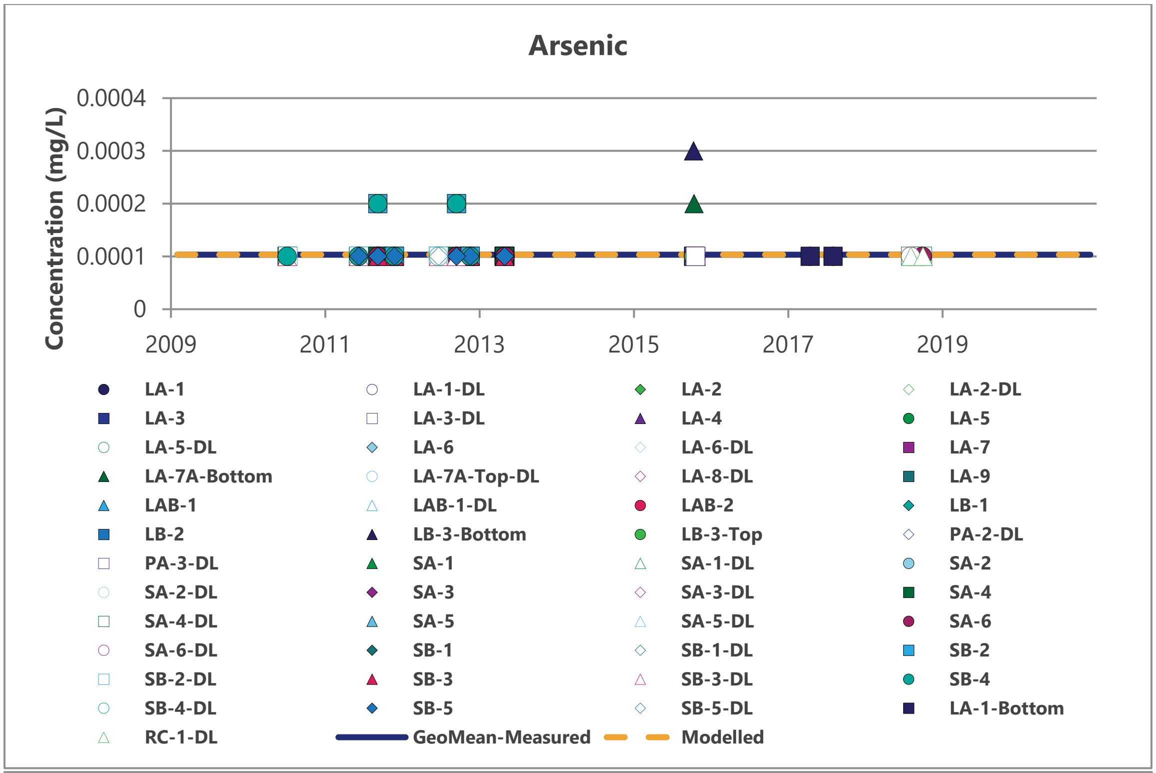
COPCs	Water Baseline	Kratchkowsky Lake	Whitefish Lake North	Whitefish Lake Middle	Whitefish Lake South	McGowan Lake	Icelander River	Russel Lake Inlet
Non-radionuclides	mg/L							
Arsenic	1.03E-04	2.70E-04	1.21E-04	4.54E-04	1.52E-03	3.50E-04	1.03E-04	2.00E-04
Cadmium	2.32E-05	2.90E-05	2.38E-05	3.54E-05	7.28E-05	3.18E-05	2.32E-05	2.66E-05
Chloride	3.22E-01	3.22E-01	3.22E-01	3.22E-01	3.22E-01	3.22E-01	3.22E-01	3.22E-01
Chromium	5.19E-04	6.19E-04	5.29E-04	7.30E-04	1.37E-03	6.68E-04	5.19E-04	5.77E-04
Cobalt	1.01E-04	1.05E-04	1.01E-04	1.10E-04	1.37E-04	1.07E-04	1.01E-04	1.03E-04
Copper	6.18E-04	6.49E-04	6.22E-04	6.84E-04	8.83E-04	6.64E-04	6.18E-04	6.36E-04
Molybdenum	1.07E-04	1.13E-04	1.07E-04	1.19E-04	1.55E-04	1.15E-04	1.07E-04	1.10E-04
Selenium	3.23E-05	4.32E-05	3.34E-05	5.51E-05	1.24E-04	4.83E-05	3.23E-05	3.86E-05
Sulphate	6.87E-01	6.87E-01	6.87E-01	6.87E-01	6.87E-01	6.87E-01	6.87E-01	6.87E-01
Uranium	3.01E-05	4.01E-05	3.11E-05	5.13E-05	1.16E-04	4.50E-05	3.01E-05	3.59E-05
Vanadium	1.46E-04	3.68E-04	1.69E-04	6.13E-04	2.03E-03	4.74E-04	1.46E-04	2.75E-04
Zinc	6.81E-04	8.52E-04	6.98E-04	1.04E-03	2.14E-03	9.34E-04	6.81E-04	7.80E-04
Radionuclides	Bq/L							
Lead-210 [a]	5.27E-03	1.60E-02	6.39E-03	2.78E-02	9.63E-02	2.12E-02	5.27E-03	1.15E-02
Polonium-210	5.36E-03	1.63E-02	6.50E-03	2.83E-02	9.80E-02	2.16E-02	5.36E-03	1.17E-02
Radium-226	5.57E-03	6.70E-03	5.69E-03	7.94E-03	1.51E-02	7.23E-03	5.57E-03	6.23E-03
Thorium-230	1.01E-02	1.05E-02	1.01E-02	1.09E-02	1.34E-02	1.07E-02	1.01E-02	1.03E-02
Uranium-234 [b]	3.71E-04	4.96E-04	3.84E-04	6.33E-04	1.43E-03	5.56E-04	3.71E-04	4.44E-04
Uranium-238 [b]	3.71E-04	4.96E-04	3.84E-04	6.33E-04	1.43E-03	5.56E-04	3.71E-04	4.44E-04

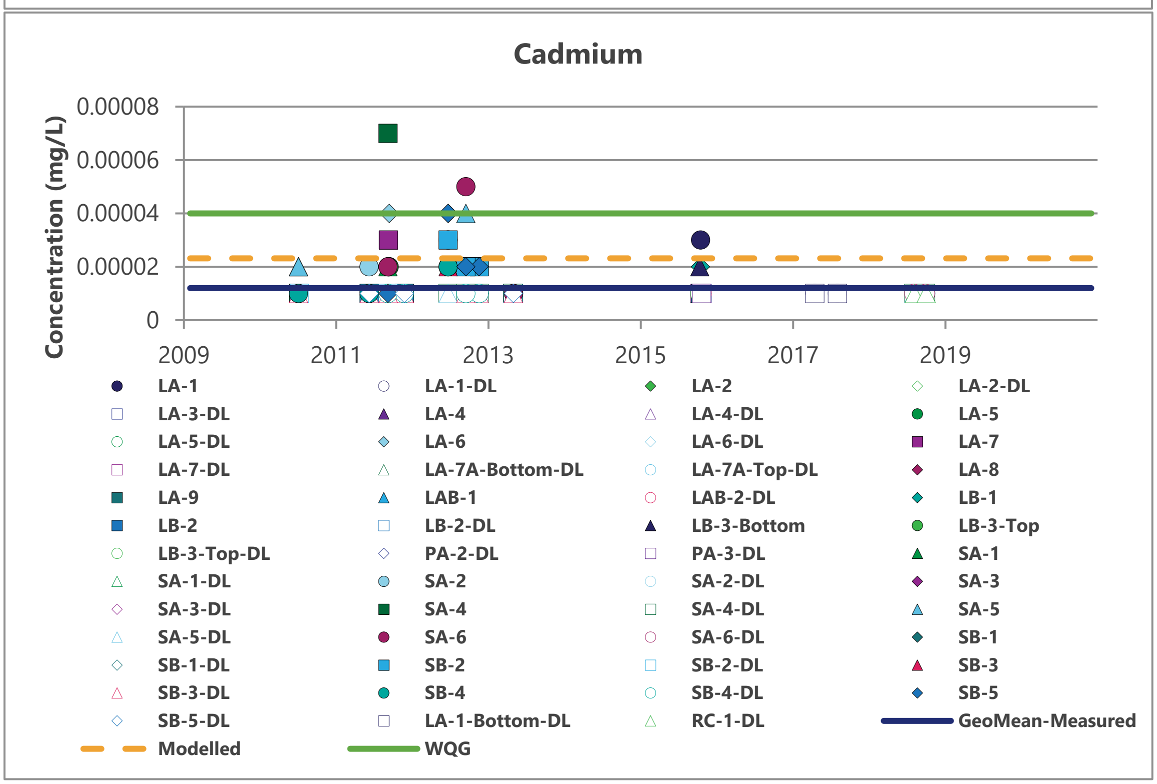
a. Calculated to be in transient equilibrium with polonium-210.

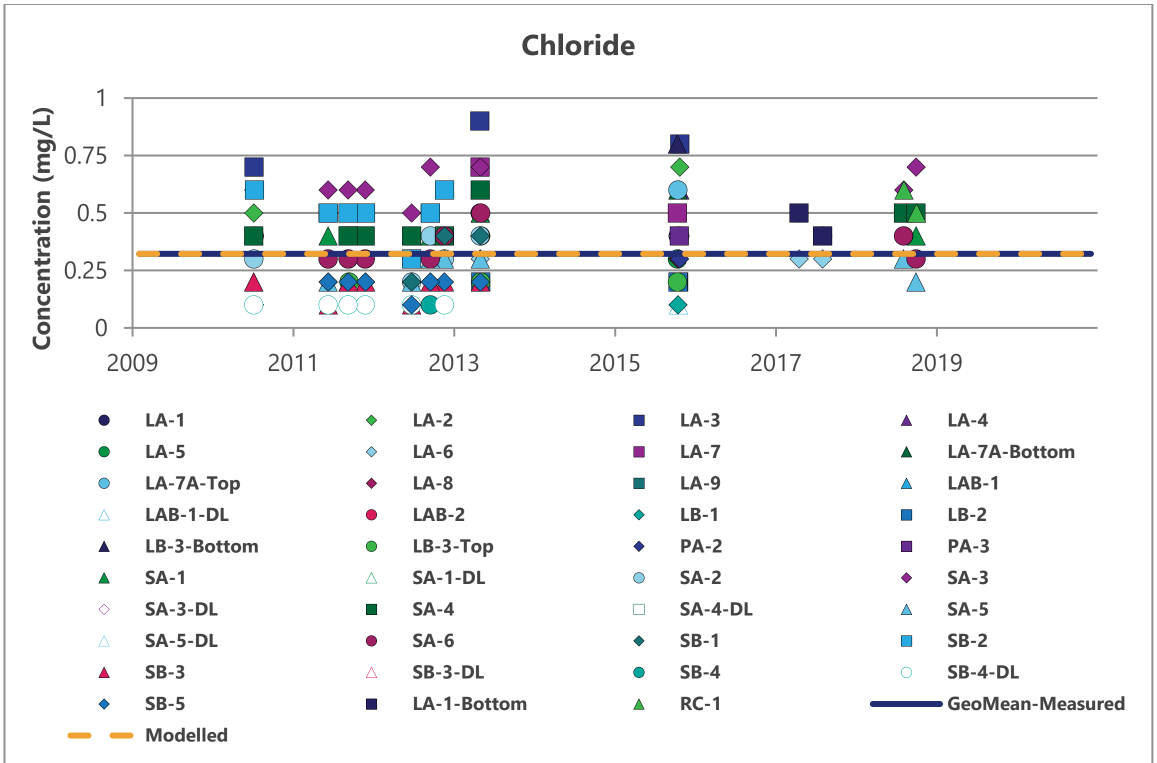
b. Estimated from uranium using the specific activity of 12,356 Bq/g and assuming secular equilibrium between uranium-238 and uranium-234 (**https://www.wise-uranium.org/rup.html**)

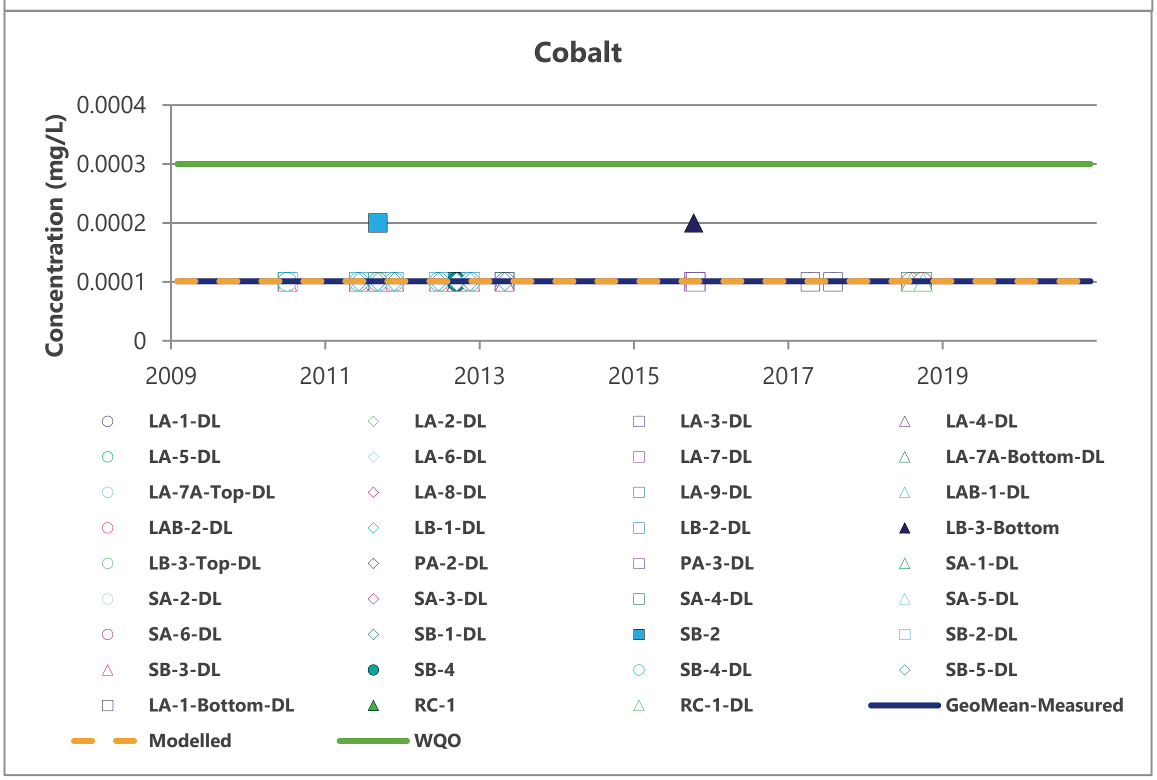
Modelled average water baseline concentrations of COPCs are presented in Table 3-4 and a comparison to measured values is shown in Figure 3-2. The purpose of these plots is to show trends over time for selected COPCs and the generally good agreement between the measured and modelled concentrations. A good agreement is considered as the modelled concentrations fall in the range of measured concentrations, which is the case for most of the COPCs with the exception for selenium, uranium and lead-210. Water concentrations for selenium, uranium and lead-210 are unlikely underestimated because more than 96% of the measured values (142 in total) are below their detection limit. Water concentration for copper is likely overestimated, since the modelled concentration is over the detection limit, with 98% of the measured values (139 out of 142) being under the detection limit for copper. This under (selenium, uranium and lead-210) or overestimation (cadmium, chromium, copper and vanadium) is a result of the method for derivation of water concentrations based on their measured sediment values

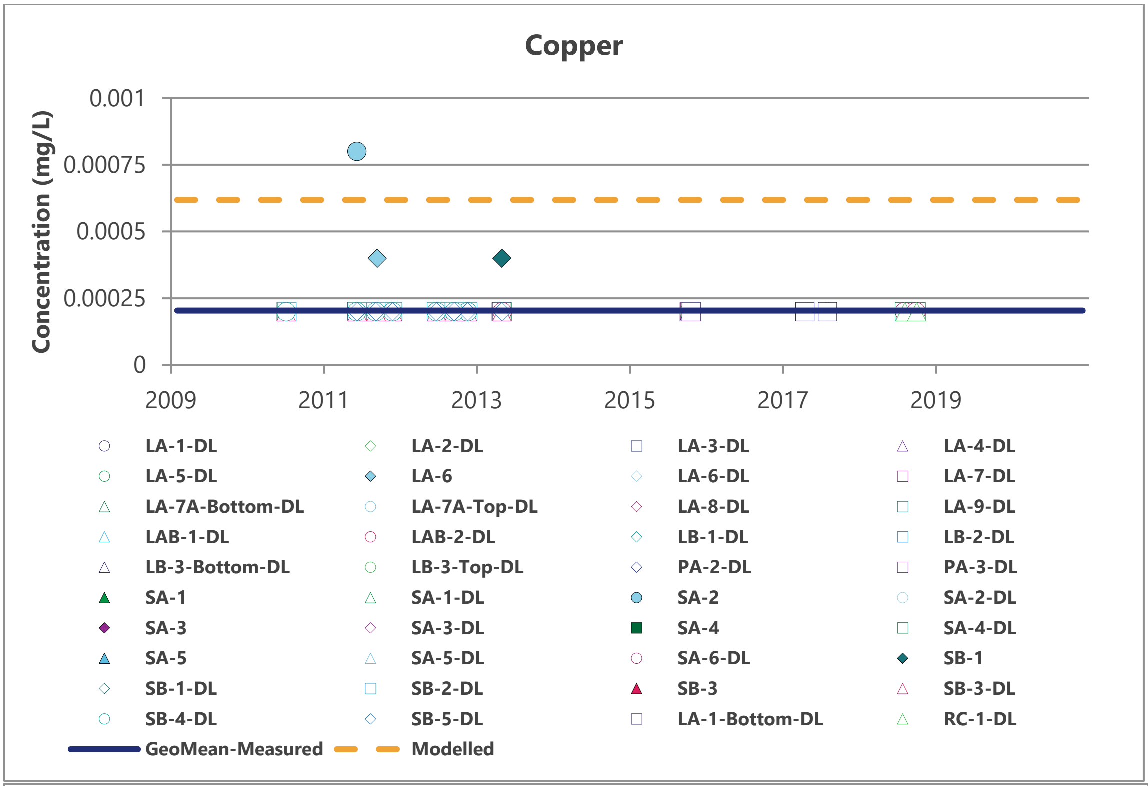
(Section 3.3, Sediment Quality). Unlike chloride and sulphate, metals and radionuclides are expected to interact with sediment. In the case of radionuclides, ingrowth and decay are other factors that may influence activities in the receiving environment.

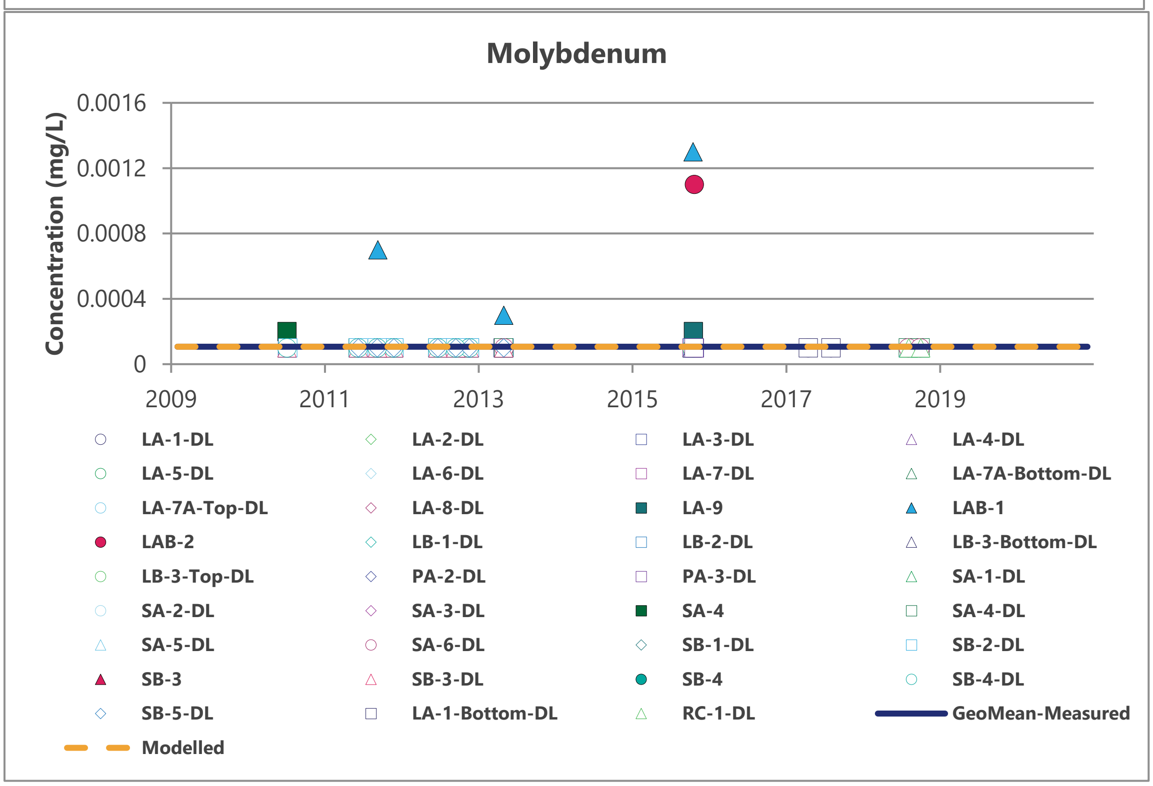


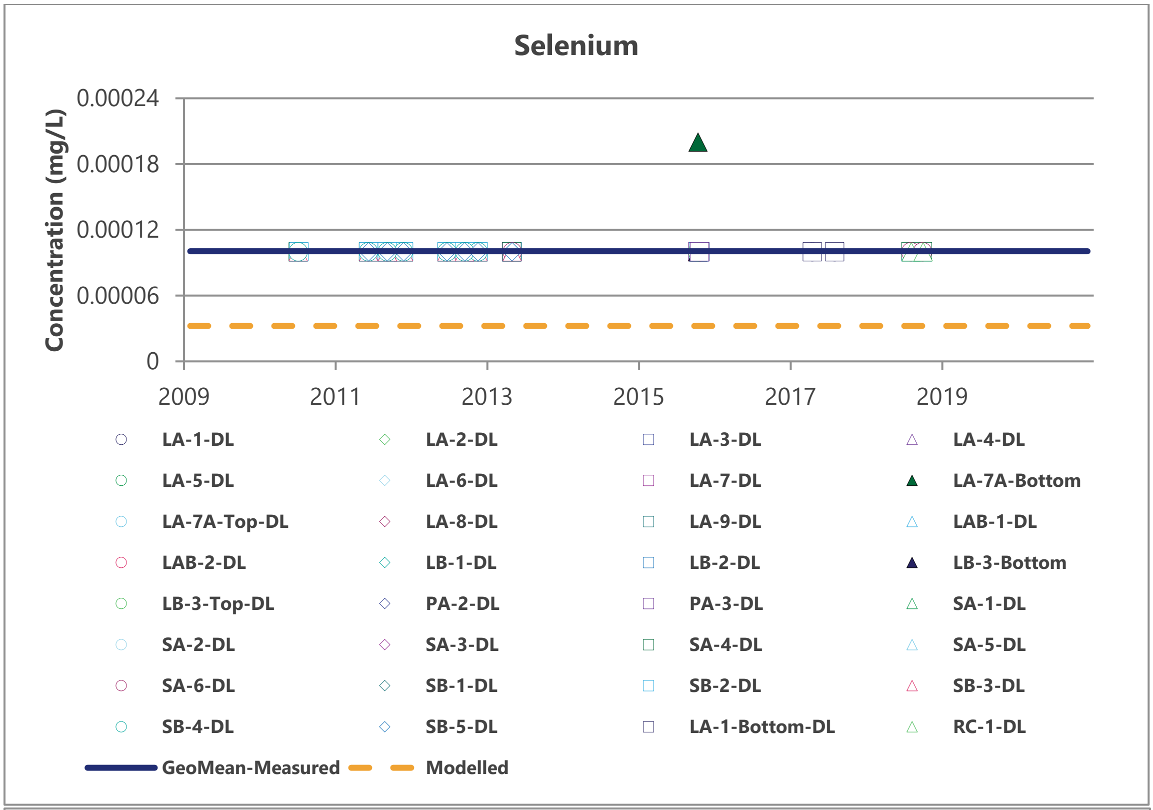


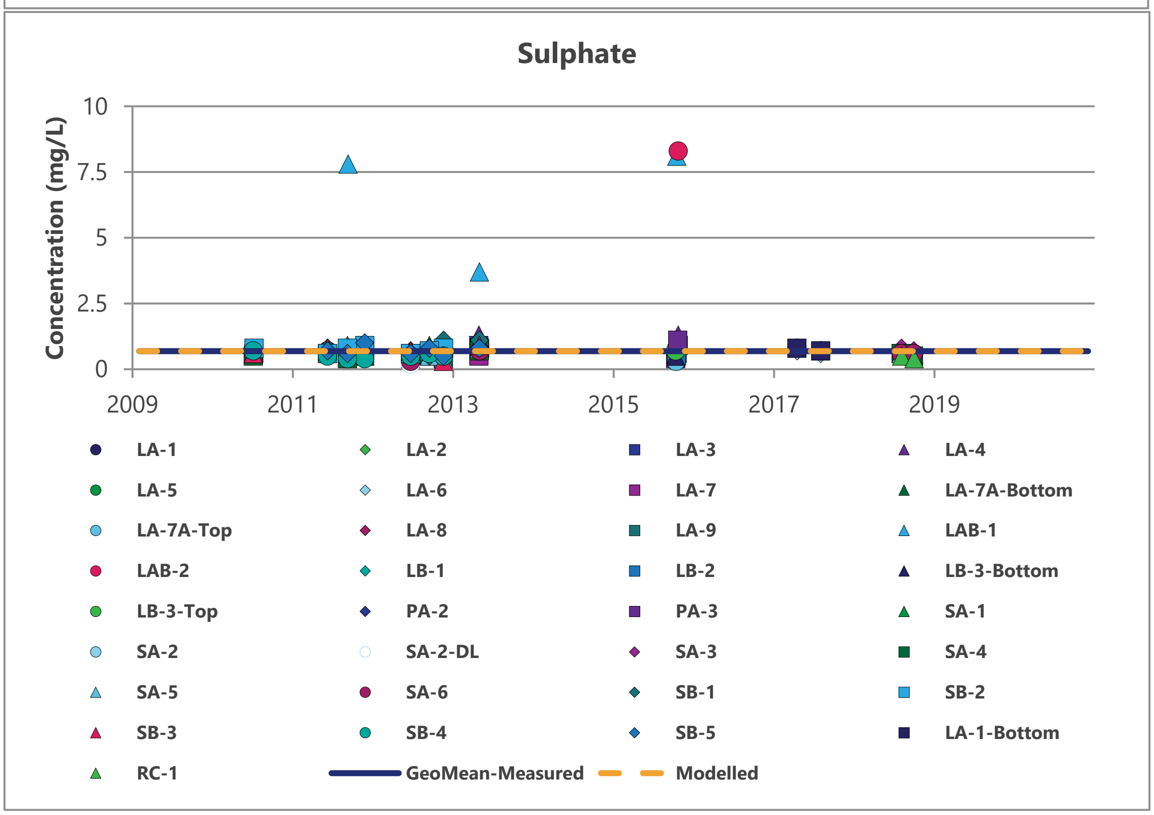

Chloride
Concentration (mg/L)
1
0.75
0.5
0.25
0
2009
2011
2013
2015
2017
2019
LA-1
LA-2
LA-3
LA-4
LA-5
LA-6
LA-7
LA-7A-Bottom
LA-7A-Top
LA-8
LA-9
LAB-1
LAB-1-DL
LAB-2
LB-1
LB-2
LB-3-Bottom
LB-3-Top
PA-2
PA-3
SA-1
SA-1-DL
SA-2
SA-3
SA-3-DL
SA-4
SA-4-DL
SA-5
SA-5-DL
SA-6
SB-1
SB-2
SB-3
SB-3-DL
SB-4
SB-4-DL
SB-5
LA-1-Bottom
RC-1
GeoMean-Measured
Modelled

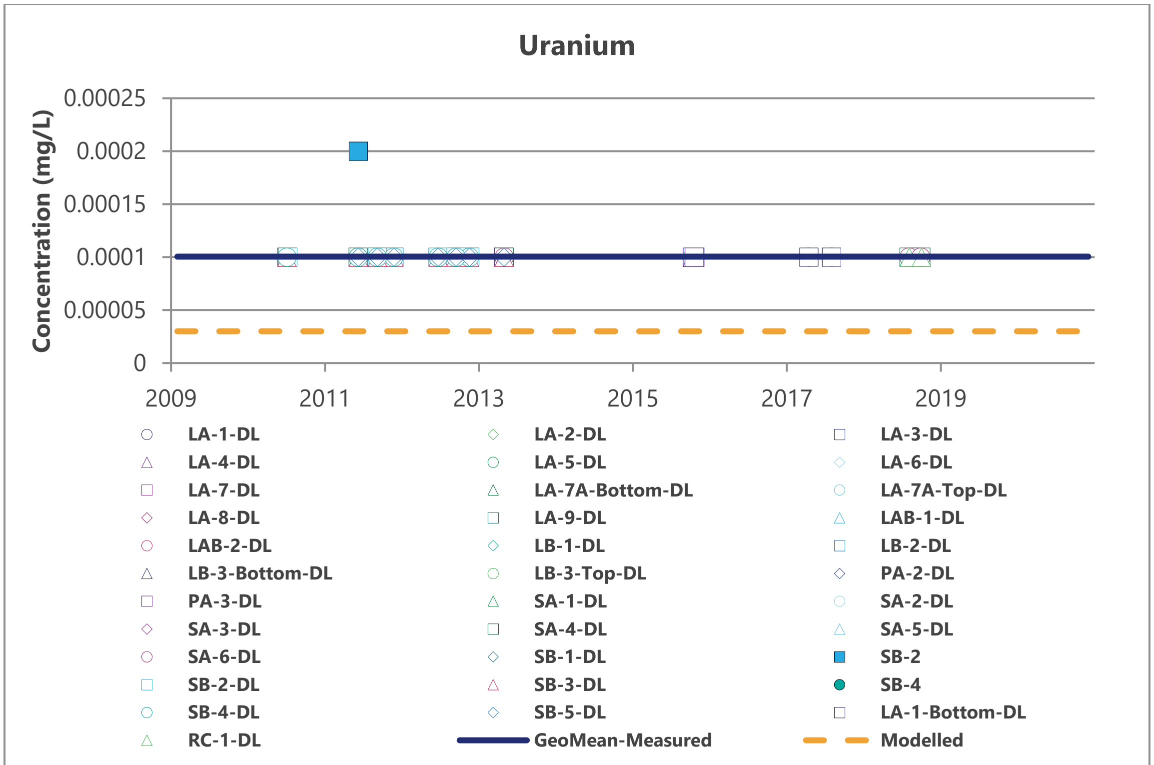

Cobalt
Concentration (mg/L)
0.0004
0.0003
0.0002
0.0001
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6-DL
LA-7-DL
LA-7A-Bottom-DL
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1-DL
SA-2-DL
SA-3-DL
SA-4-DL
SA-5-DL
SA-6-DL
SB-1-DL
SB-2
SB-2-DL
SB-3-DL
SB-4
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1
RC-1-DL
GeoMean-Measured
Modelled
WQO

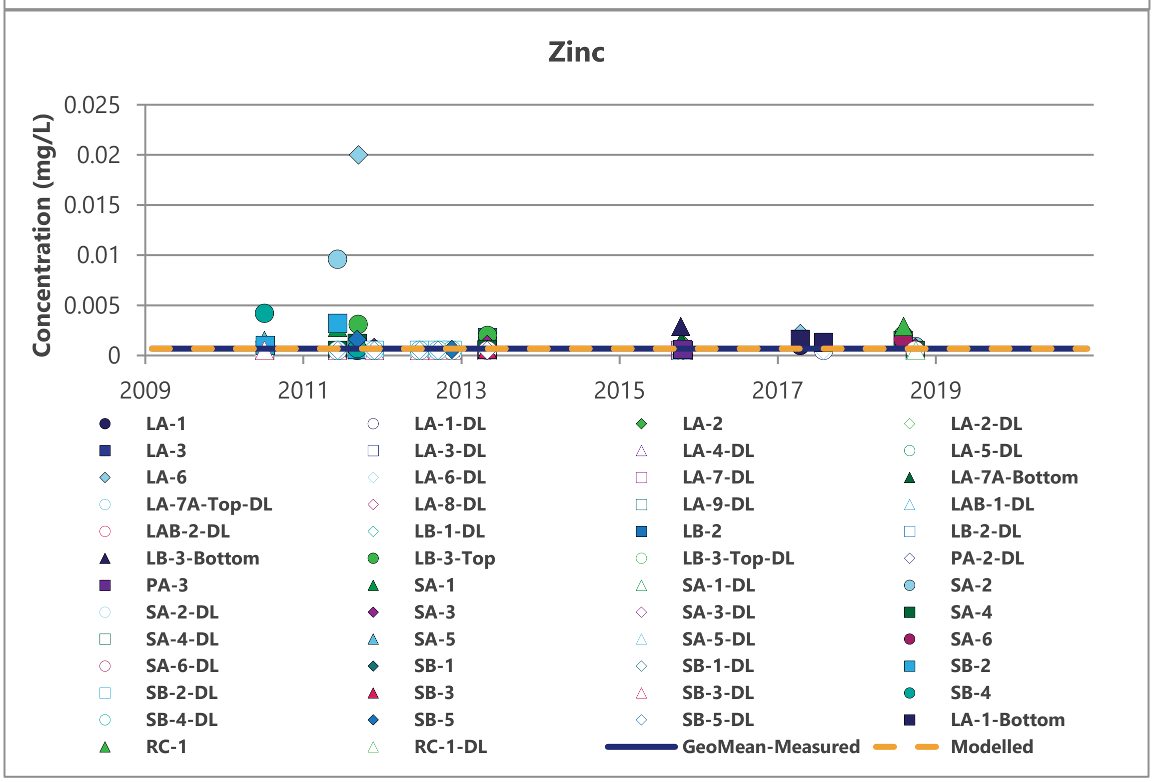

Copper
Concentration (mg/L)
0.001
0.00075
0.0005
0.00025
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6
LA-6-DL
LA-7-DL
LA-7A-Bottom-DL
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom-DL
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1
SA-1-DL
SA-2
SA-2-DL
SA-3
SA-3-DL
SA-4
SA-4-DL
SA-5
SA-5-DL
SA-6-DL
SB-1
SB-1-DL
SB-2-DL
SB-3
SB-3-DL
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled

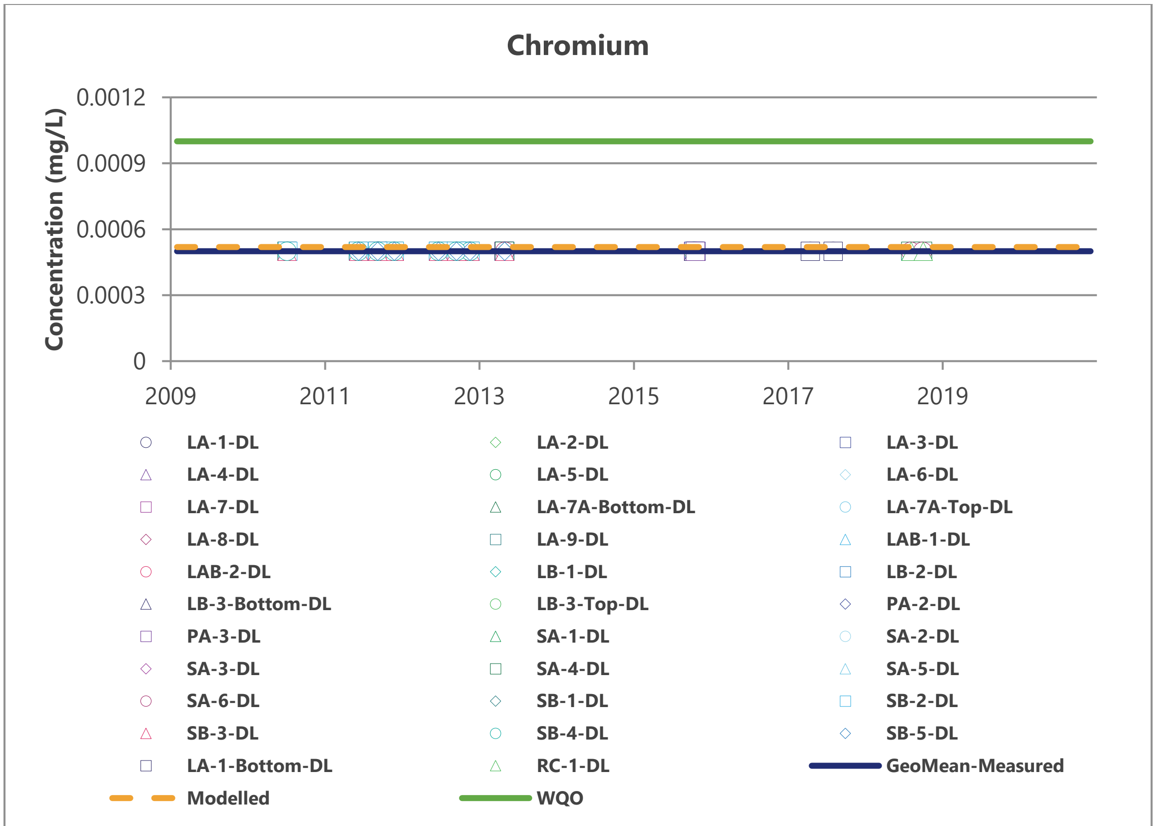

Molybdenum
Concentration (mg/L)
0.0016
0.0012
0.0008
0.0004
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6-DL
LA-7-DL
LA-7A-Bottom-DL
LA-7A-Top-DL
LA-8-DL
LA-9
LAB-1
LAB-2
LB-1-DL
LB-2-DL
LB-3-Bottom-DL
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1-DL
SA-2-DL
SA-3-DL
SA-4
SA-4-DL
SA-5-DL
SA-6-DL
SB-1-DL
SB-2-DL
SB-3
SB-3-DL
SB-4
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled

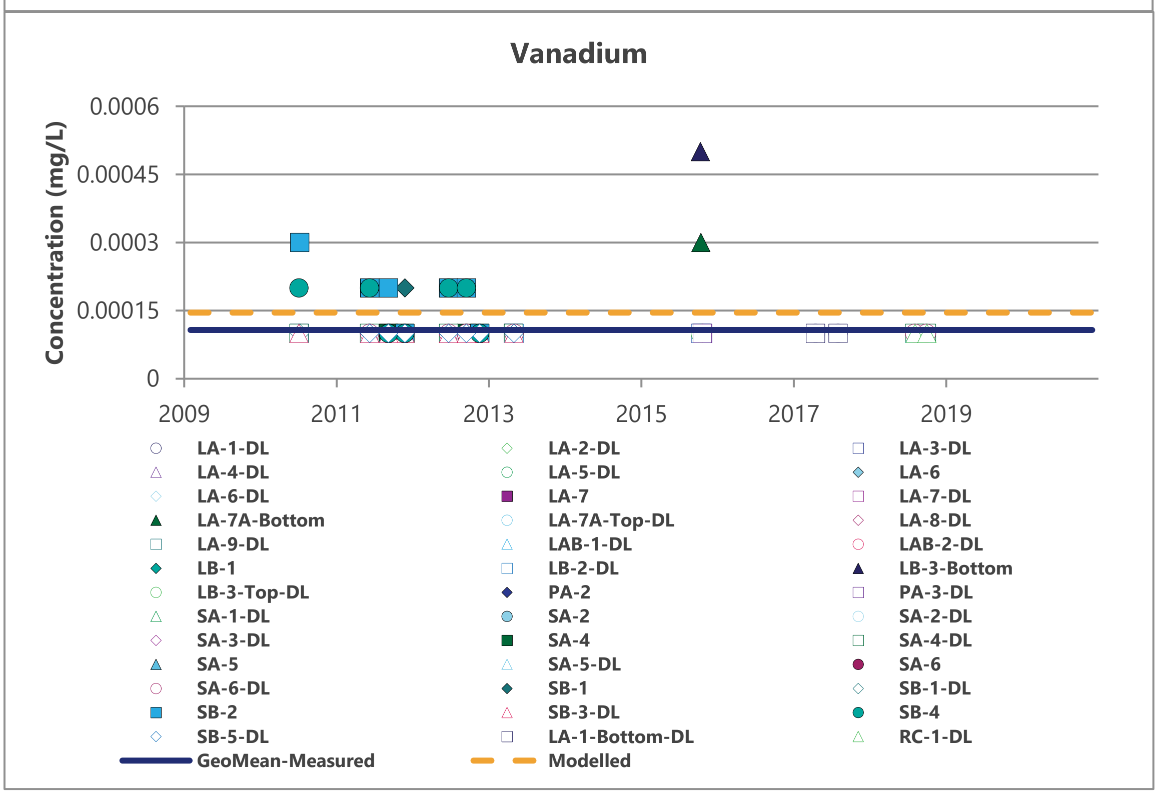

Selenium
Concentration (mg/L)
0.00024
0.00018
0.00012
0.00006
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6-DL
LA-7-DL
LA-7A-Bottom
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1-DL
SA-2-DL
SA-3-DL
SA-4-DL
SA-5-DL
SA-6-DL
SB-1-DL
SB-2-DL
SB-3-DL
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled

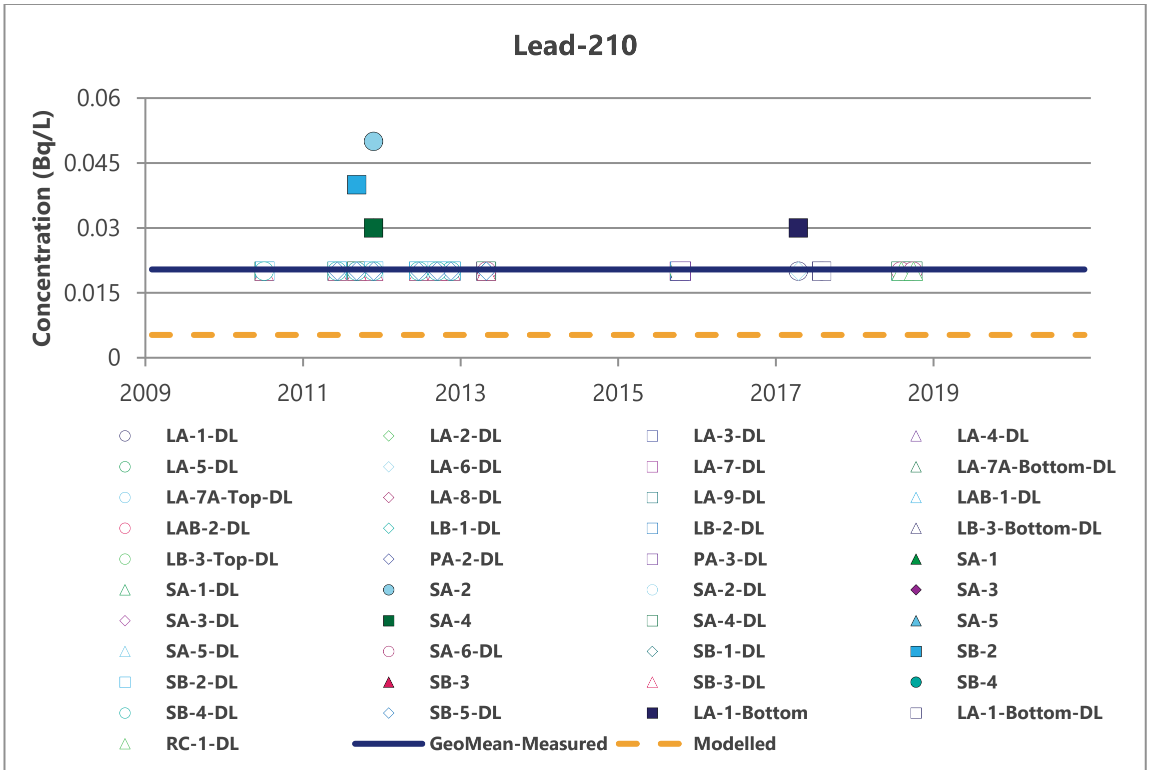

Sulphate
Concentration (mg/L)
10
7.5
5
2.5
0
2009
2011
2013
2015
2017
2019
LA-1
LA-2
LA-3
LA-4
LA-5
LA-6
LA-7
LA-7A-Bottom
LA-7A-Top
LA-8
LA-9
LAB-1
LAB-2
LB-1
LB-2
LB-3-Bottom
LB-3-Top
PA-2
PA-3
SA-1
SA-2
SA-2-DL
SA-3
SA-4
SA-5
SA-6
SB-1
SB-2
SB-3
SB-4
SB-5
LA-1-Bottom
RC-1
GeoMean-Measured
Modelled

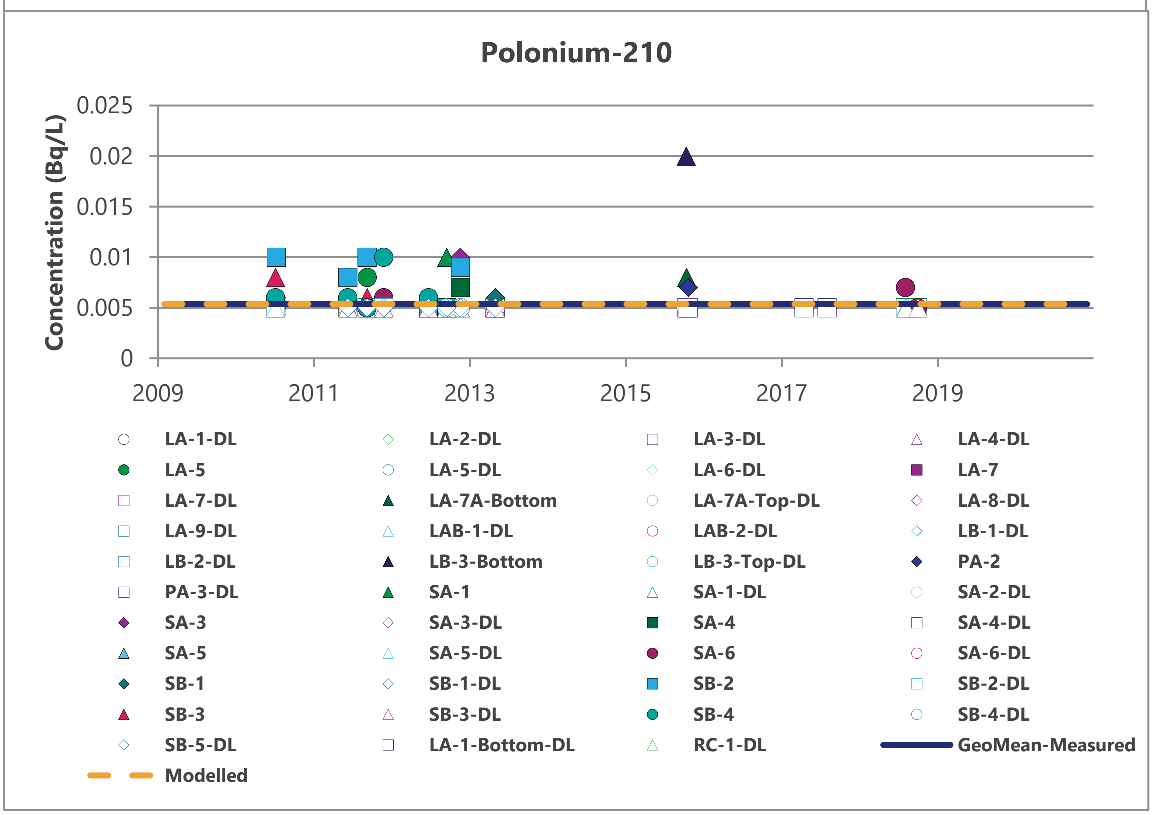

Uranium
Concentration (mg/L)
0.00025
0.0002
0.00015
0.0001
0.00005
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6-DL
LA-7-DL
LA-7A-Bottom-DL
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom-DL
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1-DL
SA-2-DL
SA-3-DL
SA-4-DL
SA-5-DL
SA-6-DL
SB-1-DL
SB-2
SB-2-DL
SB-3-DL
SB-4
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled

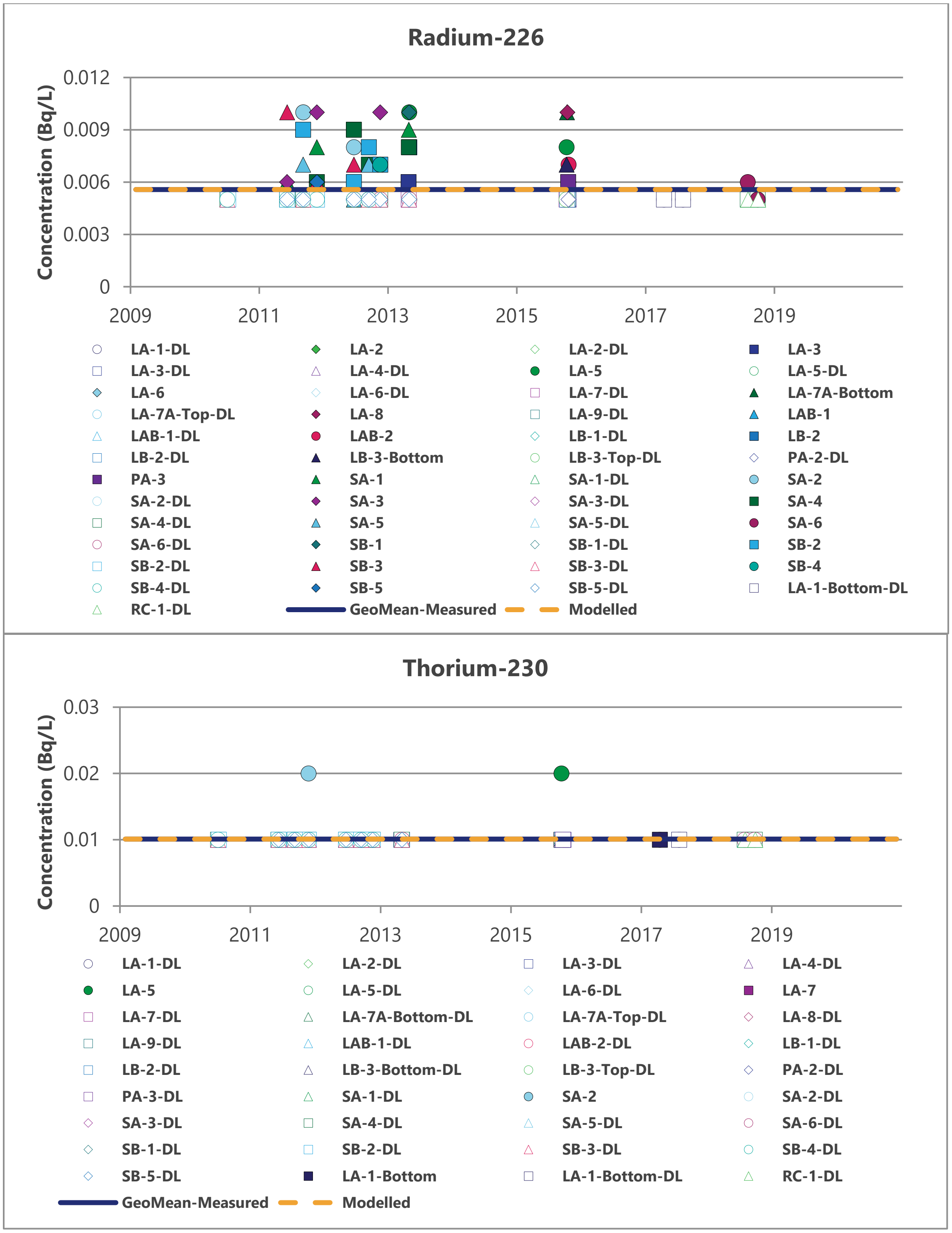

Zinc
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
2009
2011
2013
2015
2017
2019
LA-1
LA-1-DL
LA-2
LA-2-DL
LA-3
LA-3-DL
LA-4-DL
LA-5-DL
LA-6
LA-6-DL
LA-7-DL
LA-7A-Bottom
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2
LB-2-DL
LB-3-Bottom
LB-3-Top
LB-3-Top-DL
PA-2-DL
PA-3
SA-1
SA-1-DL
SA-2
SA-2-DL
SA-3
SA-3-DL
SA-4
SA-4-DL
SA-5
SA-5-DL
SA-6
SA-6-DL
SB-1
SB-1-DL
SB-2
SB-2-DL
SB-3
SB-3-DL
SB-4
SB-4-DL
SB-5
SB-5-DL
LA-1-Bottom
RC-1
RC-1-DL
GeoMean-Measured
Modelled


Chromium
Concentration (mg/L)
0.0012
0.0009
0.0006
0.0003
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6-DL
LA-7-DL
LA-7A-Bottom-DL
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom-DL
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1-DL
SA-2-DL
SA-3-DL
SA-4-DL
SA-5-DL
SA-6-DL
SB-1-DL
SB-2-DL
SB-3-DL
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled
WQO


Vanadium
Concentration (mg/L)
0.0006
0.00045
0.0003
0.00015
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6
LA-6-DL
LA-7
LA-7-DL
LA-7A-Bottom
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1
LB-2-DL
LB-3-Bottom
LB-3-Top-DL
PA-2
PA-3-DL
SA-1-DL
SA-2
SA-2-DL
SA-3-DL
SA-4
SA-4-DL
SA-5
SA-5-DL
SA-6
SA-6-DL
SB-1
SB-1-DL
SB-2
SB-3-DL
SB-4
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled


Lead-210
Concentration (Bq/L)
0.06
0.045
0.03
0.015
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5-DL
LA-6-DL
LA-7-DL
LA-7A-Bottom-DL
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom-DL
LB-3-Top-DL
PA-2-DL
PA-3-DL
SA-1
SA-1-DL
SA-2
SA-2-DL
SA-3
SA-3-DL
SA-4
SA-4-DL
SA-5
SA-5-DL
SA-6-DL
SB-1-DL
SB-2
SB-2-DL
SB-3
SB-3-DL
SB-4
SB-4-DL
SB-5-DL
LA-1-Bottom
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled


Polonium-210
Concentration (Bq/L)
0.025
0.02
0.015
0.01
0.005
0
2009
2011
2013
2015
2017
2019
LA-1-DL
LA-2-DL
LA-3-DL
LA-4-DL
LA-5
LA-5-DL
LA-6-DL
LA-7
LA-7-DL
LA-7A-Bottom
LA-7A-Top-DL
LA-8-DL
LA-9-DL
LAB-1-DL
LAB-2-DL
LB-1-DL
LB-2-DL
LB-3-Bottom
LB-3-Top-DL
PA-2
PA-3-DL
SA-1
SA-1-DL
SA-2-DL
SA-3
SA-3-DL
SA-4
SA-4-DL
SA-5
SA-5-DL
SA-6
SA-6-DL
SB-1
SB-1-DL
SB-2
SB-2-DL
SB-3
SB-3-DL
SB-4
SB-4-DL
SB-5-DL
LA-1-Bottom-DL
RC-1-DL
GeoMean-Measured
Modelled



WQO = Water Quality Objective. The WQO is only shown in the figures for those COPCs whose measured/modelled concentrations are close to its WQO. Blank symbol indicates that the measurement was under the detection limit. The location of sampling stations is described in detail in baseline aquatic environment study report (Ecometrix, 2020a).

Figure 3-2: Modelled and Measured Baseline Concentrations in Water

3.3 Sediment Quality

3.3.1 Background Sediment Quality

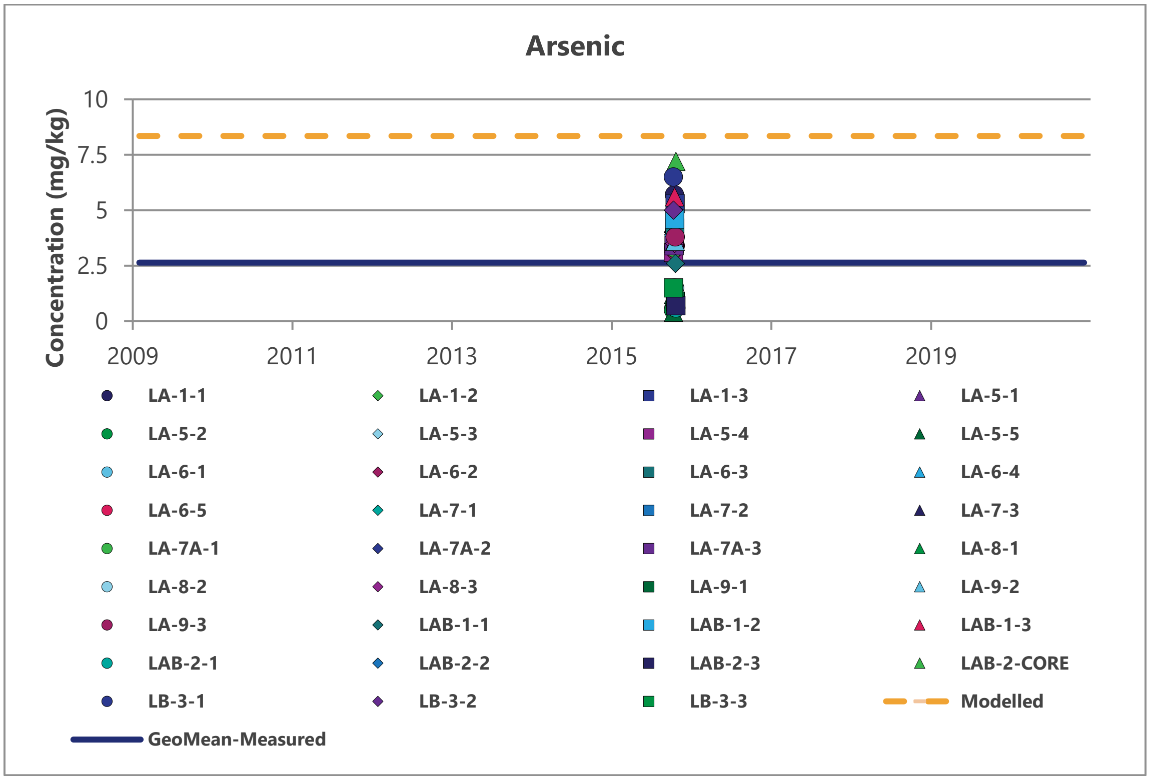
To characterize regional background sediment quality, a database of baseline water and sediment quality data was compiled from baseline studies performed between 2011 and 2019 (Ecometrix, 2020a). Concentrations in sediment were modelled based on concentrations in water using the partitioning coefficients (K_d) as discussed in Section 3.2.1.

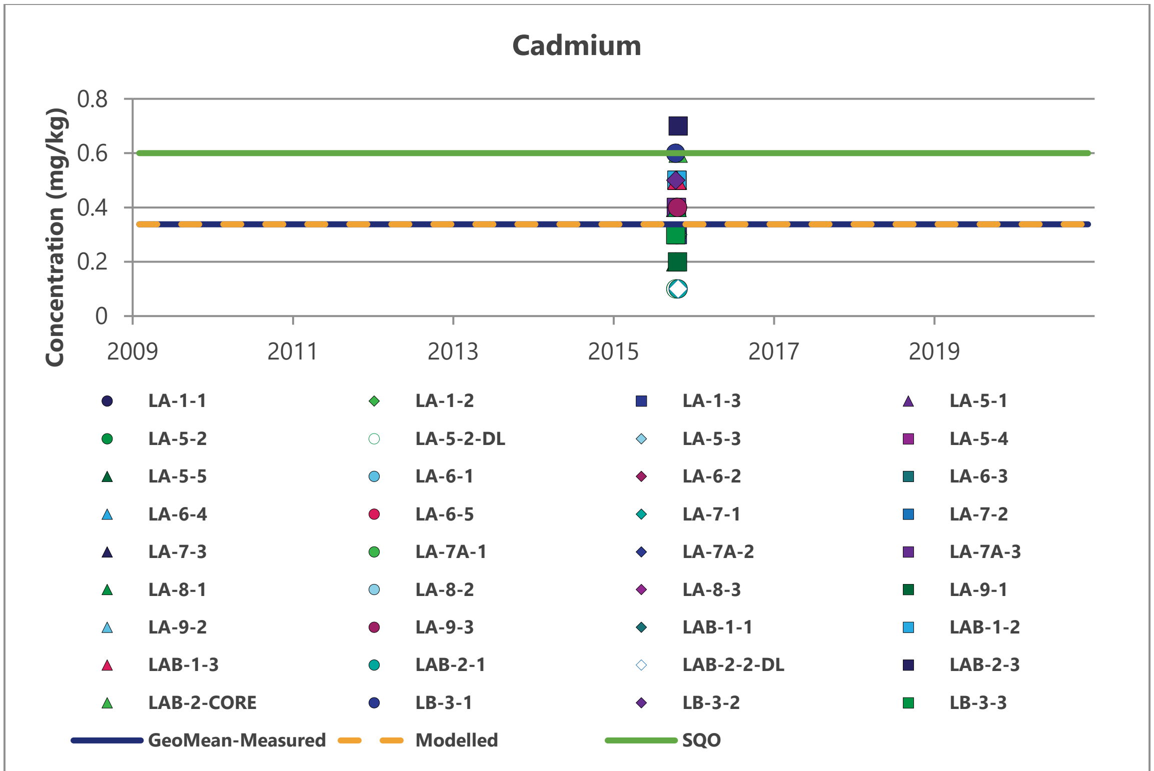
Average water and sediment baseline concentrations are presented in Table 3-5, and a comparison to measured values is shown in Figure 3-2 and Figure 3-3. These plots indicate generally good agreement between measured and modelled COPC concentrations in water and sediment. Metals and radionuclides are expected to interact with water and, in the case of radionuclides, ingrowth and decay are other factors that may influence activities in the receiving environment. As shown in Figure 3-3, the modelled concentration in sediment falls in the range of measured concentrations for most of the COPCs with the exception for arsenic and radium-226 which are likely overestimated (which is conservative). Poor agreement between modelled and measured concentration of arsenic and radium-226 are likely due to lack of measured data; only one sampling campaign was conducted for sediment. The modelled sediment concentrations can be refined in the future when more measured sediment data are available.

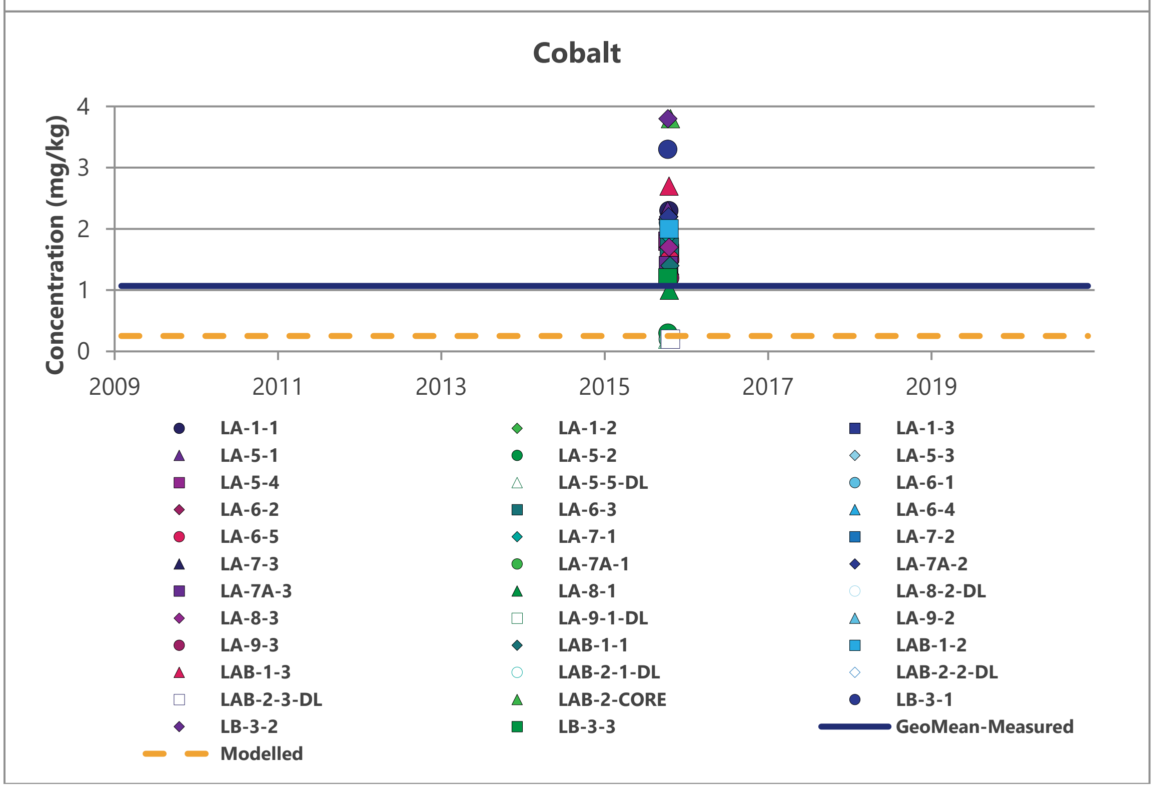
Table 3-5: Baseline Water and Sediment Concentrations Used in the IMPACT model

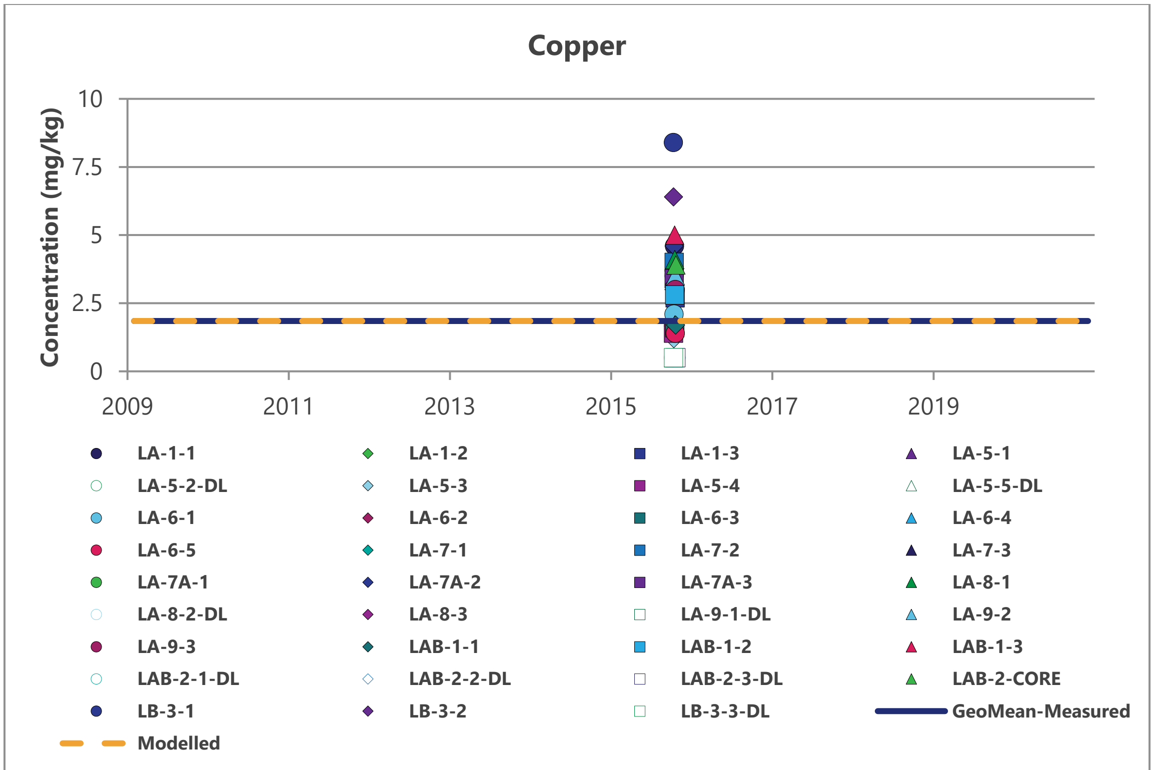
COPCs	Water Baseline Concentration	Sediment Baseline Concentration
Non-radionuclides	**mg/L**	**mg/kg dw**
Arsenic	**1.03E-04**	8.35E+00
Cadmium	2.32E-05	**3.38E-01**
Chloride	**3.22E-01**	-
Chromium	5.19E-04	**5.86E+00**
Cobalt	**1.01E-04**	2.52E-01
Copper	6.18E-04	**1.85E+00**
Molybdenum	**1.07E-04**	3.37E-01
Selenium	3.23E-05	**6.22E-01**
Sulphate	**6.87E-01**	-
Uranium	3.01E-05	**5.78E-01**
Vanadium	1.46E-04	**1.12E+01**
Zinc	**6.81E-04**	9.93E+00
Radionuclides	**Bq/L**	**Bq/kg dw**
Lead-210 [a]	5.27E-03	3.74E+02
Polonium-210	**5.36E-03**	3.80E+02
Radium-226	**5.57E-03**	6.51E+01
Thorium-230	**1.01E-02**	2.32E+01
Uranium-234 [b]	3.71E-04	7.14E+00
Uranium-238 [b]	3.71E-04	7.14E+00

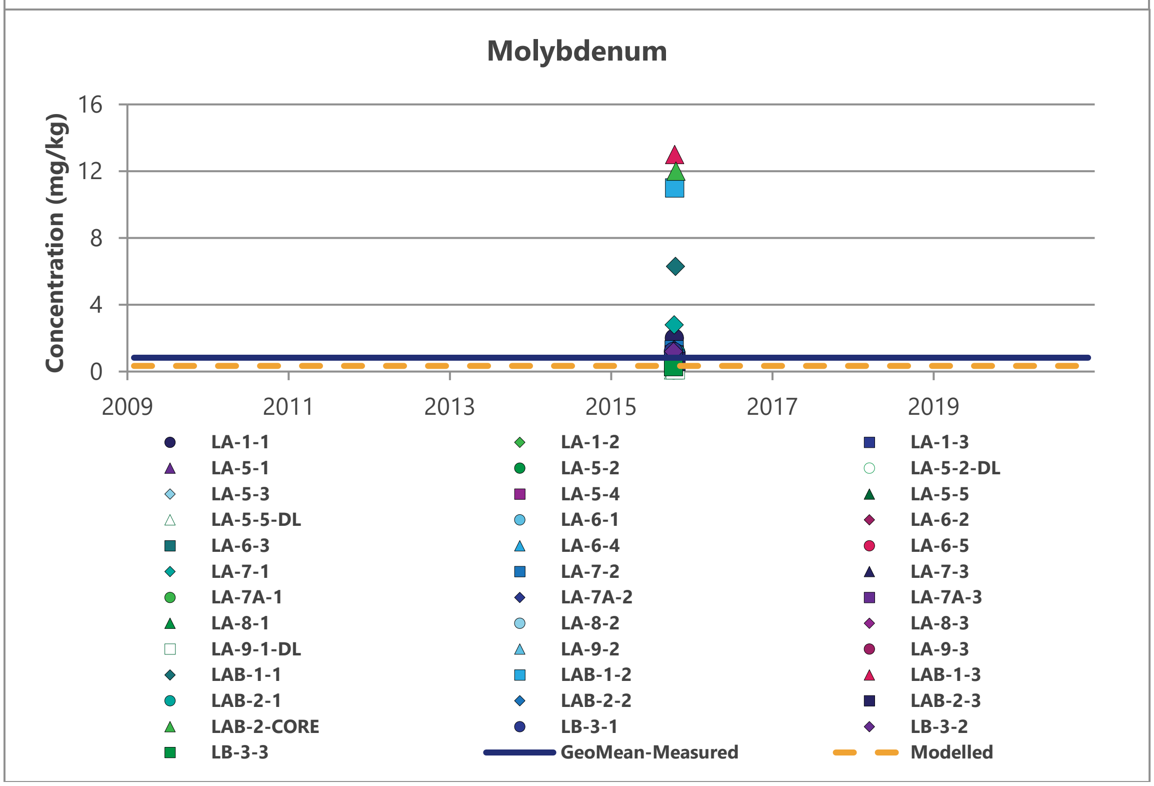
Dash (-) represents no value calculated as COPC does not partition to sediment.
Bold = measured values. Values that are not bolded indicate modelled values.
a. Calculated to be in transient equilibrium with polonium-210.
b. Estimated from uranium using the specific activity of 12,356 Bq/g and assuming secular equilibrium between uranium-238 and uranium-234 **(https://www.wise-uranium.org/rup.html).**
COPC = constituent of potential concern; dw = dry weight.

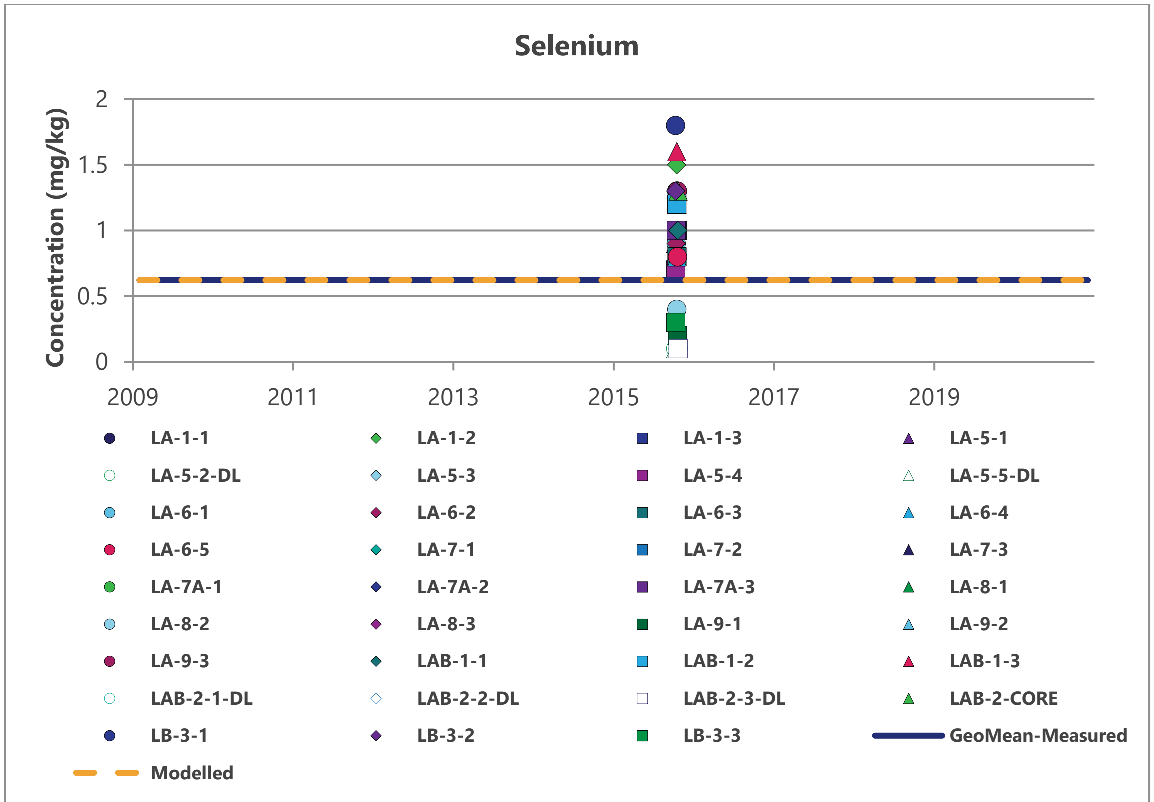


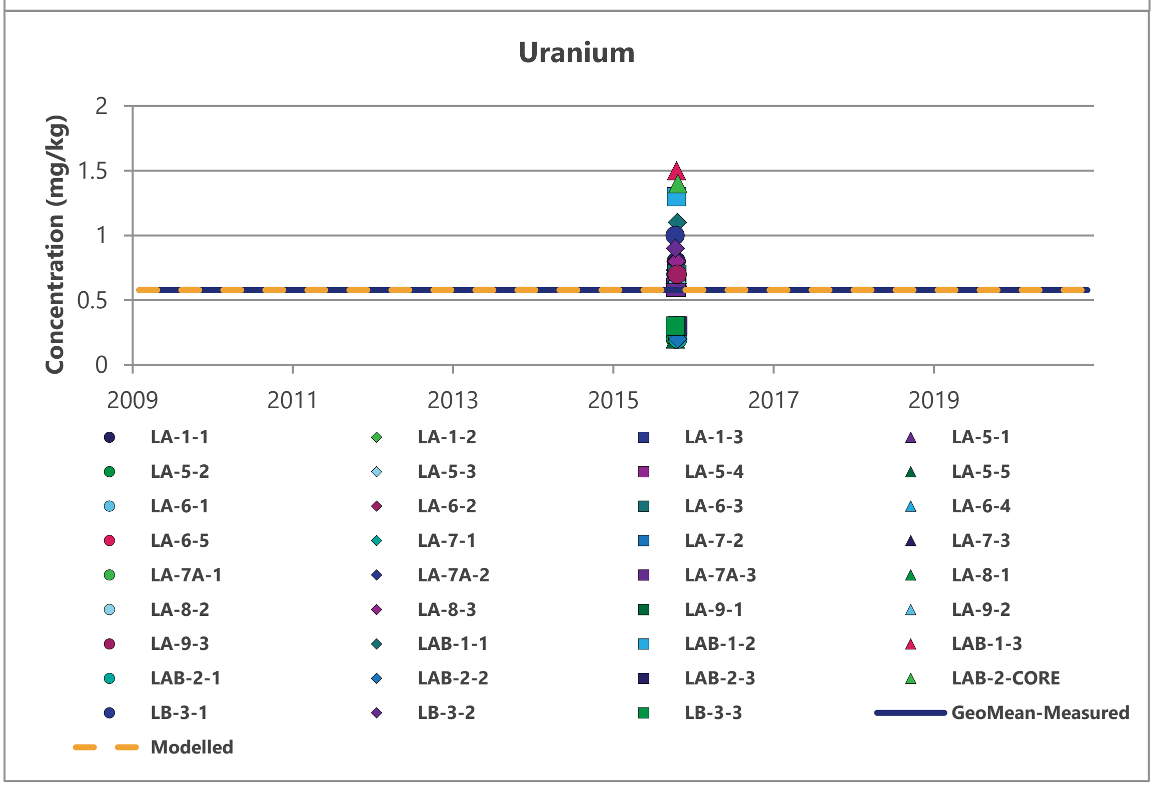

Cadmium
Concentration (mg/kg)
0
0.2
0.4
0.6
0.8
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1
LAB-2-2-DL
LAB-2-3
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled
SQO

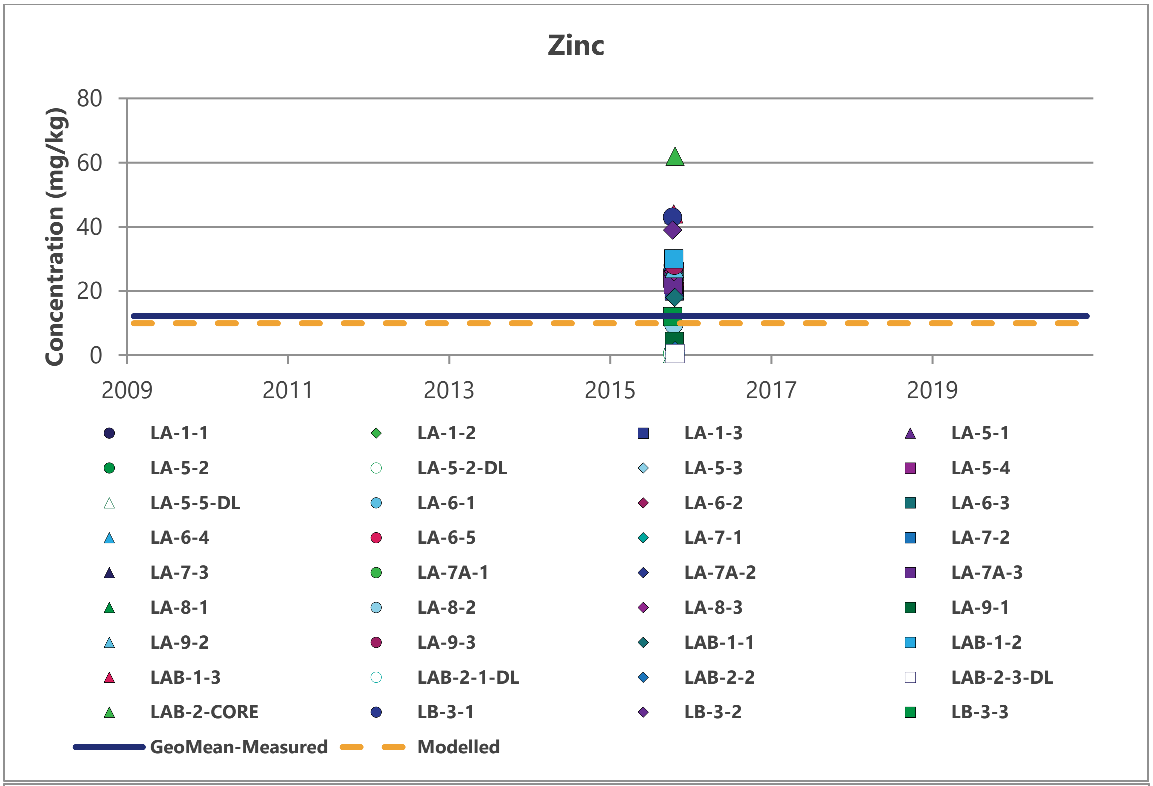

Cobalt
Concentration (mg/kg)
0
1
2
3
4
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-3
LA-5-4
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2-DL
LA-8-3
LA-9-1-DL
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2-DL
LAB-2-3-DL
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled

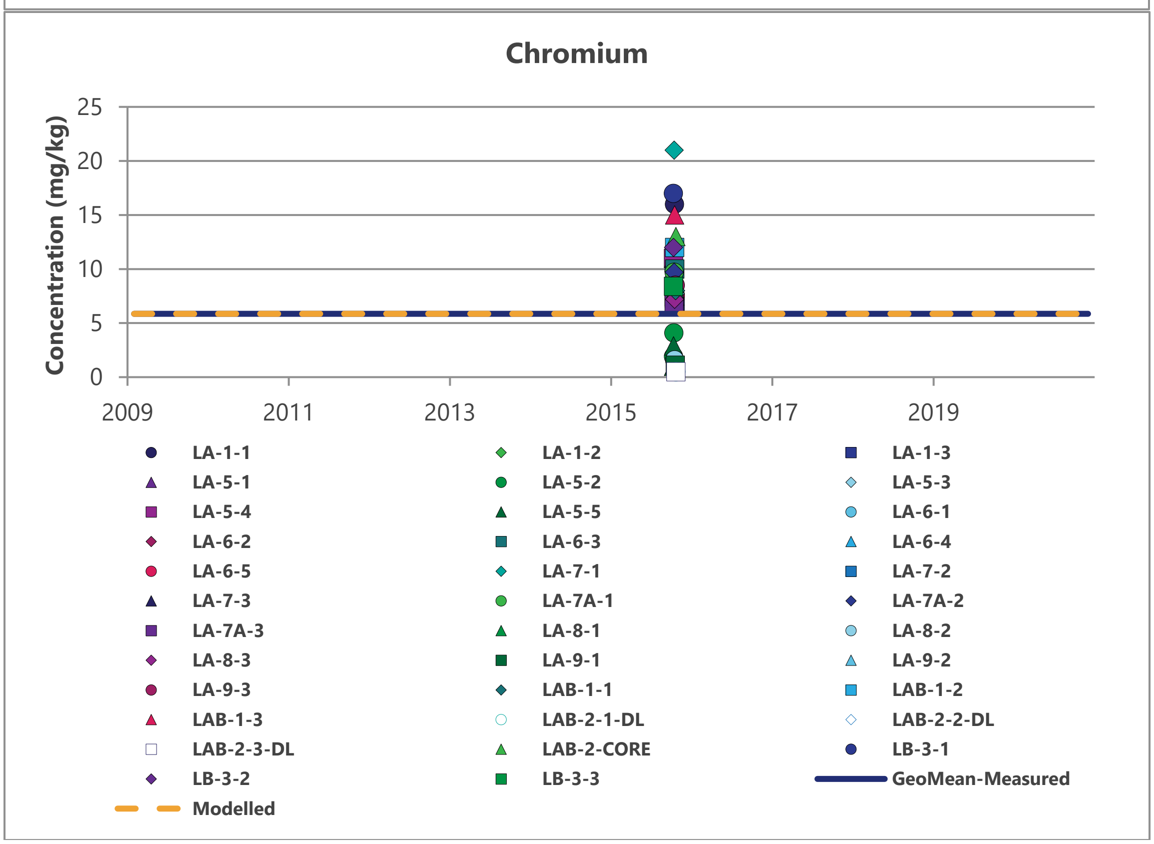

Copper
Concentration (mg/kg)
10
7.5
5
2.5
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2-DL
LA-8-3
LA-9-1-DL
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2-DL
LAB-2-3-DL
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3-DL
GeoMean-Measured
Modelled

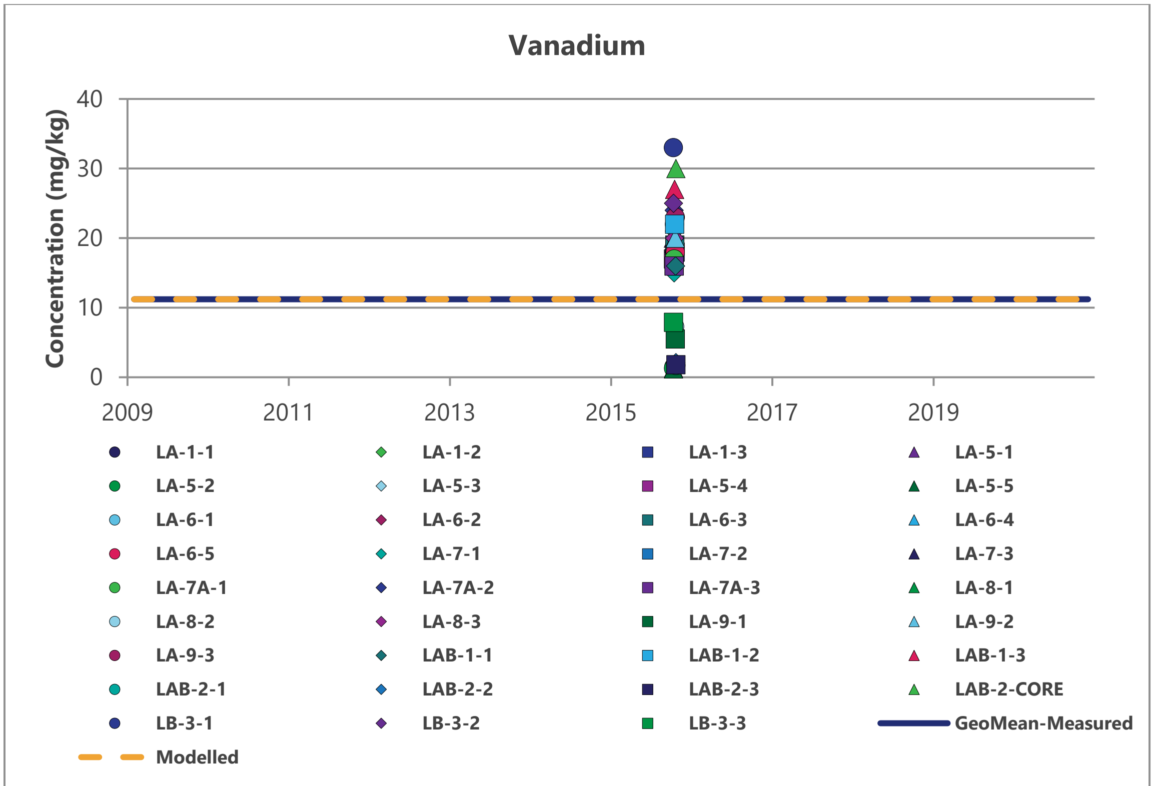

Molybdenum
Concentration (mg/kg)
16
12
8
4
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1-DL
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1
LAB-2-2
LAB-2-3
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled

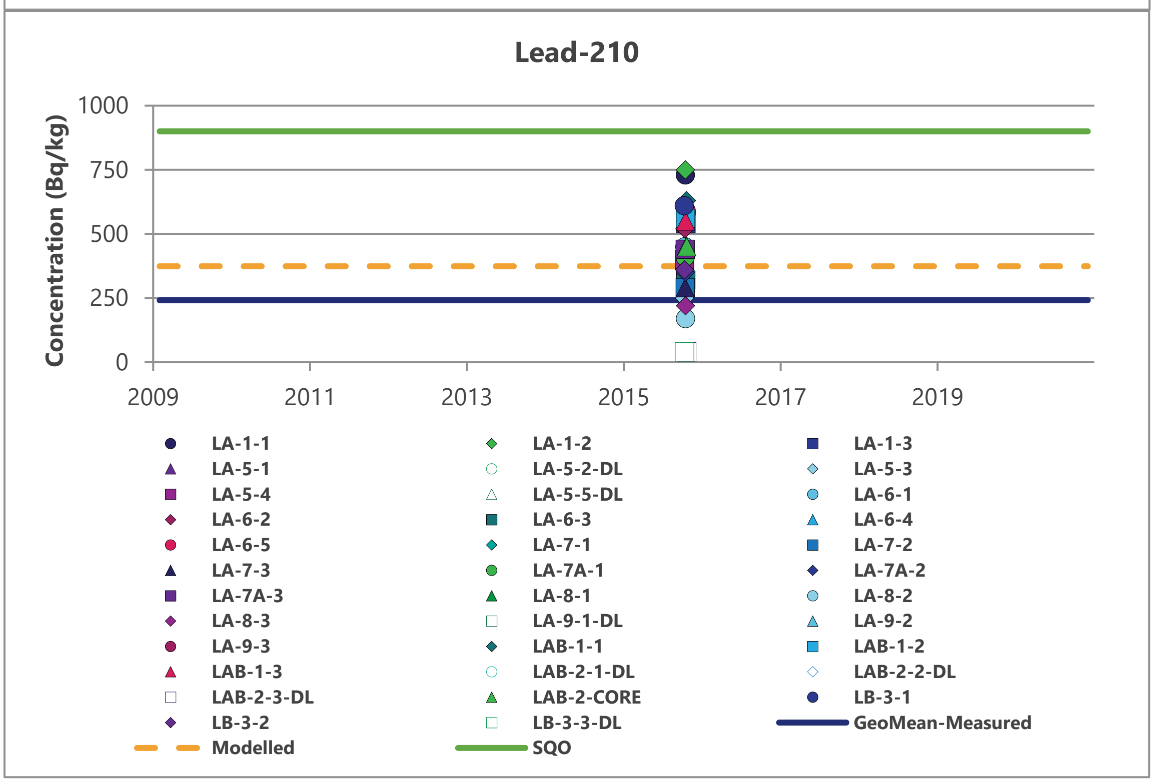

Selenium
Concentration (mg/kg)
2
1.5
1
0.5
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2-DL
LAB-2-3-DL
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled

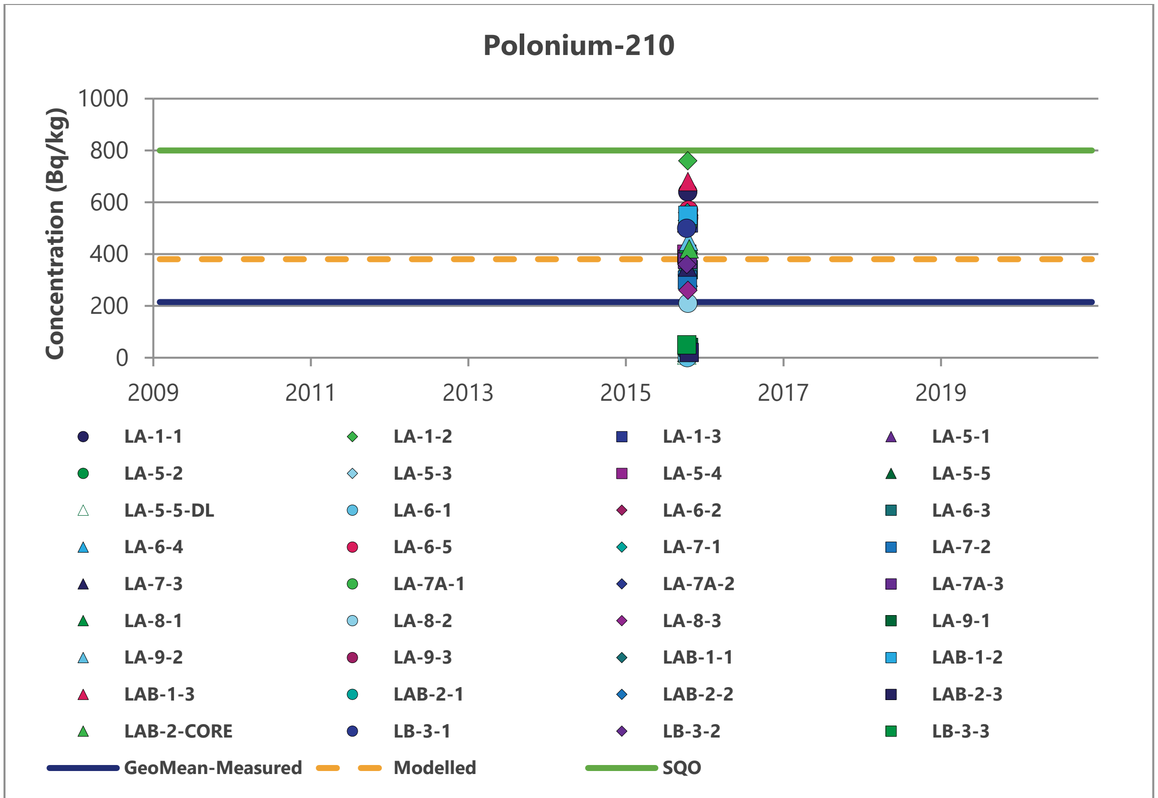

Uranium
Concentration (mg/kg)
2
1.5
1
0.5
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-3
LA-5-4
LA-5-5
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1
LAB-2-2
LAB-2-3
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled

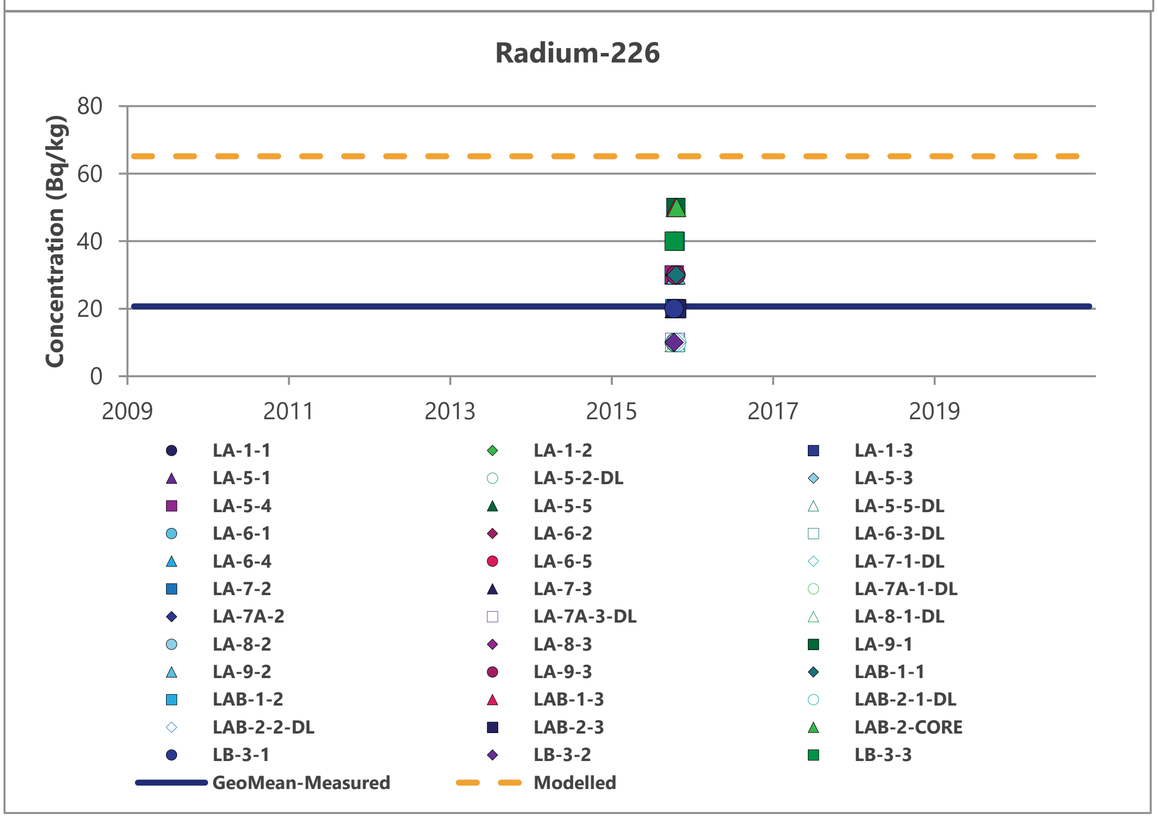

Zinc
Concentration (mg/kg)
80
60
40
20
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2
LAB-2-3-DL
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled

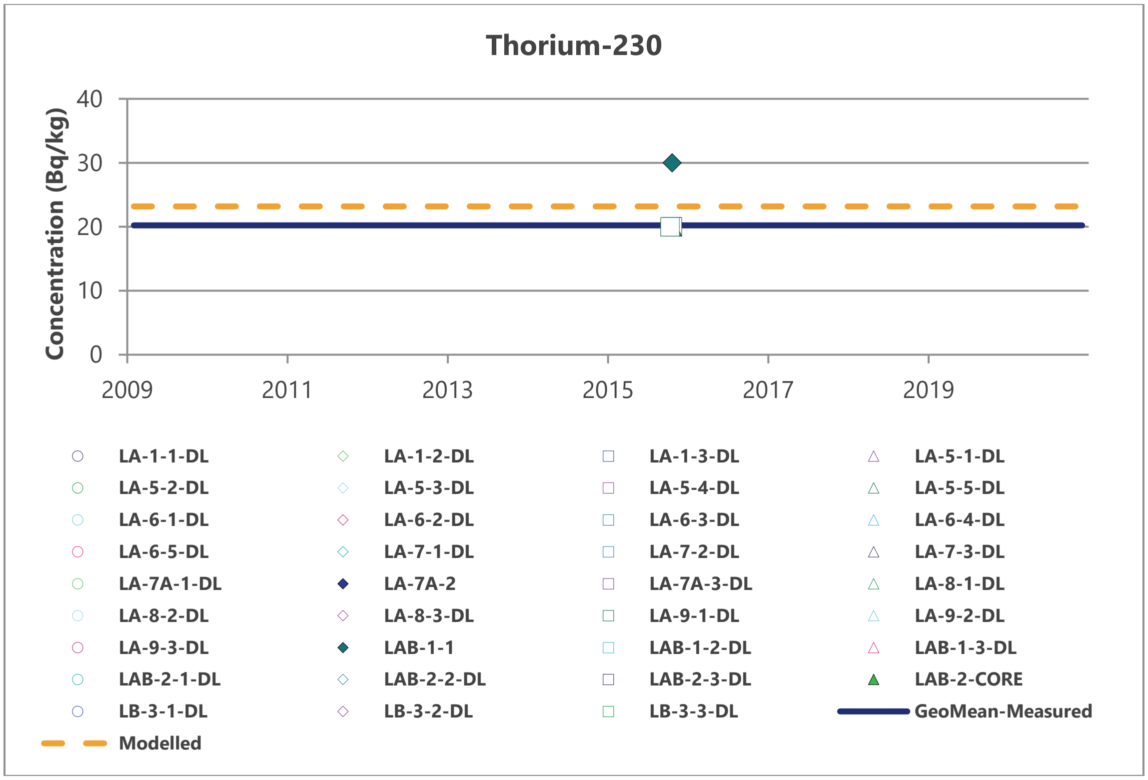

Chromium
Concentration (mg/kg)
25
20
15
10
5
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-3
LA-5-4
LA-5-5
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2-DL
LAB-2-3-DL
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled


Vanadium
Concentration (mg/kg)
0
10
20
30
40
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-3
LA-5-4
LA-5-5
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1
LAB-2-2
LAB-2-3
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled


Lead-210
Concentration (Bq/kg)
0
250
500
750
1000
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1-DL
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2-DL
LAB-2-3-DL
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3-DL
GeoMean-Measured
Modelled
SQO


Polonium-210
Concentration (Bq/kg)
1000
800
600
400
200
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2
LA-5-3
LA-5-4
LA-5-5
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3
LA-6-4
LA-6-5
LA-7-1
LA-7-2
LA-7-3
LA-7A-1
LA-7A-2
LA-7A-3
LA-8-1
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1
LAB-2-2
LAB-2-3
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled
SQO


Radium-226
Concentration (Bq/kg)
80
60
40
20
0
2009
2011
2013
2015
2017
2019
LA-1-1
LA-1-2
LA-1-3
LA-5-1
LA-5-2-DL
LA-5-3
LA-5-4
LA-5-5
LA-5-5-DL
LA-6-1
LA-6-2
LA-6-3-DL
LA-6-4
LA-6-5
LA-7-1-DL
LA-7-2
LA-7-3
LA-7A-1-DL
LA-7A-2
LA-7A-3-DL
LA-8-1-DL
LA-8-2
LA-8-3
LA-9-1
LA-9-2
LA-9-3
LAB-1-1
LAB-1-2
LAB-1-3
LAB-2-1-DL
LAB-2-2-DL
LAB-2-3
LAB-2-CORE
LB-3-1
LB-3-2
LB-3-3
GeoMean-Measured
Modelled



SQO = Sediment Quality Objective, The SQO is only shown in the figures for those COPCs whose measured/modelled concentrations are close to its SQO. Blank symbol indicates that the measurement was under the detection limit. The location of sampling stations is described in detail in baseline aquatic environment study report (Ecometrix, 2020a).

Figure 3-3: Modelled and Measured Baseline Concentrations in Sediment

3.3.2 Water to Sediment Partitioning Coefficients

The water-to-sediment partitioning coefficients (K_d) are regional parameters governing the exchange between sediment and water in lakes. The K_d values are used to estimate the fraction of a constituent that is associated with the particulate fraction in the shallow sediment layer (f_s). The fraction of COPC in the solid phase is estimated using the following equation:

$$f_s = \frac{K_d \cdot \frac{\rho_s}{\varepsilon_s}}{1 + K_d \cdot \frac{\rho_s}{\varepsilon_s}}$$

where:

ε_s	=	porosity of surficial sediment (unitless)
K_d	=	distribution coefficient between water and sediment (L/kg)
ρ_s	=	bulk density of surficial sediment (kg/L)

The K_d values used in this model are presented in Table 3-6. They consist of regional published values that have been calibrated on similar sites in northern Saskatchewan and have been checked against Wheeler River measurement data as shown in Figure 3-2 and Figure 3-3.

Table 3-6: Distribution Coefficients (K_d) Used in the IMPACT Model

COPC	Distribution Coefficient
	L/kg (dw)
Arsenic	9.64E+04
Cadmium	1.50E+04
Chromium	1.16E+04
Cobalt	2.50E+03
Copper	3.00E+03
Molybdenum	3.17E+03
Selenium	2.00E+04
Uranium	2.00E+04
Vanadium	9.10E+04
Zinc	1.50E+04
Lead-210	1.20E+05
Polonium-210	1.20E+05
Radium-226	1.20E+04
Thorium-230	2.30E+03
Uranium-234	2.00E+04
Uranium-238	2.00E+04

COPC = constituent of potential concern; dw = dry weight.

3.4 Air Quality

Risk through air exposure pathways is considered during Construction, Operation, and Decommissioning. Table 3-7 presents the modelled air quality, based on Project emissions and baseline air quality during Construction, Operation, and Decommissioning at the locations of interest for human and ecological receptors. Air quality data was obtained from the Air Quality Impact Assessment report (IEC, 2024).

Table 3-7: Modelled Air Quality for Human and Ecological Receptors

Project Phase	Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc	Radon-222	Uranium-234[a]	Uranium-238[a]
	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	mg/m³	Bq/m³	Bq/m³	Bq/m³
	Air Baseline												
Baseline	7.00E-07	7.44E-08	7.07E-07	1.49E-07	6.30E-05	7.19E-07	1.54E-07	6.00E-07	1.43E-06	2.16E-04	0.00E+00	7.41E-06	7.41E-06
	Air Quality at Camp Location for Human Receptors												
Construction	7.05E-07	7.50E-08	7.10E-07	1.53E-07	6.31E-05	7.25E-07	1.55E-07	4.12E-06	1.44E-06	2.16E-04	2.15E+00	5.09E-05	5.09E-05
Operation	7.04E-07	7.58E-08	7.14E-07	1.68E-07	6.33E-05	7.24E-07	1.57E-07	1.77E-05	1.46E-06	2.16E-04	1.24E+01	2.19E-04	2.19E-04
Decommissioning	7.00E-07	7.44E-08	7.07E-07	1.49E-07	6.30E-05	7.19E-07	1.54E-07	7.70E-07	1.43E-06	2.16E-04	8.57E+00	9.51E-06	9.51E-06
	Air Quality at Whitefish Lake for Ecological Receptors												
Construction	7.01E-07	7.45E-08	7.07E-07	1.50E-07	6.30E-05	7.20E-07	1.54E-07	1.26E-06	1.43E-06	2.16E-04	1.98E+00	1.55E-05	1.55E-05
Operation	7.12E-07	7.75E-08	7.22E-07	1.93E-07	6.38E-05	7.34E-07	1.61E-07	3.45E-05	1.51E-06	2.16E-04	3.61E+01	4.26E-04	4.26E-04
Decommissioning	7.01E-07	7.45E-08	7.07E-07	1.51E-07	6.30E-05	7.21E-07	1.54E-07	1.47E-06	1.43E-06	2.16E-04	1.71E+01	1.82E-05	1.82E-05
	Air Quality at McGowan Lake for Human and Ecological Receptors												
Construction	7.00E-07	7.44E-08	7.07E-07	1.49E-07	6.30E-05	7.19E-07	1.54E-07	6.90E-07	1.43E-06	2.16E-04	2.60E-01	8.53E-06	8.53E-06
Operation	7.01E-07	7.47E-08	7.08E-07	1.54E-07	6.31E-05	7.20E-07	1.55E-07	5.05E-06	1.43E-06	2.16E-04	2.50E+00	6.23E-05	6.23E-05
Decommissioning	7.00E-07	7.44E-08	7.07E-07	1.49E-07	6.30E-05	7.19E-07	1.54E-07	6.39E-07	1.43E-06	2.16E-04	1.51E+00	7.90E-06	7.90E-06
	Air Quality at Russell Lake Inlet for Human and Ecological Receptors												
Construction	7.00E-07	7.44E-08	7.07E-07	1.49E-07	6.30E-05	7.19E-07	1.54E-07	6.19E-07	1.43E-06	2.16E-04	5.64E-02	7.65E-06	7.65E-06
Operation	7.00E-07	7.45E-08	7.07E-07	1.50E-07	6.30E-05	7.19E-07	1.54E-07	1.79E-06	1.43E-06	2.16E-04	5.92E-01	2.21E-05	2.21E-05
Decommissioning	7.00E-07	7.44E-08	7.07E-07	1.49E-07	6.30E-05	7.19E-07	1.54E-07	6.08E-07	1.43E-06	2.16E-04	3.71E-01	7.51E-06	7.51E-06

Note:

a) Uranium-234/238 concentration was calculated using a specific activity of 12.356 Bq/mg.

COPC = constituent of potential concern; Bq = becquerel.

3.5 Soil Quality

3.5.1 Background Soil Quality

Regional background soil chemistry was derived from baseline data collected from 10 sample sites in August 2017 (Omnia, 2020). The geometric mean of 10 soil sample results was used to characterize background concentrations of metals and radionuclides in soil. Table 3-8 presents the selected background soil concentrations used in the IMPACT model. Sandy soil was selected for the IMPACT model based on baseline studies identifying sandy and gravelly Podzols, Brunisols, and Luvisols occurring on till materials, while sand and sandy loam Brunisols have developed on glaciofluvial deposits.

Table 3-8: Soil Baseline Concentrations

COPC	Unit	Soil Baseline Concentration
Arsenic	mg/kg (dw)	6.16E-01
Cadmium	mg/kg (dw)	3.61E-01
Chromium	mg/kg (dw)	3.31E+00
Cobalt	mg/kg (dw)	2.65E-01
Copper	mg/kg (dw)	1.46E+00
Molybdenum	mg/kg (dw)	1.15E-01
Selenium	mg/kg (dw)	1.07E-01
Uranium	mg/kg (dw)	3.82E-01
Vanadium	mg/kg (dw)	4.81E+00
Zinc	mg/kg (dw)	5.31E+00
Lead-210	Bq/kg (dw)	7.29E+01
Polonium-210	Bq/kg (dw)	6.55E+01
Radium-226	Bq/kg (dw)	1.52E+01
Thorium-230	Bq/kg (dw)	2.00E+01
Uranium-234	Bq/kg (dw)	4.72E+00
Uranium-238	Bq/kg (dw)	4.72E+00

a) Uranium-234/238 concentration was calculated using a specific activity of 12.356 Bq/mg.
COPC = constituent of potential concern; Bq = becquerel; dw = dry weight.

3.5.2 Soil Quality during the Project

Soil quality during construction, operation, and decommissioning was estimated based on the modelled air quality at each location of interest for human and ecological receptors. IMPACT calculates COPC concentrations in soil in terms of concentration per kg of dry soil, following the soil model equations in CSA N288.1-20 (Section 2.3.4).

For wet deposition, the fraction of the time that precipitation falls when the wind blows from a specific sector was set conservatively to 0.36 for all wind directions (CSA Group, 2020).

Concentrations calculated based on deposition from air to soil during project phases were added to baseline concentrations to represent the total exposure concentrations in soil.

3.6 Transfer of Constituents to Aquatic Receptors

A fundamental premise of pathways analysis is that chemical uptake by receptors is related to the receptors' level of exposure. A linear relationship is usually assumed and is represented by a bioaccumulation factor (BAF). For aquatic receptors, the BAF is the concentration in the organism (e.g., C_{fish}) divided by the concentration in water (C_{water}). The BAF may be estimated from organism and water data by fitting a regression line that generally is assumed to pass through the origin, such as "$C_{fish} = Slope \cdot C_{water}$". The slope of the regression line is the BAF. It represents the equilibrium ratio of C_{fish} / C_{water}.

The IMPACT model uses the BAF model as a simplification of the more complex multi-media uptake process. While several media (e.g., water and food) may contribute to COPC uptake into the animal tissue, at steady state, all media concentrations will have a fixed ratio to the tissue concentration. Thus, the BAF based on water and tissue measurements will reflect all the multi-media contributions to uptake. If animals and their prey are in equilibrium with the COPC in the environment, their concentrations can be estimated using an overall BAF between the water and the organism (Thomann and Mueller 1987). If animals have not reached equilibrium because they have not spent enough time in the exposure situation, because they are migratory or the project effects are transient, the BAF provides a conservative estimate of tissue concentrations.

As a result of physiological control, intracellular storage, and different excretion mechanisms, biota have an ability to actively regulate the body burden of many metals, including selenium, and maintain homeostatic control over a range of exposures (Chapman et al. 1996; Hamilton and Mehrle 1986; Wood and Port 2000). These homeostatic controls can produce non-linear relationships between the steady-state tissue concentrations and the environmental exposure concentrations (Newman and Unger 2002). However, these complicating issues do not diminish the importance, or negate the practical application, of BAFs in the assessment of environmental risks associated with COPCs.

Because of non-linearity and other factors, BAF values cited in the literature vary over a considerable range. BAF values based on site-specific data are preferred. The values of BAFs based on background concentrations tend to be higher than those based on higher exposure concentrations in affected environments. In this model BAFs representative of regional conditions have been used. The predictions are compared to the measured baseline values in Section 3.6.2.

3.6.1 Aquatic Bioaccumulation Factors

Bioaccumulation factors relate the COPCs in the environmental media to the concentration in the receptor. Water-based BAFs were used to calculate COPC concentrations in aquatic and terrestrial plant, invertebrate, and fish tissues. These factors were generally obtained from CSA N288.1-20 and the International Atomic Energy Agency (IAEA 2010), and from publicly available regional data from other uranium mine sites in northern Saskatchewan. Table 3-9 shows all aquatic BAFs used in the model.

The water-based BAFs for aquatic organisms were based on measured ratios of COPC concentration in tissue vs. water, under multi-media equilibrium conditions.

$$\text{BAF (L/kg fresh weight)} = \frac{\text{Concentration in Tissue (mg/kg fresh weight)}}{\text{Concentration in Water (mg/L)}}$$

While expressed relative to water, BAFs represent all pathways of COPC uptake into the organism, because all pathways were operating under the environmental conditions of BAF measurement. These pathways include food ingestion, dermal absorption, and uptake across the gills.

Table 3-9: Aquatic Bioaccumulation Factors (L/kg fw)

COPC	BAF (L/kg fw)					
	Macrophytes	Phytoplankton	Benthic Invertebrate [a]	Northern Pike	White Sucker	Zooplankton
Arsenic	1.72E+02	1.72E+02	5.40E+02	3.00E+02	3.00E+02	5.40E+02
Cadmium	6.53E+01	6.53E+01	2.60E+02	3.00E+00	3.00E+00	2.60E+02
Chromium [b]	1.00E+01	1.00E+01	3.90E+02	5.50E+01	5.50E+01	3.90E+02
Cobalt	1.58E+02	1.58E+02	2.00E+02	1.20E+01	1.20E+01	2.00E+02
Copper	2.17E+02	2.17E+02	7.80E+03	5.00E+02	5.00E+02	7.80E+03
Molybdenum	6.80E+00	6.80E+00	1.62E+02	1.00E-01	1.00E-01	1.62E+02
Selenium	1.77E+02	1.77E+02	1.07E+03	9.49E+02	4.43E+03	1.07E+03
Uranium	5.04E+01	5.04E+01	1.00E+02	2.00E+01	2.00E+01	1.00E+02
Vanadium [c]	3.25E+02	3.25E+02	3.90E+02	9.70E+01	9.70E+01	3.90E+02
Zinc	5.62E+02	5.62E+02	4.30E+03	2.00E+03	2.00E+03	4.30E+03
Lead-210 [d]	1.90E+03	1.90E+03	2.30E+03	6.00E+01	6.00E+01	2.30E+03
Polonium-210	2.93E+02	2.93E+02	1.58E+04	1.50E+02	1.50E+02	1.58E+04
Radium-226	1.63E+02	1.63E+02	2.50E+02	1.20E+01	1.20E+01	2.50E+02
Thorium-230	2.32E+02	2.32E+02	5.00E+02	6.00E+00	6.00E+00	5.00E+02
Uranium-234	5.04E+01	5.04E+01	1.00E+02	2.00E+01	2.00E+01	1.00E+02
Uranium-238	5.04E+01	5.04E+01	1.00E+02	2.00E+01	2.00E+01	1.00E+02

COPC = constituent of potential concern; fw = fresh weight.

Regional data was used for aquatic BAFs, except for:

a. Thorium-230, Radium-226, Uranium and Cobalt BAFs for Benthic Invertebrates are from Thompson et al. (1972)

b. Chromium BAFs are from CSA N288.1-20.

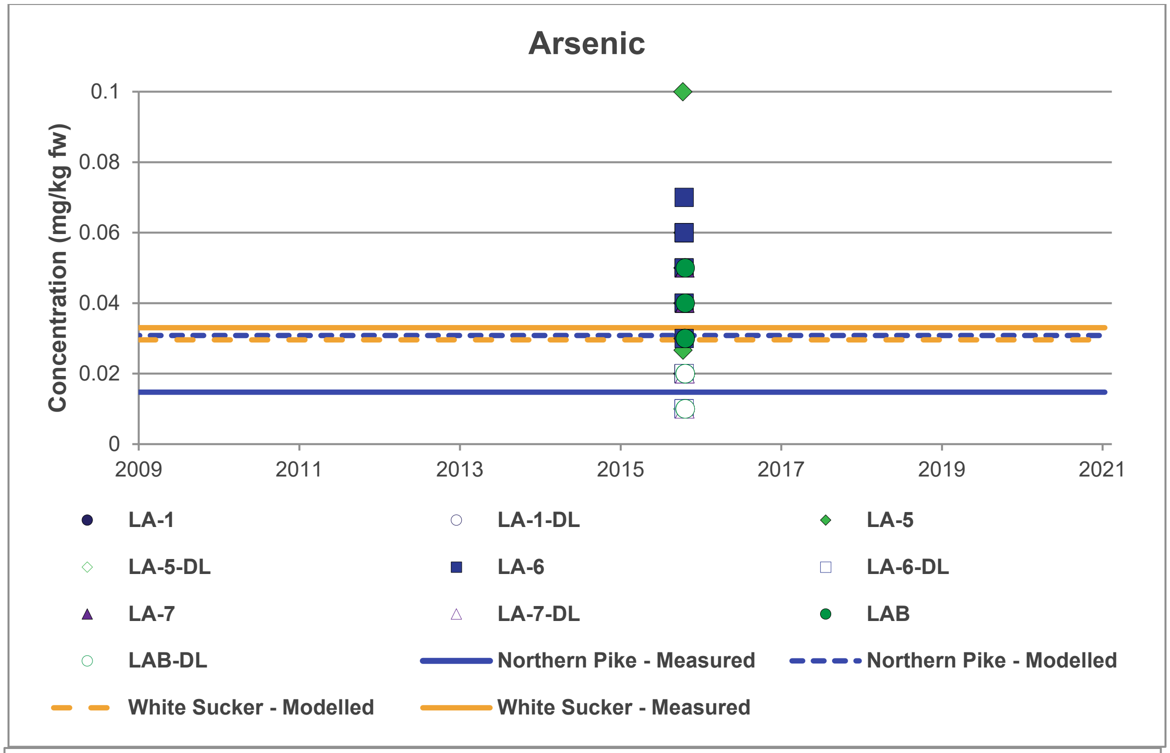
c. Vanadium BAFs are from IAEA TRS 472 (2010)

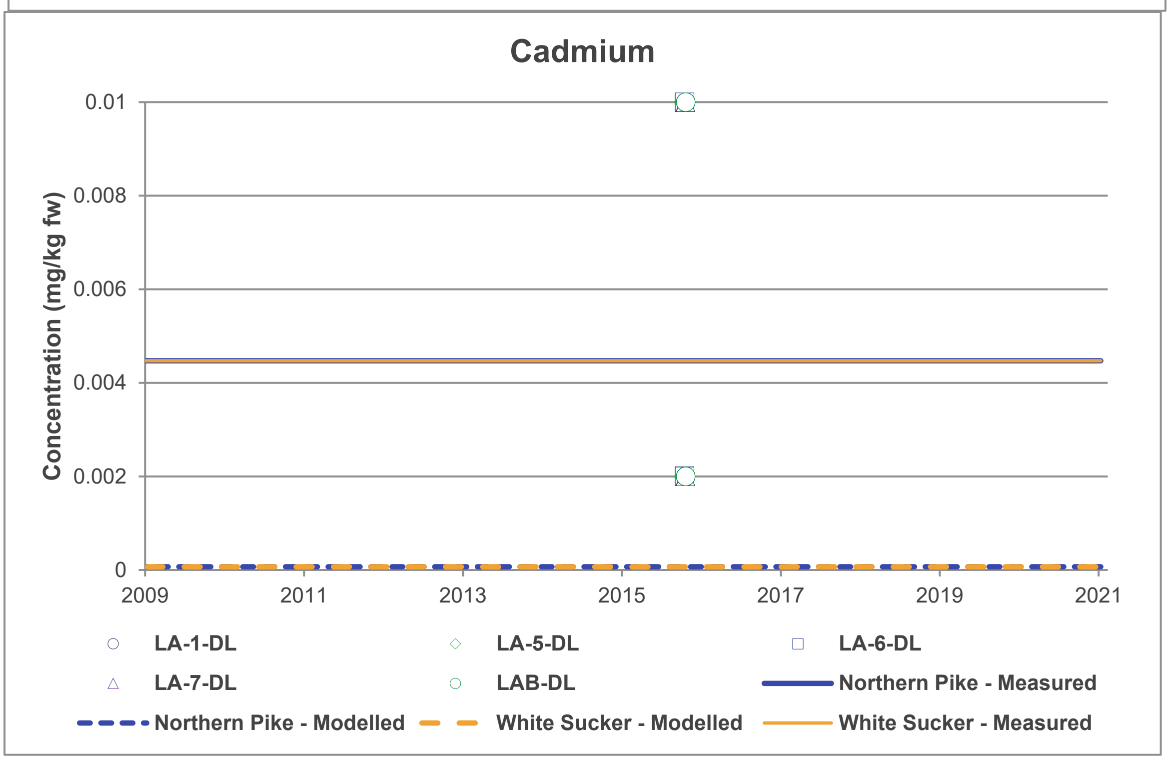
d. Lead-210 BAFs for macrophytes and phytoplankton are from IAEA TRS 472 (2010)

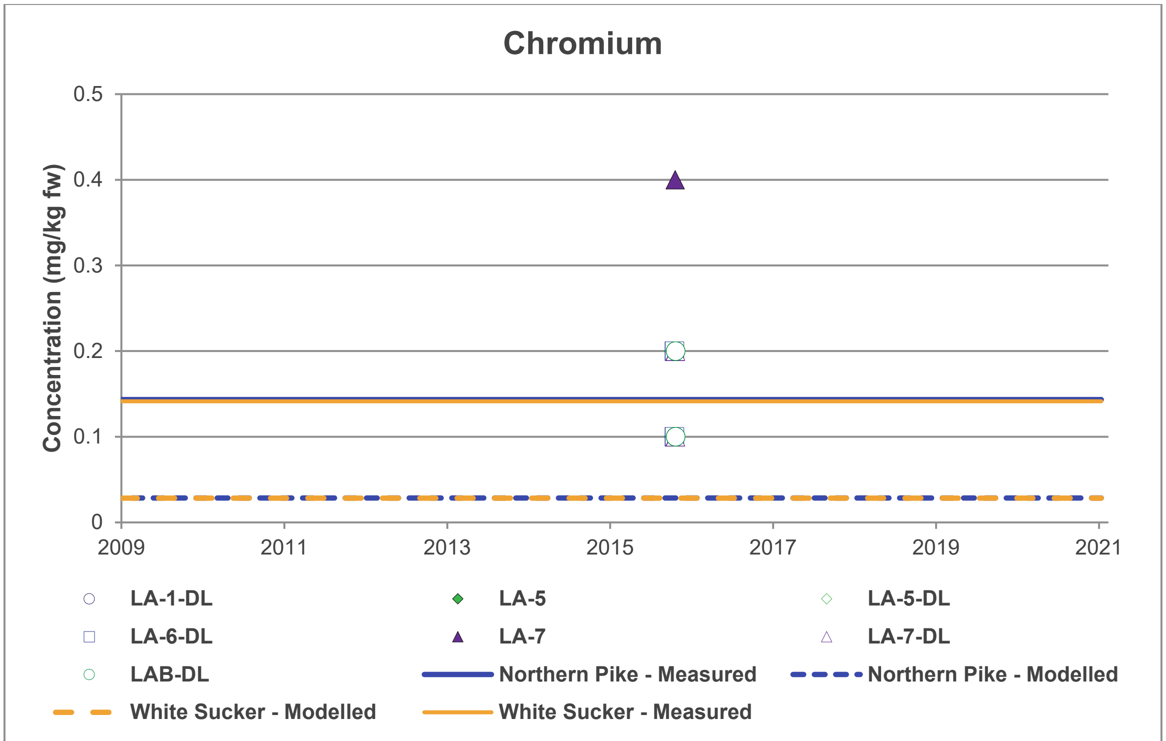
3.6.2 Model Validation

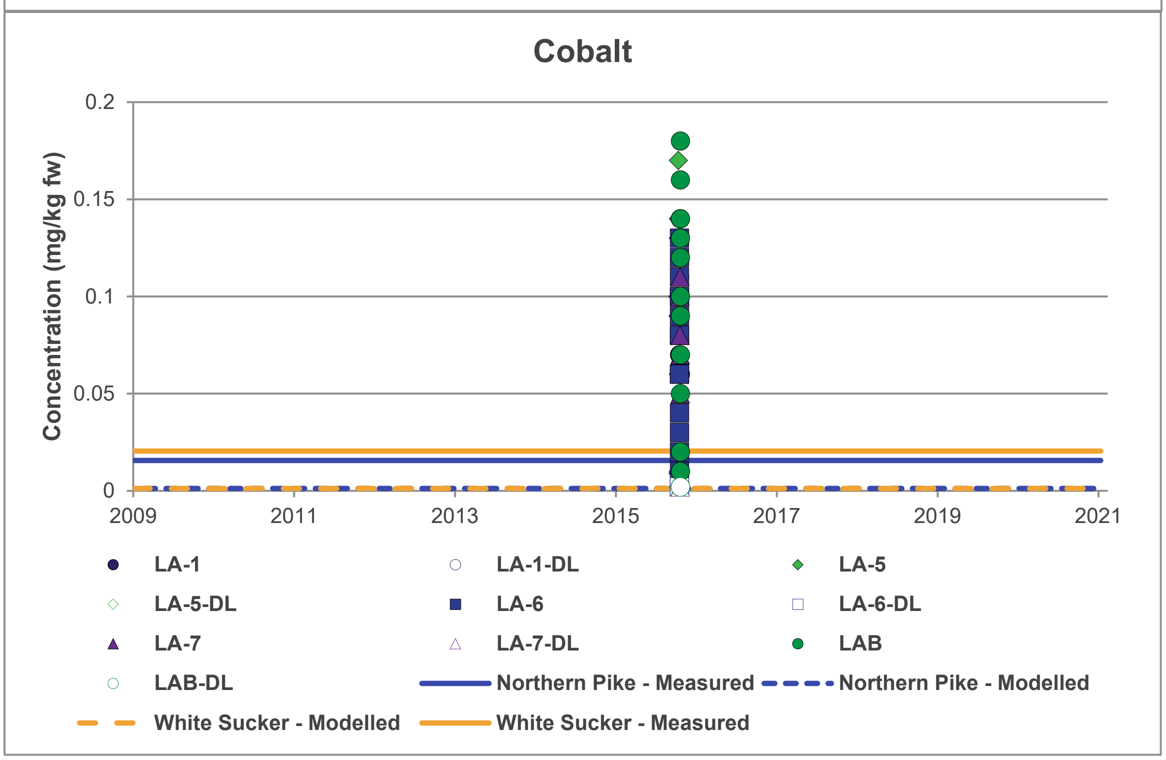
No measured data was available for other aquatic receptors except for northern pike and white sucker. Figure 3-4 presents the modelled and measured concentrations of COPCs in northern pike and white sucker from baseline sampling in 2016 and 2017 (Ecometrix, 2020a). Measured concentrations of radionuclides are mostly under the detection limit which agrees with the modelled concentrations.

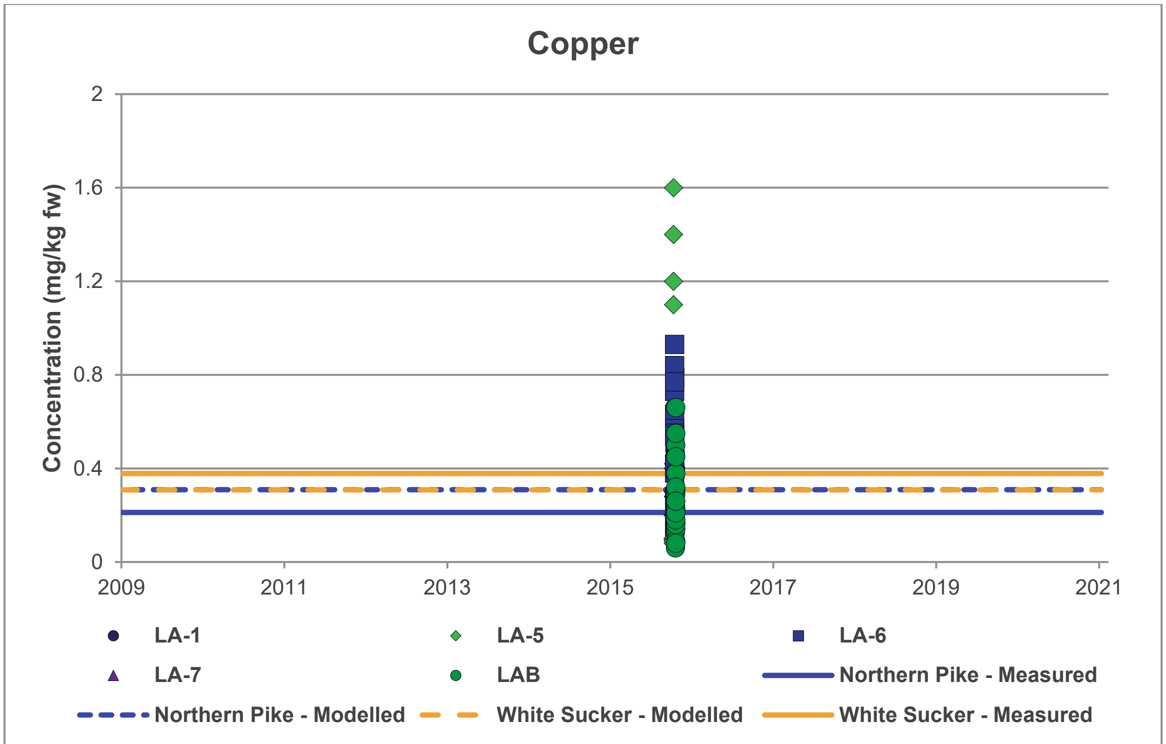
The modelled concentrations of the COPCs are generally in good agreement with the measured values. However, the data suggest that the model may be slightly underpredicting COPC concentrations in northern pike and white sucker, except for arsenic, copper, polonium-210 and selenium whose modelled concentrations are in good agreement with the measured ones. This is mainly due to data limitations: that only one sampling event was available and that measured values were often non-detectable. For instance, more than 90% of the measured concentrations for cadmium (100%), chromium (99%), molybdenum (95%), uranium (97%), vanadium (100%), lead-210 (96%), radium-226 (92%) and thorium-230 (97%) are below their detection limits, respectively. For non-detectable samples, the detection limit was used for calculation of averages in fish. The BAFs used are consistent with regionally calibrated values representing exposure conditions. The generally good agreement of the modelled results with the measured data validates the use of the selected BAFs and modelled processes. However, refinement of the BAFs for aquatic animals can be completed as new data become available during future phases of the Project.

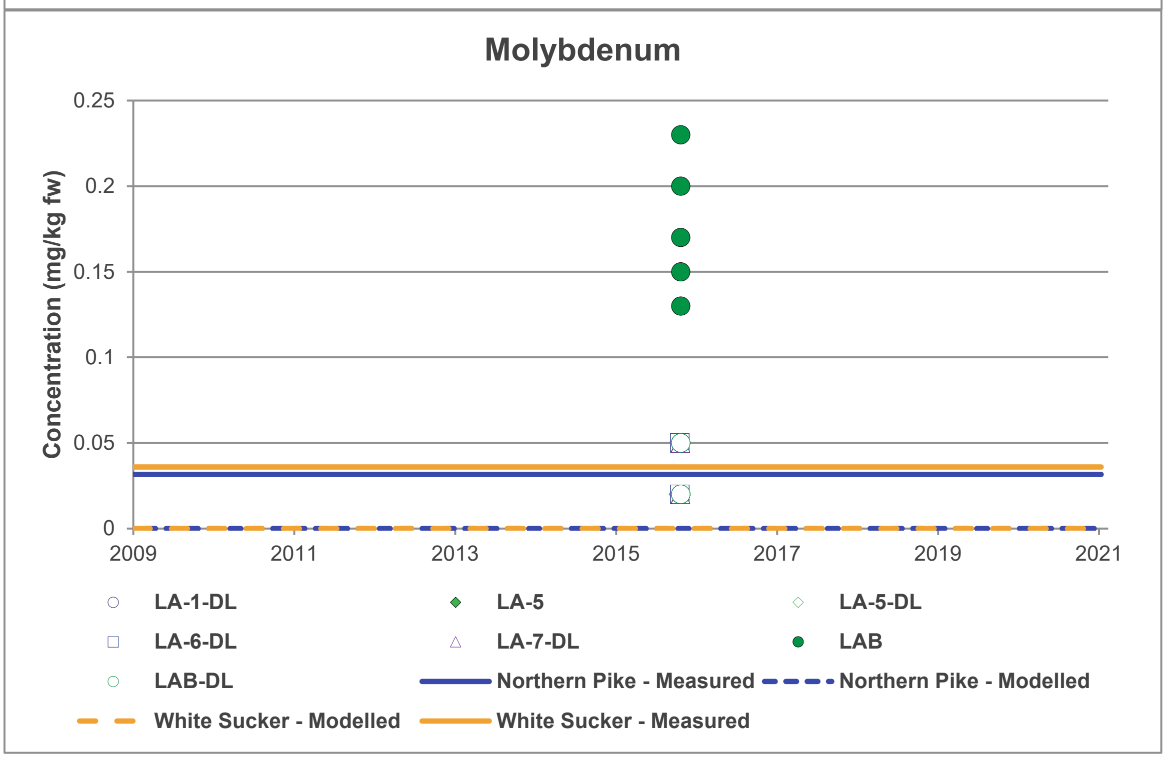

Arsenic
Concentration (mg/kg fw)
0.1
0.08
0.06
0.04
0.02
0
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-1-DL
LA-5
LA-5-DL
LA-6
LA-6-DL
LA-7
LA-7-DL
LAB
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

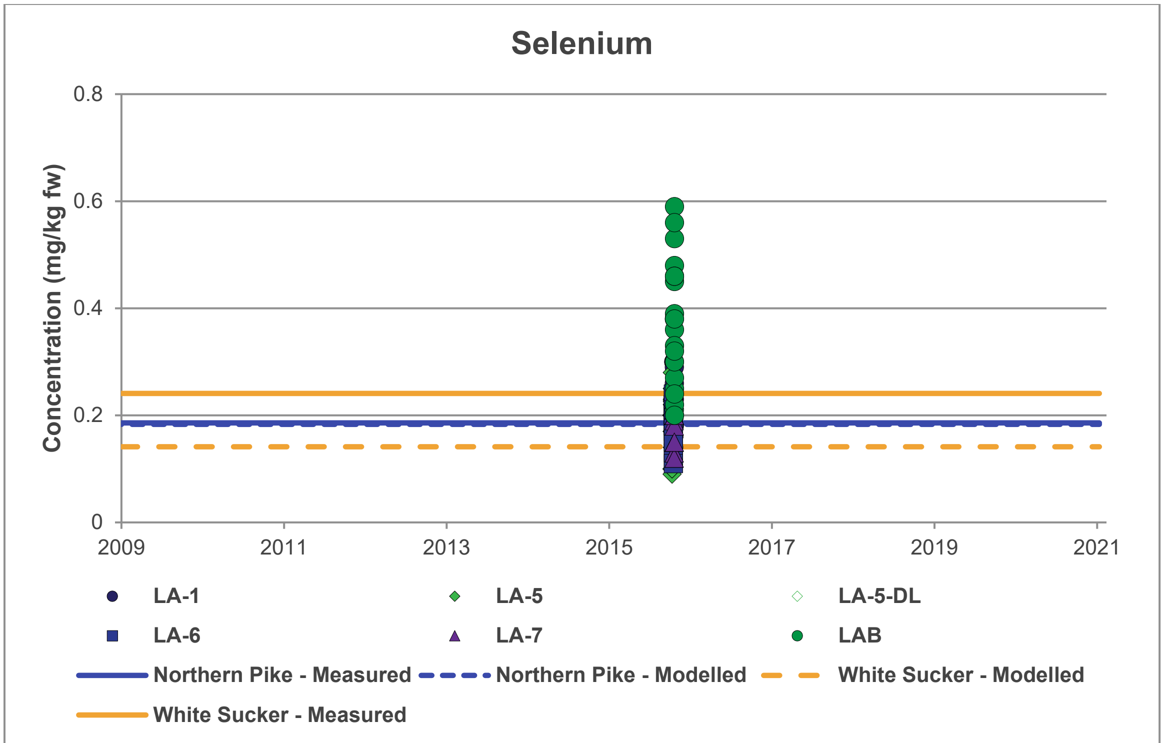

Cadmium
Concentration (mg/kg fw)
0.01
0.008
0.006
0.004
0.002
0
2009
2011
2013
2015
2017
2019
2021
LA-1-DL
LA-5-DL
LA-6-DL
LA-7-DL
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

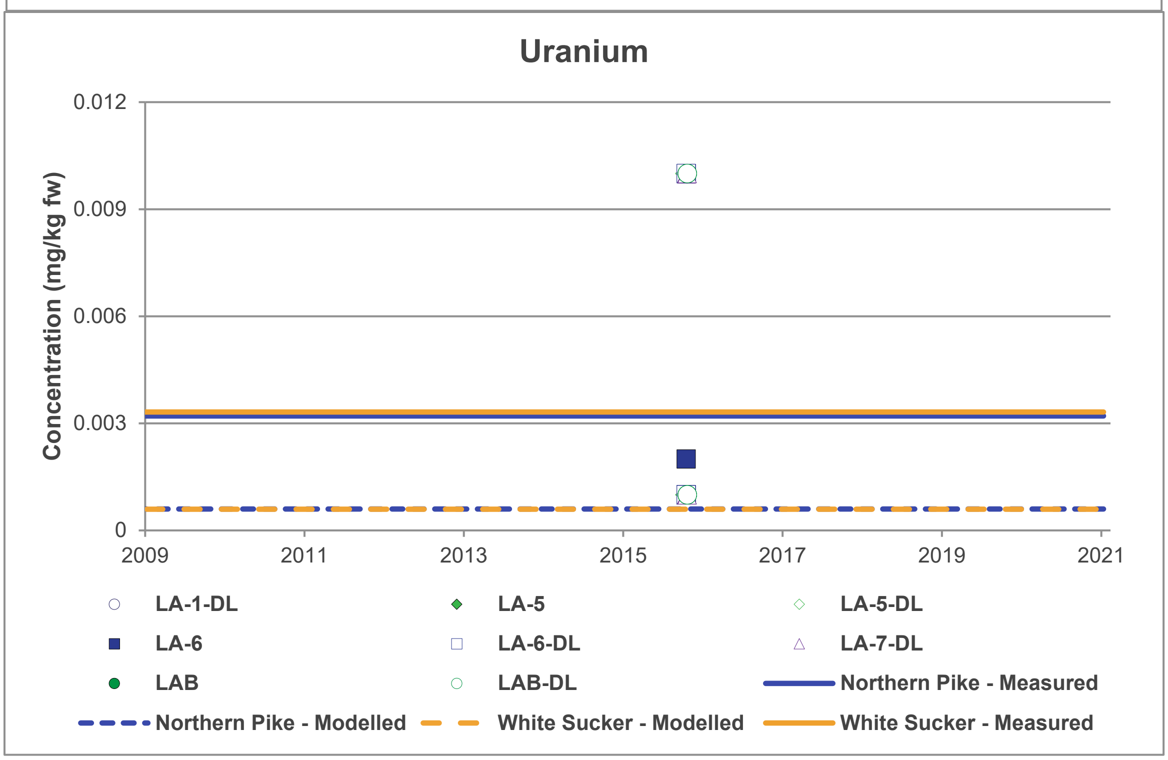

Chromium
Concentration (mg/kg fw)
0.5
0.4
0.3
0.2
0.1
0
2009
2011
2013
2015
2017
2019
2021
LA-1-DL
LA-5
LA-5-DL
LA-6-DL
LA-7
LA-7-DL
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

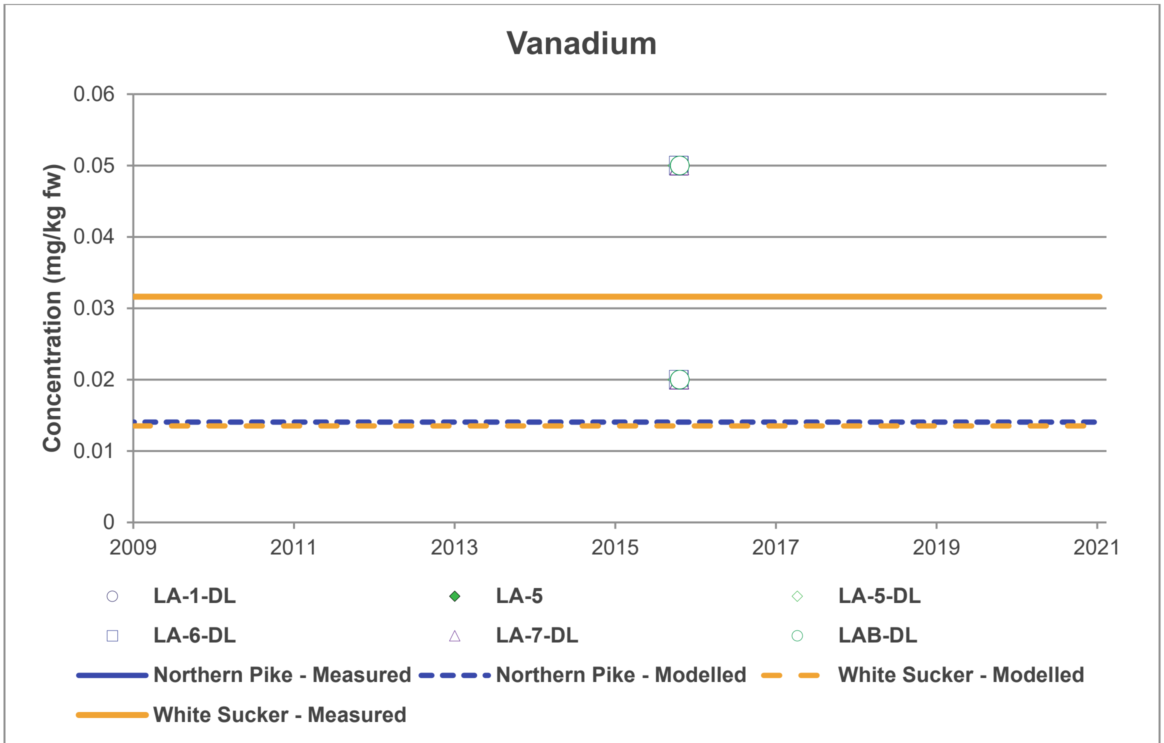

Cobalt
Concentration (mg/kg fw)
0.2
0.15
0.1
0.05
0
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-1-DL
LA-5
LA-5-DL
LA-6
LA-6-DL
LA-7
LA-7-DL
LAB
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

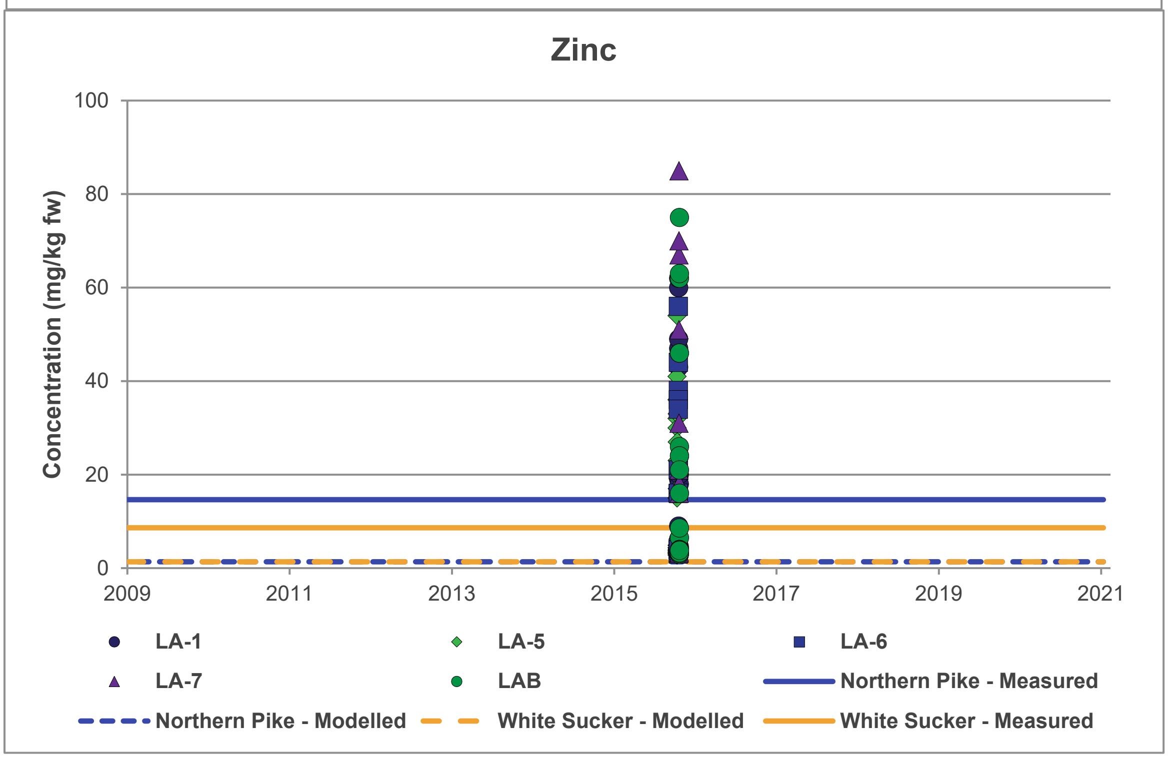

Copper
Concentration (mg/kg fw)
0
0.4
0.8
1.2
1.6
2
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-5
LA-6
LA-7
LAB
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

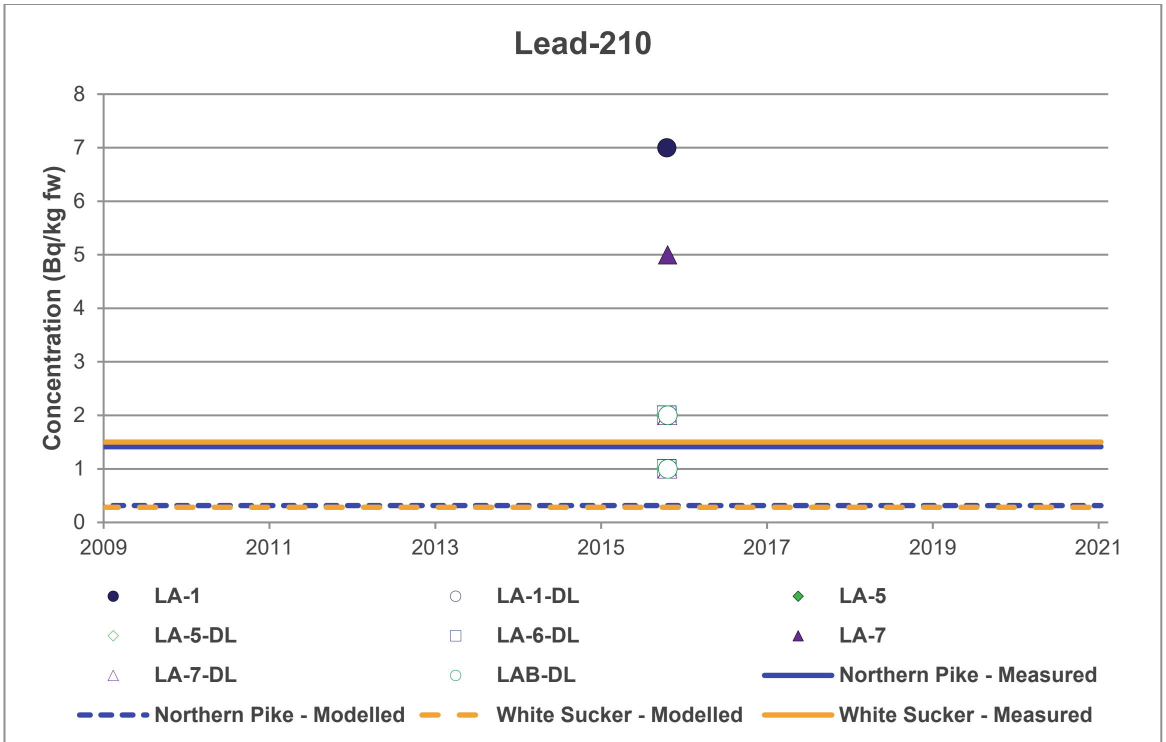

Molybdenum
Concentration (mg/kg fw)
0
0.05
0.1
0.15
0.2
0.25
2009
2011
2013
2015
2017
2019
2021
LA-1-DL
LA-5
LA-5-DL
LA-6-DL
LA-7-DL
LAB
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

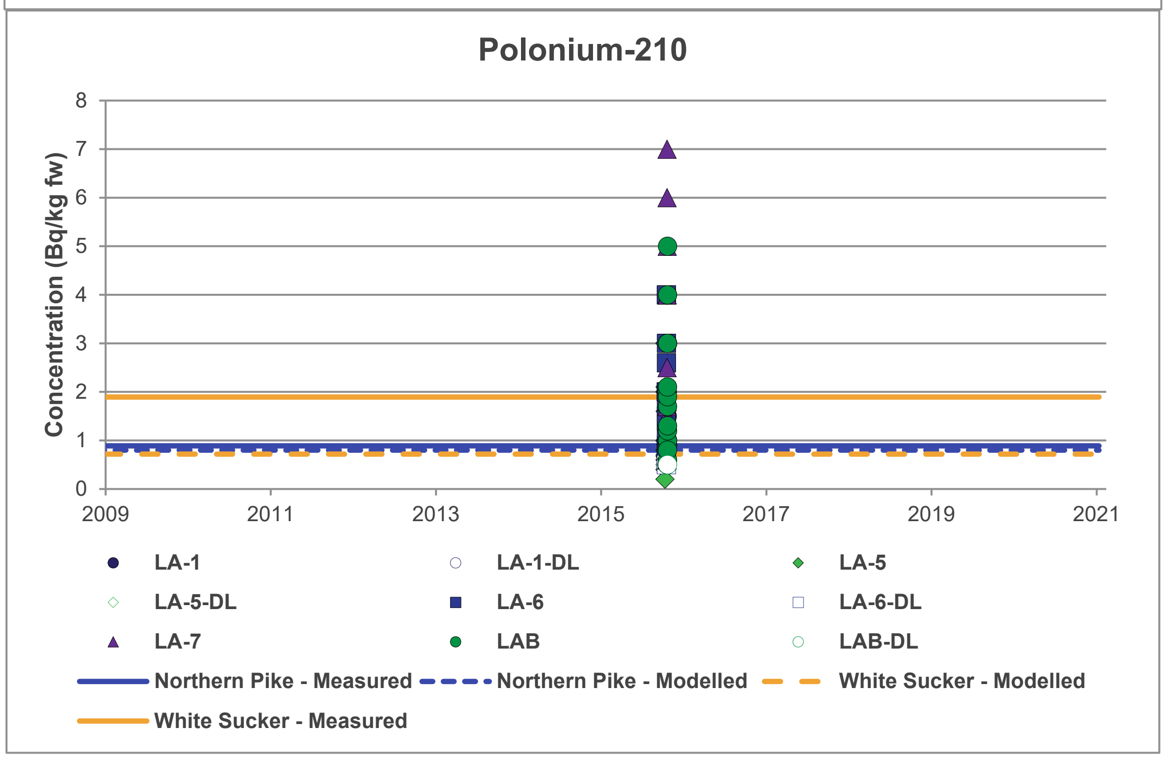

Selenium
Concentration (mg/kg fw)
0.8
0.6
0.4
0.2
0
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-5
LA-5-DL
LA-6
LA-7
LAB
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured

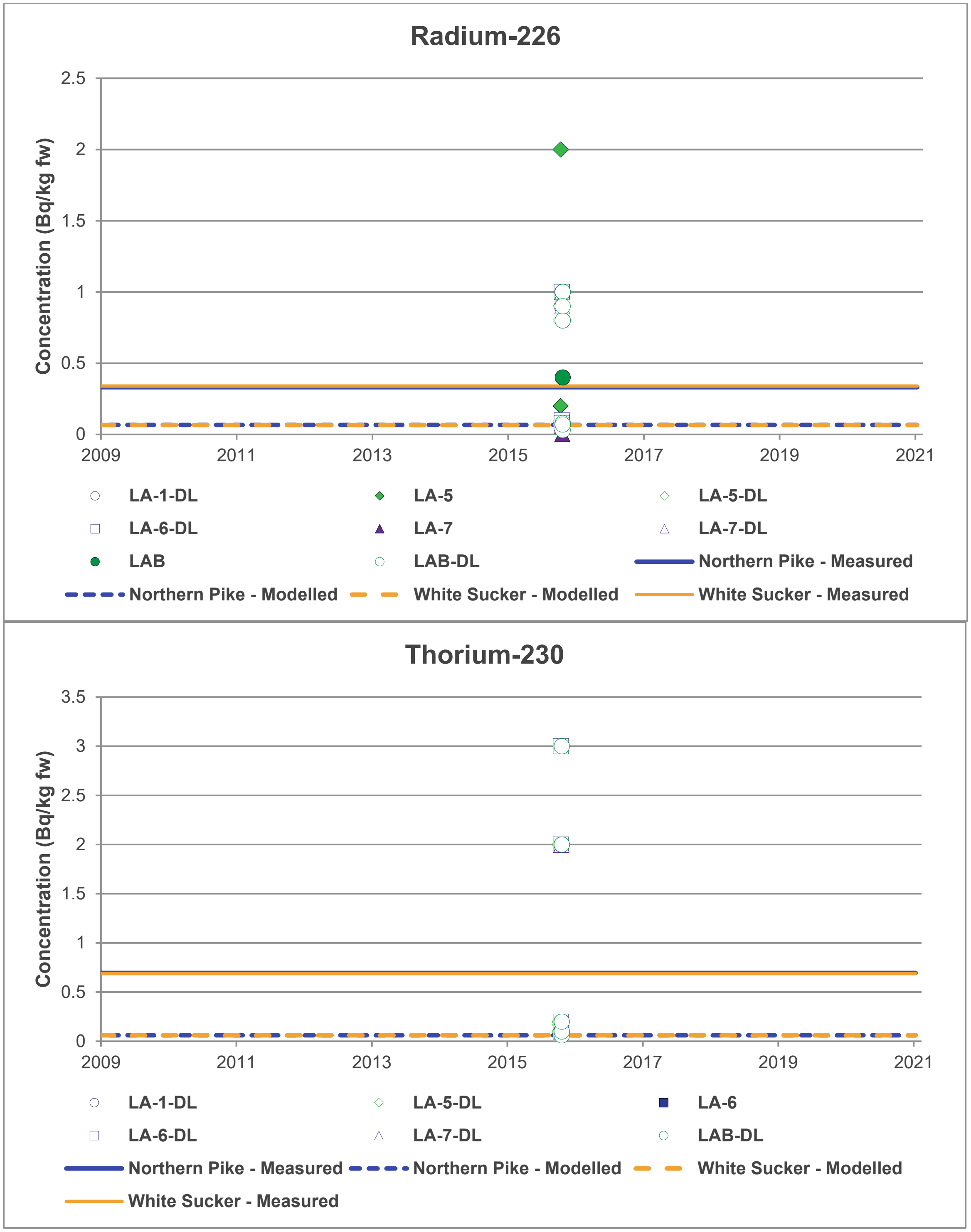

Uranium
Concentration (mg/kg fw)
0.012
0.009
0.006
0.003
0
2009
2011
2013
2015
2017
2019
2021
LA-1-DL
LA-5
LA-5-DL
LA-6
LA-6-DL
LA-7-DL
LAB
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured


Vanadium
Concentration (mg/kg fw)
0.06
0.05
0.04
0.03
0.02
0.01
0
2009
2011
2013
2015
2017
2019
2021
LA-1-DL
LA-5
LA-5-DL
LA-6-DL
LA-7-DL
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured


Zinc
Concentration (mg/kg fw)
100
80
60
40
20
0
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-5
LA-6
LA-7
LAB
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured


Lead-210
Concentration (Bq/kg fw)
0
1
2
3
4
5
6
7
8
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-1-DL
LA-5
LA-5-DL
LA-6-DL
LA-7
LA-7-DL
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured


Polonium-210
Concentration (Bq/kg fw)
0
1
2
3
4
5
6
7
8
2009
2011
2013
2015
2017
2019
2021
LA-1
LA-1-DL
LA-5
LA-5-DL
LA-6
LA-6-DL
LA-7
LAB
LAB-DL
Northern Pike - Measured
Northern Pike - Modelled
White Sucker - Modelled
White Sucker - Measured



The measured lines indicate the geometric mean of the measured concentrations. fw: fresh weight. Blank symbol indicates that the measurement was under the detection limit. The location of sampling stations is described in detail in baseline aquatic environment study report (Ecometrix, 2020a).

Figure 3-4: Modelled and Measured Baseline Concentrations (fresh weight) of COPCs in Northern Pike and White Sucker

3.6.3 Dose Coefficients for Aquatic Receptors

Dose coefficients (DCFs) for all external and internal exposure routes considered are presented in Table 3-10 and Table 3-11, respectively. DCFs for internal and external exposure pathways are based on values published by the International Commission on Radiological Protection (ICRP) for aquatic plants and northern pike (ICRP 2008). For benthic invertebrates, zooplankton, and white sucker, DCFs were calculated with the ERICA Tool (Brown et al. 2008).

The DCF values from the ICRP (2008) and the ERICA Tool 1.3.1 (Brown et al. 2008) do not incorporate radiation quality factors for relative biological effectiveness for low beta and alpha components. The relative biological effectiveness is a radioecological weighting factor that represents the ratio of doses from different types of radiation needed to produce the same biological effect. Therefore, the "low beta" components of the DCFs were multiplied by 2, and the alpha components were multiplied by 10 (as per CSA N288.6-22), to represent their greater relative effectiveness.

Table 3-10: External Dose Coefficients for Aquatic Receptors

COPC	DCF External (μGy/hr)/(Bq/kg(fw sediment) or Bq/L(water))					
	Macrophytes [a]	Phytoplankton [a]	Benthic Invertebrate [b]	Northern Pike [c]	White Sucker [d]	Zooplankton [e]
Lead-210	3.38E-05	3.38E-05	1.10E-04	4.00E-06	3.80E-06	1.50E-04
Polonium-210	4.58E-09	4.58E-09	4.90E-09	4.17E-09	4.30E-09	4.90E-09
Radium-226	1.13E-03	1.13E-03	1.30E-03	9.17E-04	9.10E-04	1.40E-03
Thorium-230	4.58E-07	4.58E-07	9.00E-07	2.50E-07	2.40E-07	1.00E-06
Uranium-234	4.17E-07	4.17E-07	9.40E-07	1.63E-07	1.50E-07	1.00E-06
Uranium-238	3.17E-07	3.17E-07	7.20E-07	1.00E-07	9.50E-08	7.80E-07

a. DCFs are based on seaweed (ICRP 2008).
b. DCFs are the value for insect larvae from the ERICA Database (Brown et al. 2008).
c. DCFs are based on trout (ICRP 2008).
d. DCFs are the value for benthic fish from the ERICA Database (Brown et al. 2008).
e. DCFs are from the ERICA Database (Brown et al. 2008).
μGy = microgray; Bq = becquerel; fw = fresh weight.
COPC = constituent of potential concern; DCF = dose coefficient.

Table 3-11: Internal Dose Coefficients for Aquatic Receptors

COPC	DCF Internal (μGy/hr)/(Bq/kg fw)					
	Macrophytes [a]	Phytoplankton [a]	Benthic Invertebrate [b]	Northern Pike [c]	White Sucker [d]	Zooplankton [e]
Lead-210	2.17E-04	2.17E-04	1.40E-04	2.46E-04	2.50E-04	1.00E-04
Polonium-210	3.04E-02	3.04E-02	3.10E-03	3.04E-02	3.10E-03	3.10E-02
Radium-226	1.38E-01	1.38E-01	1.37E-01	1.39E-01	1.43E-01	1.37E-01
Thorium-230	2.71E-02	2.71E-02	2.70E-02	2.71E-02	2.70E-02	2.70E-02
Uranium-234	2.75E-02	2.75E-02	2.80E-02	2.75E-02	2.80E-02	2.80E-02
Uranium-238	2.42E-02	2.42E-02	2.40E-02	2.42E-02	2.40E-02	2.40E-02

a. DCFs are based on seaweed (ICRP 2008).
b. DCFs are the value for insect larvae from the ERICA Database (Brown et al. 2008).
c. DCFs are based on trout (ICRP 2008).
d. DCFs are the value for benthic fish from the ERICA Database (Brown et al. 2008).
e. DCFs are from the ERICA Database (Brown et al. 2008).
μGy = microgray; Bq = becquerel; fw = fresh weight.
COPC = constituent of potential concern; DCF = dose coefficient.

3.7 Transfer of Constituents to Terrestrial Receptors and Humans

The COPCs may be transferred from environmental media to terrestrial receptors through food, water, and air. Ingestion and inhalation transfer factors (TFs) are defined as the ratio between the COPC concentrations in the receptor and the COPC intake rates. The TF may be determined for specific organs or other body tissues (e.g., food to liver; food to eggs). Soil to terrestrial plant transfers may include deposition from air to plant, as well as soil-to-plant bioaccumulation, and are defined as the ratio between the concentration of a COPC in the plant and that in the soil, both in dry weight.

3.7.1 Soil-to-Plant Transfer

A plant may take up COPCs by dry and wet deposition of COPCs from air and raindrop splash onto the plant, as well as from uptake of COPCs from soil to the plant via the root system. In the case of most COPCs, transfer from deposition on soil and then uptake from soil into the plant is considered to be the dominant pathway. The terrestrial plants include blueberries, browse, Labrador tea, and lichen. The soil-to-plant pathway is not considered applicable to lichen; therefore, the soil-to-plant BAFs are zero for lichen. Lichens are considered to take up COPCs via wet and dry deposition directly from air only (IAEA, 2010). Uptake of COPCs by blueberries, browse, and Labrador tea is represented by soil-to-plant BAF values derived from regional data from northern Saskatchewan, as shown in Table 3-12. Uptake of COPCs by terrestrial invertebrates from soil is represented by the soil-to-invertebrate BAFs, as shown in Table 3-12.

Table 3-12: Bioaccumulation Factors for Terrestrial Plants and Invertebrates

Soil-to-Plant BAFs kg(dw soil)/kg(dw plant)		
COPC	**Terrestrial Plant [a]**	**Terrestrial Invertebrate [b]**
Arsenic	4.26E-01	2.24E-01
Cadmium	4.20E-02 (blueberries) 7.80E-01 (browse and Labrador tea)	1.24E+01
Chromium	8.20E-03	3.06E-01
Cobalt	5.80E-01	3.58E-02
Copper	6.64E+00	5.15E-01
Molybdenum	1.00E+00	1.54E+00
Selenium	1.00E+00	8.71E+00
Uranium	1.70E-01	5.20E-02

Soil-to-Plant BAFs kg(dw soil)/kg(dw plant)		
COPC	**Terrestrial Plant [a]**	**Terrestrial Invertebrate [b]**
Vanadium	1.90E-03	4.20E-02
Zinc	4.20E+00	3.20E+00
Lead-210	2.64E-01	1.68E-01
Polonium-210	3.86E-01	1.64E-01
Radium-226	6.00E-01	5.29E-01
Thorium-230	3.12E-02	5.20E-02
Uranium-234	1.70E-01	5.20E-02
Uranium-238	1.70E-01	5.20E-02

dw = dry weight; COPC = constituent of potential concern.

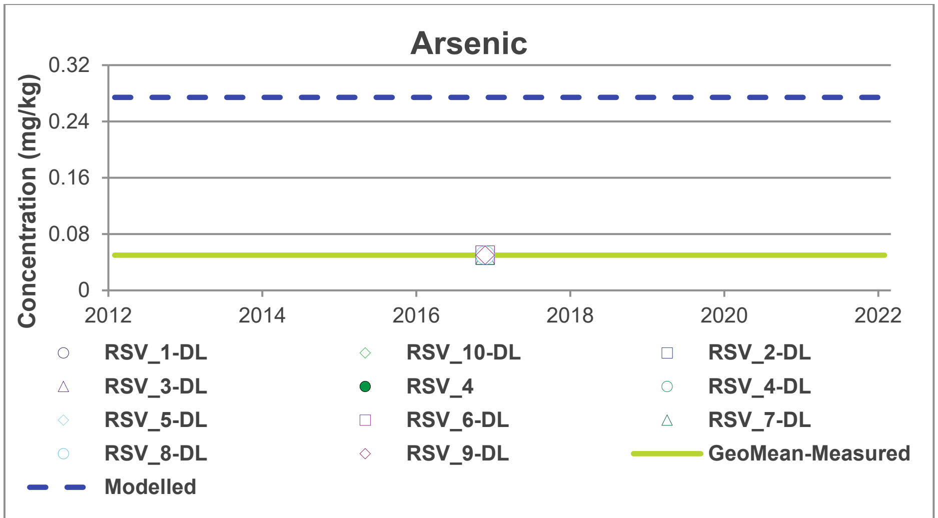
a. BAFs for terrestrial plants are compiled from regional data, except chromium from CSA N288.1-20 (Table G.3); cadmium and vanadium from Sheppard (2009); uranium, uranium-234/238 and zinc from IAEA (2010).

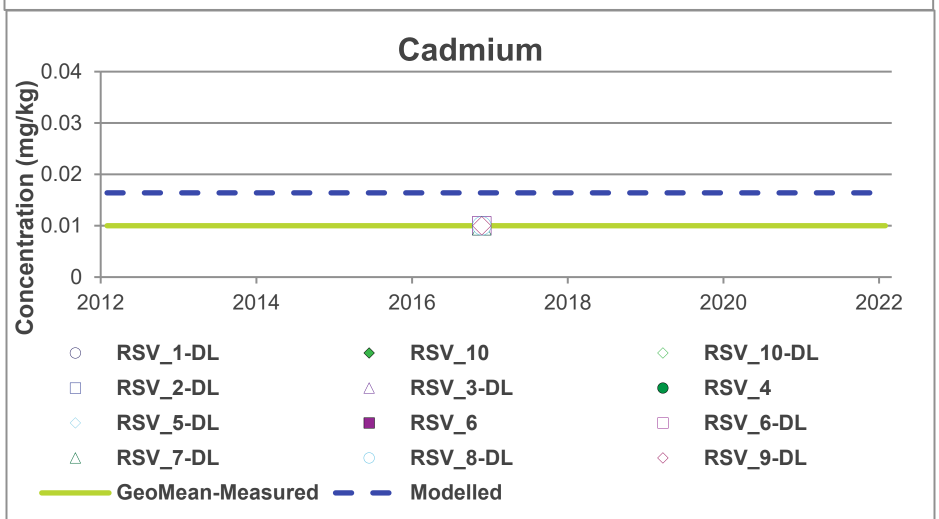
b. BAFs for terrestrial invertebrates are from Beresford et al. (2008), except molybdenum from Barnett et al. (2014), arsenic, chromium, copper, vanadium and zinc from Sample et al. (1998).

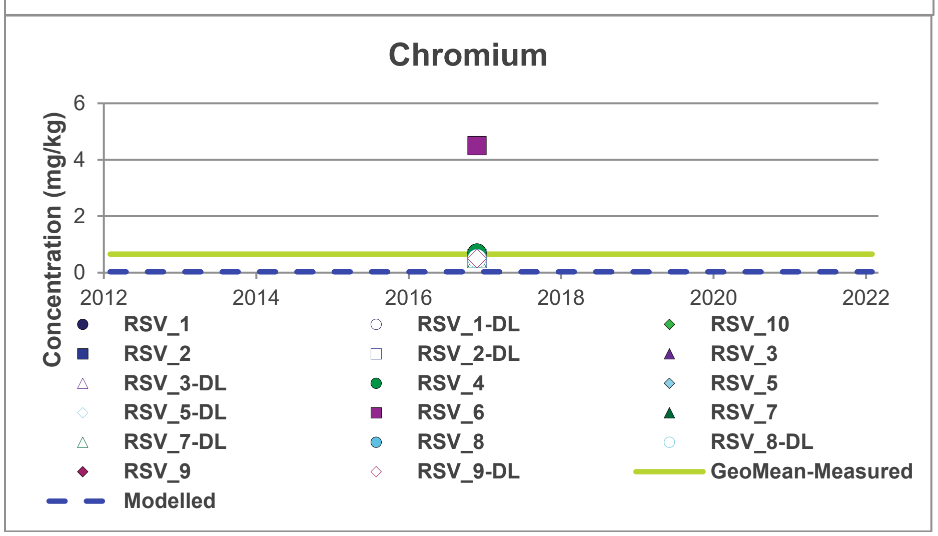
3.7.2 Model Validation

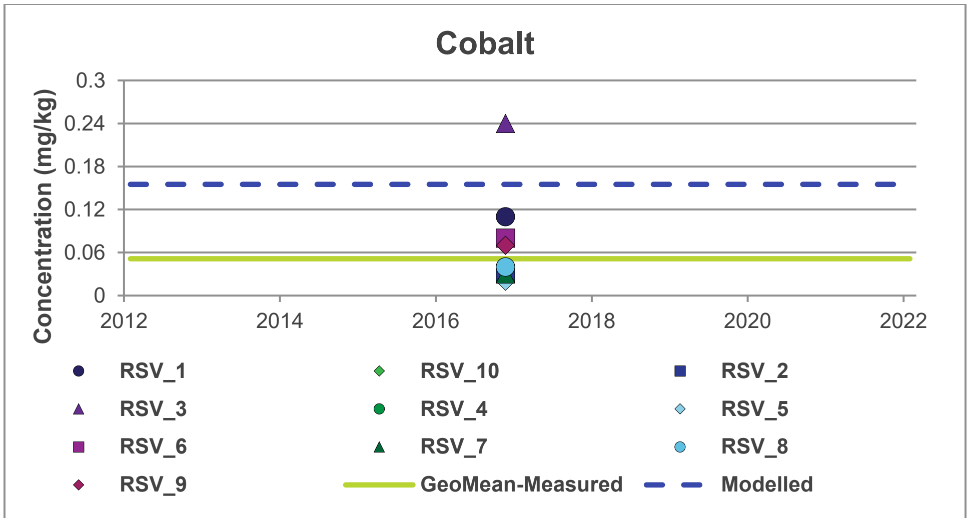
Figure 3-5 presents the predicted and observed concentrations of COPCs in blueberries obtained from 10 sample sites in August 2017 (Omnia, 2019).

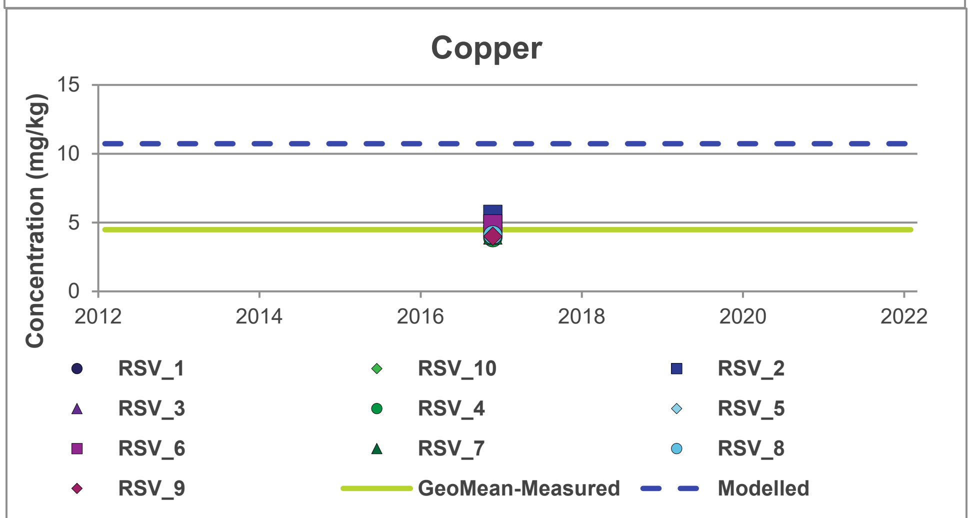
Based on available data from only one sampling event, modelled concentrations of cobalt, selenium, lead-210 and thorium-230 generally fall within the range of measured values, suggesting a good agreement of available data with the modelled values. For constituents for which the model predictions fall outside of the observed range, concentrations are conservatively overestimated for arsenic (which is non-detect in blueberry samples), cadmium, copper, molybdenum, uranium, zinc, polonium-210 and radium-226. Since the measured values are obtained from only 10 locations in one sampling event and more than 70% of the measured concentrations of chromium (7/10), and vanadium (9/10) are below the detection limit, it is reasonable that the modelled concentrations of these two COPCs are slightly lower than the measured geometric mean values.

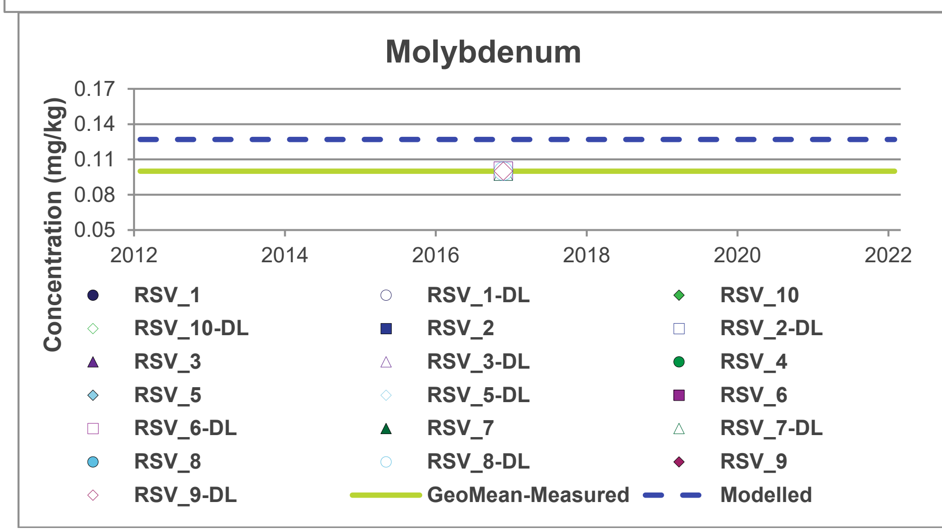

Arsenic
Concentration (mg/kg)
0.32
0.24
0.16
0.08
0
2012
2014
2016
2018
2020
2022
RSV_1-DL
RSV_10-DL
RSV_2-DL
RSV_3-DL
RSV_4
RSV_4-DL
RSV_5-DL
RSV_6-DL
RSV_7-DL
RSV_8-DL
RSV_9-DL
GeoMean-Measured
Modelled

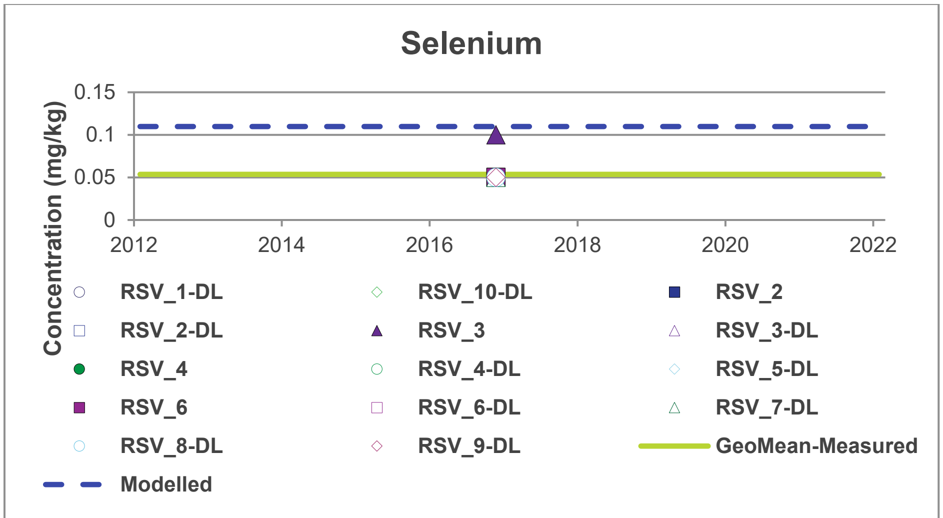

Cadmium
Concentration (mg/kg)
0.04
0.03
0.02
0.01
0
2012
2014
2016
2018
2020
2022
RSV_1-DL
RSV_10
RSV_10-DL
RSV_2-DL
RSV_3-DL
RSV_4
RSV_5-DL
RSV_6
RSV_6-DL
RSV_7-DL
RSV_8-DL
RSV_9-DL
GeoMean-Measured
Modelled

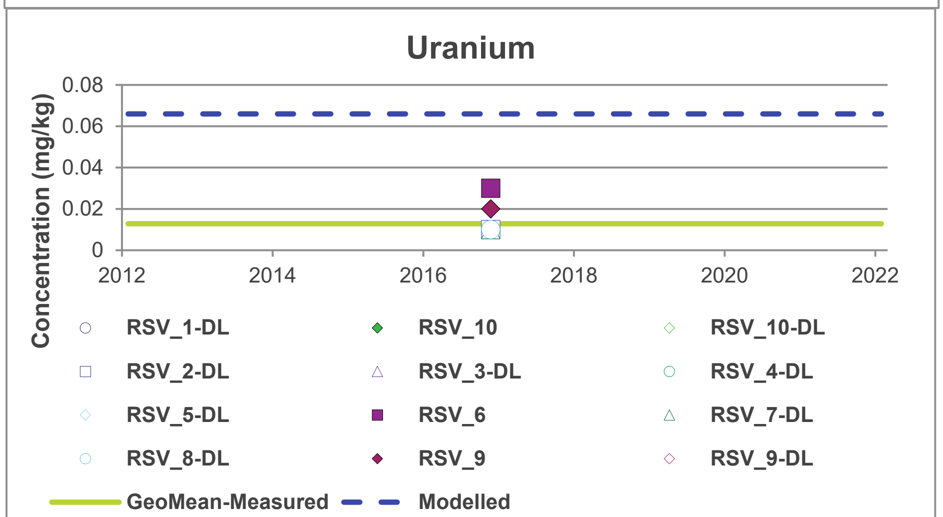

Chromium
Concentration (mg/kg)
6
4
2
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_1-DL
RSV_10
RSV_2
RSV_2-DL
RSV_3
RSV_3-DL
RSV_4
RSV_5
RSV_5-DL
RSV_6
RSV_7
RSV_7-DL
RSV_8
RSV_8-DL
RSV_9
RSV_9-DL
GeoMean-Measured
Modelled

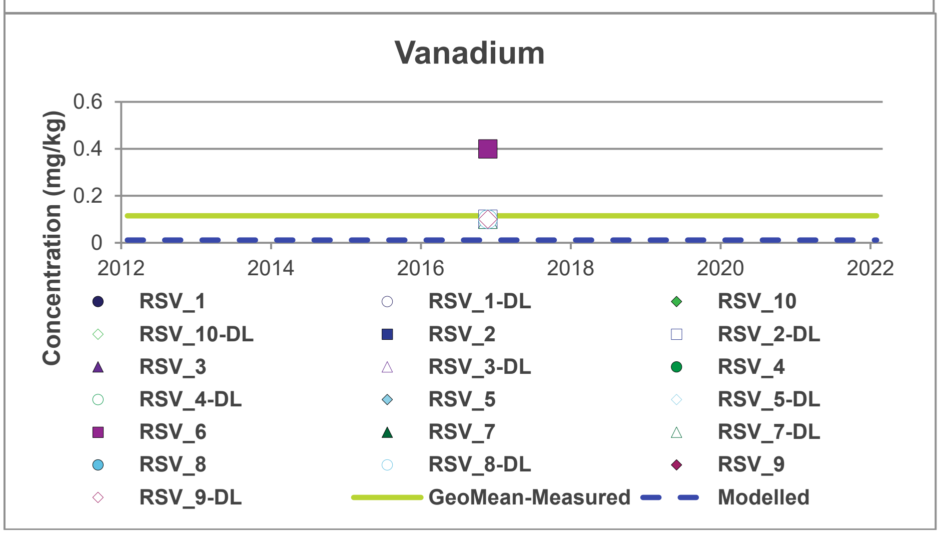

Cobalt
Concentration (mg/kg)
0.3
0.24
0.18
0.12
0.06
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_10
RSV_2
RSV_3
RSV_4
RSV_5
RSV_6
RSV_7
RSV_8
RSV_9
GeoMean-Measured
Modelled

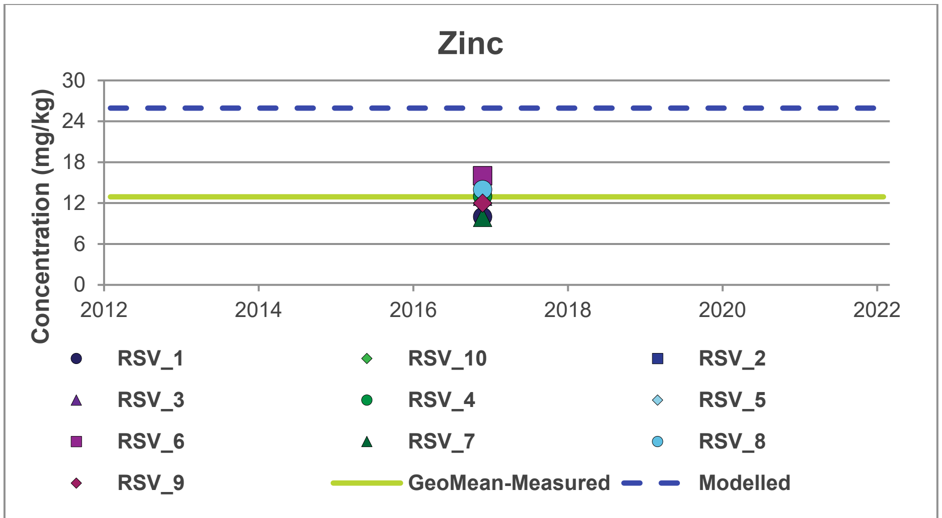

Copper
Concentration (mg/kg)
15
10
5
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_10
RSV_2
RSV_3
RSV_4
RSV_5
RSV_6
RSV_7
RSV_8
RSV_9
GeoMean-Measured
Modelled

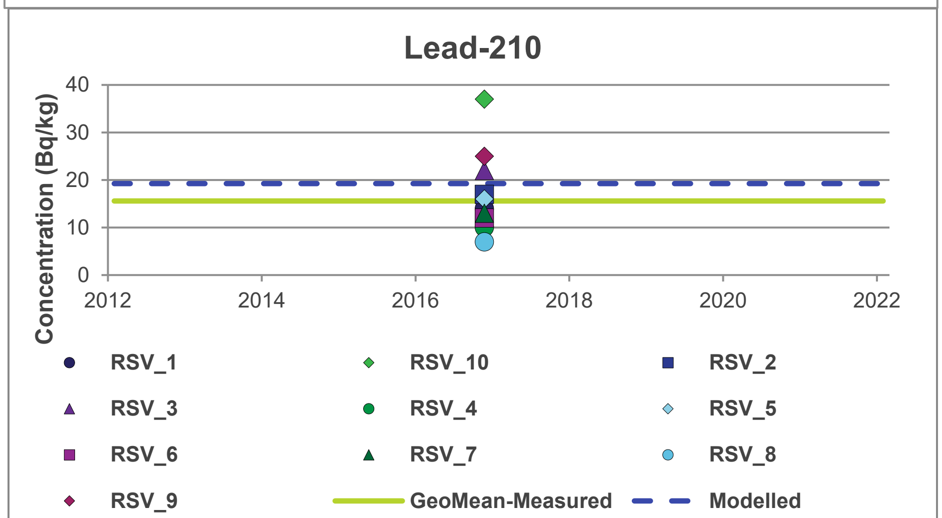

Molybdenum
Concentration (mg/kg)
0.17
0.14
0.11
0.08
0.05
2012
2014
2016
2018
2020
2022
RSV_1
RSV_1-DL
RSV_10
RSV_10-DL
RSV_2
RSV_2-DL
RSV_3
RSV_3-DL
RSV_4
RSV_5
RSV_5-DL
RSV_6
RSV_6-DL
RSV_7
RSV_7-DL
RSV_8
RSV_8-DL
RSV_9
RSV_9-DL
GeoMean-Measured
Modelled

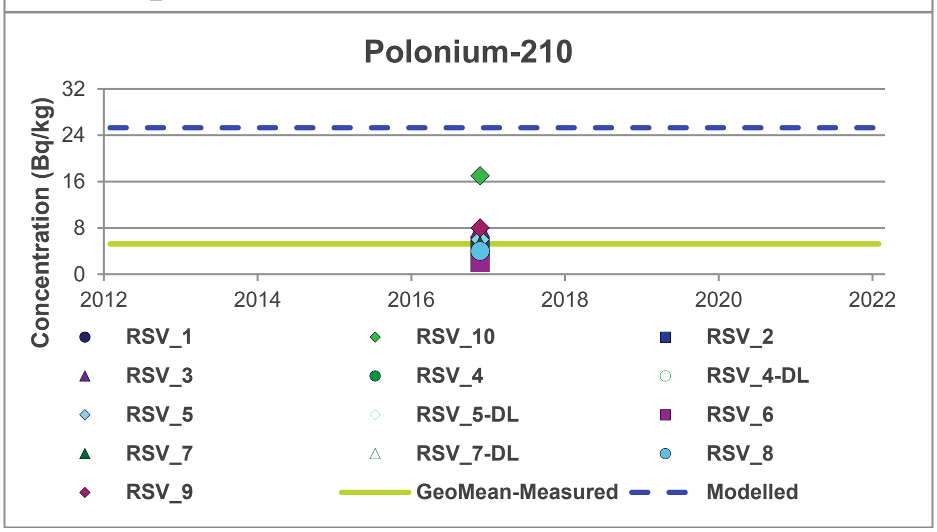

Selenium
Concentration (mg/kg)
0.15
0.1
0.05
0
2012
2014
2016
2018
2020
2022
RSV_1-DL
RSV_10-DL
RSV_2
RSV_2-DL
RSV_3
RSV_3-DL
RSV_4
RSV_4-DL
RSV_5-DL
RSV_6
RSV_6-DL
RSV_7-DL
RSV_8-DL
RSV_9-DL
GeoMean-Measured
Modelled

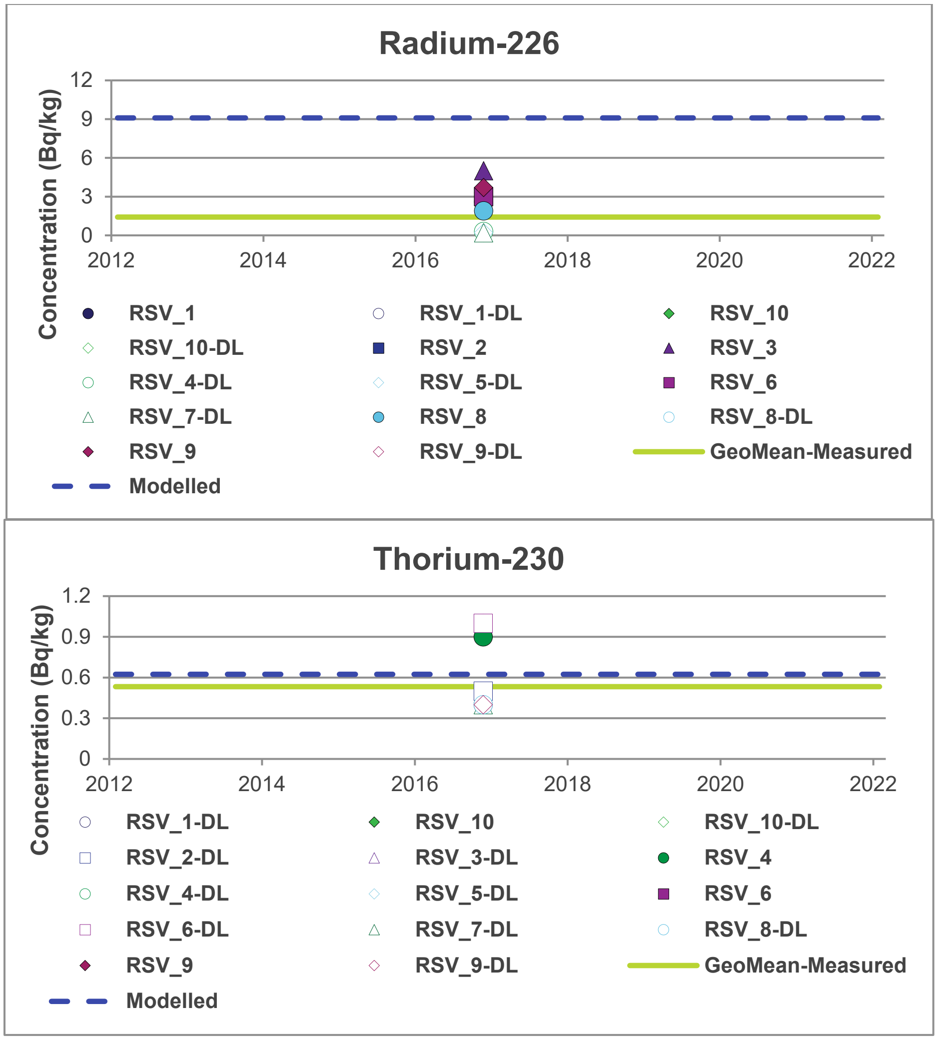

Uranium
Concentration (mg/kg)
0.08
0.06
0.04
0.02
0
2012
2014
2016
2018
2020
2022
RSV_1-DL
RSV_10
RSV_10-DL
RSV_2-DL
RSV_3-DL
RSV_4-DL
RSV_5-DL
RSV_6
RSV_7-DL
RSV_8-DL
RSV_9
RSV_9-DL
GeoMean-Measured
Modelled


Vanadium
Concentration (mg/kg)
0.6
0.4
0.2
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_1-DL
RSV_10
RSV_10-DL
RSV_2
RSV_2-DL
RSV_3
RSV_3-DL
RSV_4
RSV_4-DL
RSV_5
RSV_5-DL
RSV_6
RSV_7
RSV_7-DL
RSV_8
RSV_8-DL
RSV_9
RSV_9-DL
GeoMean-Measured
Modelled


Zinc
Concentration (mg/kg)
30
24
18
12
6
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_10
RSV_2
RSV_3
RSV_4
RSV_5
RSV_6
RSV_7
RSV_8
RSV_9
GeoMean-Measured
Modelled


Lead-210
Concentration (Bq/kg)
40
30
20
10
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_10
RSV_2
RSV_3
RSV_4
RSV_5
RSV_6
RSV_7
RSV_8
RSV_9
GeoMean-Measured
Modelled


Polonium-210
Concentration (Bq/kg)
32
24
16
8
0
2012
2014
2016
2018
2020
2022
RSV_1
RSV_10
RSV_2
RSV_3
RSV_4
RSV_4-DL
RSV_5
RSV_5-DL
RSV_6
RSV_7
RSV_7-DL
RSV_8
RSV_9
GeoMean-Measured
Modelled



Blank symbol indicates that the measurement was under the detection limit. The vegetation sampling plot locations are described in the terrestrial environment wildlife and vegetation baseline inventory report (Omnia, 2019).

Figure 3-5: Modelled and Measured Concentrations (dry weight) of COPCs in Blueberries

3.7.3 Dose Coefficients for Terrestrial Plants and Invertebrates

Dose coefficients for all external and internal exposure routes to terrestrial plants and invertebrates are presented in Table 3-13 and Table 3-14, respectively. Dose coefficients for internal and external exposure pathways are based on values published by the ICRP (ICRP 2008).

Table 3-13: External Dose Coefficients for Terrestrial Plants and Invertebrates

COPC	DCF external soil surface (μGy/hr)/(Bq/m²)				DCF external soil (μGy/hr)/(Bq/kg(dw soil))
	Blueberries [a]	Browse [b]	Labrador Tea [b]	Lichen [c]	Terrestrial Invertebrate [d]
Lead-210	7.50E-09	1.13E-06	1.13E-06	2.08E-09	5.83E-07
Polonium-210	1.96E-11	6.67E-11	6.67E-11	1.24E-11	4.58E-09
Radium-226	3.88E-06	1.33E-05	1.33E-05	2.47E-06	9.17E-04
Thorium-230	2.67E-09	3.04E-07	3.04E-07	5.14E-10	2.08E-07
Uranium-234	3.38E-09	3.67E-07	3.67E-07	5.12E-10	1.75E-07
Uranium-238	2.63E-09	3.04E-07	3.04E-07	3.57E-10	1.25E-07

a. DCFs are based on pine tree (ICRP 2008).
b. DCFs are based on grass (ICRP 2008).
c. DCFs are from the ERICA Database (Brown et al. 2008).
d. DCFs are from ICRP (2008).
μGy = microgray; Bq = becquerel; fw = fresh weight.
COPC = constituent of potential concern; DCF = dose coefficient.

Table 3-14: Internal Dose Coefficients for Terrestrial Plants and Invertebrates

COPC	DCF internal (μGy/hr)/(Bq/kg(fw plant))				
	Blueberries [a]	Browse [b]	Labrador Tea [b]	Lichen [c]	Terrestrial Invertebrate [d]
Lead-210	2.50E-04	2.25E-04	2.25E-04	1.82E-04	2.25E-04
Polonium-210	3.04E-02	3.04E-02	3.04E-02	3.06E-02	3.04E-02
Radium-226	1.41E-01	1.38E-01	1.38E-01	1.38E-01	1.38E-01
Thorium-230	2.71E-02	2.71E-02	2.71E-02	2.70E-02	2.71E-02
Uranium-234	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02
Uranium-238	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02

a. DCFs are based on pine tree (ICRP 2008).
b. DCFs are based on grass (ICRP 2008).
c. DCFs are from the ERICA Database (Brown et al. 2008).
d. DCFs are from ICRP (2008).
μGy = microgray; Bq = becquerel; fw = fresh weight.
COPC = constituent of potential concern; DCF = dose coefficient.

3.7.4 Ingestion Transfer Factors for Terrestrial Receptors

Ingestion transfer factors (TFs) are COPC- and biota-specific. Ingestion TFs from forage to tissue for agricultural livestock are available in CSA N288.1-20. An allometric equation (i.e., transfer proportional to a -3/4 power of body weight) (CSA N288.6-22) was applied to TFs available for beef and poultry from CSA N288.1-20, the IAEA (2010), or the National Council on Radiation Protection and Measurements (NCRP 1996) to estimate the TFs for the mammal and bird receptors, respectively. The derived ingestion TFs are presented in Table 3-15 and Table 3-16.

3.7.5 Inhalation Transfer Factors for Terrestrial Receptors

Inhalation TFs were calculated from the ingestion TF, by adjusting the ingestion TF by a COPC-specific inhalation/ingestion ratio (II) from CSA N288.1-20. The derived inhalation TFs are presented in Table 3-17.

Table 3-15: Ingestion Transfer Factors for Mammals (d/kg fw)

COPC	Beef Transfer Factor	Ref	Black Bear	Canada Lynx	Mink	Moose	Muskrat	Snowshoe Hare	Southern Red-Backed Vole	Woodland Caribou	Beef Organs Transfer Factor (a, d)	Moose Organs
Non-radionuclides												
Arsenic	2.00E-02	(a)	7.53E-02	3.35E-01	2.39E+00	2.71E-02	2.15E+00	1.56E+00	3.14E+01	4.93E-02	1.70E-01	2.30E-01
Cadmium	5.80E-03	(b)	2.18E-02	9.72E-02	6.93E-01	7.86E-03	6.23E-01	4.52E-01	9.11E+00	1.43E-02	2.00E-03	2.71E-03
Chromium	1.10E-02	(a)	4.14E-02	1.84E-01	1.31E+00	1.49E-02	1.18E+00	8.58E-01	1.73E+01	2.71E-02	5.00E-03	6.78E-03
Cobalt	4.30E-04	(a)	1.62E-03	7.20E-03	5.14E-02	5.83E-04	4.62E-02	3.35E-02	6.75E-01	1.06E-03	1.00E-01	1.36E-01
Copper	1.00E-02	(c)	3.76E-02	1.68E-01	1.19E+00	1.36E-02	1.07E+00	7.80E-01	1.57E+01	2.47E-02	4.00E-01	5.42E-01
Molybdenum	1.00E-03	(a)	3.76E-03	1.68E-02	1.19E-01	1.36E-03	1.07E-01	7.80E-02	1.57E+00	2.47E-03	1.00E-01	1.36E-01
Selenium	1.00E-01	(a)	3.76E-01	1.68E+00	1.19E+01	1.36E-01	1.07E+01	7.80E+00	1.57E+02	2.47E-01	1.00E-01	1.36E-01
Uranium	3.90E-04	(a)	1.47E-03	6.53E-03	4.66E-02	5.29E-04	4.19E-02	3.04E-02	6.13E-01	9.62E-04	6.90E-04	9.35E-04
Vanadium	1.00E-02	(c)	3.76E-02	1.68E-01	1.19E+00	1.36E-02	1.07E+00	7.80E-01	1.57E+01	2.47E-02	1.00E-05	1.36E-05
Zinc	1.60E-01	(a)	6.02E-01	2.68E+00	1.91E+01	2.17E-01	1.72E+01	1.25E+01	2.51E+02	3.95E-01	2.00E-03	2.71E-03
Radionuclides												
Lead-210	7.00E-04	(b)	2.63E-03	1.17E-02	8.36E-02	9.49E-04	7.52E-02	5.46E-02	1.10E+00	1.73E-03	2.20E-02	2.98E-02
Polonium-210	5.00E-03	(c)	1.88E-02	8.38E-02	5.97E-01	6.78E-03	5.37E-01	3.90E-01	7.85E+00	1.23E-02	5.00E-05	6.78E-05
Radium-226	1.70E-03	(a)	6.40E-03	2.85E-02	2.03E-01	2.30E-03	1.83E-01	1.33E-01	2.67E+00	4.19E-03	9.50E-04	1.29E-03
Thorium-230	2.30E-04	(a)	8.66E-04	3.85E-03	2.75E-02	3.12E-04	2.47E-02	1.79E-02	3.61E-01	5.67E-04	6.30E-02	8.54E-02
Uranium-234	3.90E-04	(a)	1.47E-03	6.53E-03	4.66E-02	5.29E-04	4.19E-02	3.04E-02	6.13E-01	9.62E-04	6.90E-04	9.35E-04
Uranium-238	3.90E-04	(a)	1.47E-03	6.53E-03	4.66E-02	5.29E-04	4.19E-02	3.04E-02	6.13E-01	9.62E-04	6.90E-04	9.35E-04

Notes:

Transfer factors in this table were calculated using the following allometric equation: TF (d/kg fw) = $aBW^{-0.75}$, where BW = body weight, TF = transfer factor, d/kg fw = days per kilogram fresh weight, "a" is a constant calculated using published transfer factor and body weight values for beef or beef organs as per CSA N288.1 (CSA Group 2020), and applied to calculate species-specific transfer factors.

a. TFs from N288.1 Table G3.

b. TFs from IAEA Technical Reports Series No. 472, (IAEA 2010).

c. TFs from NCRP No. 123, (NCRP 1996).

d. For elements that are not listed in N288.1 Table G.3, a surrogate element was used for organs as follows (surrogate in parentheses): Cd (Zn); Cu (Ag); Pb (Sn); Po (Te); V (Nb).

Table 3-16: Ingestion Transfer Factors for Birds (d/kg fw)

COPC	Poultry Transfer Factor	American Robin	Bald Eagle	Canada Goose	Common Loon	Lesser Scaup	Mallard	Olive-Sided Flycatcher
Non-radionuclides								
Arsenic [a]	1.20E+00	1.11E+01	5.43E-01	7.56E-01	5.78E-01	2.34E+00	1.84E+00	2.64E+01
Cadmium [b]	1.70E+00	1.57E+01	7.69E-01	1.07E+00	8.18E-01	3.32E+00	2.61E+00	3.74E+01
Chromium [a]	9.20E-01	8.51E+00	4.16E-01	5.80E-01	4.43E-01	1.80E+00	1.41E+00	2.02E+01
Cobalt [a]	9.70E-01	8.97E+00	4.39E-01	6.11E-01	4.67E-01	1.89E+00	1.49E+00	2.13E+01
Copper [c]	6.20E-01	5.74E+00	2.80E-01	3.91E-01	2.99E-01	1.21E+00	9.51E-01	1.36E+01
Molybdenum [a]	1.80E-01	1.67E+00	8.14E-02	1.13E-01	8.67E-02	3.51E-01	2.76E-01	3.95E+00
Selenium [a]	9.70E+00	8.97E+01	4.39E+00	6.11E+00	4.67E+00	1.89E+01	1.49E+01	2.13E+02
Uranium [a]	7.50E-01	6.94E+00	3.39E-01	4.73E-01	3.61E-01	1.46E+00	1.15E+00	1.65E+01
Vanadium [c]	6.20E-01	5.74E+00	2.80E-01	3.91E-01	2.99E-01	1.21E+00	9.51E-01	1.36E+01
Zinc [a]	4.70E-01	4.35E+00	2.13E-01	2.96E-01	2.26E-01	9.17E-01	7.21E-01	1.03E+01
Radionuclides								
Lead-210 [c]	5.00E-02	4.63E-01	2.26E-02	3.15E-02	2.41E-02	9.76E-02	7.67E-02	1.10E+00
Polonium-210 [b]	2.40E+00	2.22E+01	1.09E+00	1.51E+00	1.16E+00	4.68E+00	3.68E+00	5.27E+01
Radium-226 [a]	3.00E-02	2.78E-01	1.36E-02	1.89E-02	1.44E-02	5.86E-02	4.60E-02	6.59E-01
Thorium-230 [a]	1.00E-02	9.25E-02	4.52E-03	6.30E-03	4.81E-03	1.95E-02	1.53E-02	2.20E-01
Uranium-234 [a]	7.50E-01	6.94E+00	3.39E-01	4.73E-01	3.61E-01	1.46E+00	1.15E+00	1.65E+01
Uranium-238 [a]	7.50E-01	6.94E+00	3.39E-01	4.73E-01	3.61E-01	1.46E+00	1.15E+00	1.65E+01

Notes

Transfer factors in this table were calculated using the following allometric equation: TF (d/kg FW) = $aBW^{-0.75}$, where "a" was calculated using published TF and BW values for poultry, and applied to calculate species-specific TFs.

a. TFs from N288.1 Table G.3.

b. TFs from IAEA Technical Reports Series No. 472, (IAEA 2010).

c. TF was calculated based on the beef TF published in NCRP No. 123 (NCRP 1996), adjusted to poultry using a ratio of 62, as per the CANDU Owners Group DRL Guidance (Hart 2019).

Table 3-17: Inhalation Transfer Factors for Mammals and Birds (d/kg fw)

COPC	Inhalation/ Ingestion Ratio (II) a,b	Black Bear	Canada Lynx	Mink	Moose	Muskrat	Snowshoe Hare	Southern Red-Backed Vole	Woodland Caribou	American Robin	Bald Eagle	Canada Goose	Common Loon	Lesser Scaup	Mallard	Olive-Sided Flycatcher
Non-radionuclides																
Arsenic	0.75	5.64E-02	2.51E-01	1.79E+00	2.03E-02	1.61E+00	1.17E+00	2.36E+01	3.70E-02	8.33E+00	4.07E-01	5.67E-01	4.33E-01	1.76E+00	1.38E+00	1.98E+01
Cadmium	0.75	1.64E-02	7.29E-02	5.20E-01	5.90E-03	4.68E-01	3.39E-01	6.83E+00	1.07E-02	1.18E+01	5.77E-01	8.04E-01	6.14E-01	2.49E+00	1.96E+00	2.80E+01
Chromium	4.95	2.05E-01	9.12E-01	6.51E+00	7.38E-02	5.85E+00	4.25E+00	8.55E+01	1.34E-01	4.21E+01	2.06E+00	2.87E+00	2.19E+00	8.89E+00	6.99E+00	1.00E+02
Cobalt	1.71	2.77E-03	1.23E-02	8.79E-02	9.97E-04	7.90E-02	5.74E-02	1.15E+00	1.81E-03	1.53E+01	7.50E-01	1.05E+00	7.99E-01	3.24E+00	2.55E+00	3.64E+01
Copper	2.91	1.10E-01	4.87E-01	3.48E+00	3.94E-02	3.13E+00	2.27E+00	4.57E+01	7.18E-02	1.67E+01	8.16E-01	1.14E+00	8.69E-01	3.52E+00	2.77E+00	3.96E+01
Molybdenum	0.63	2.37E-03	1.06E-02	7.53E-02	8.54E-04	6.77E-02	4.91E-02	9.90E-01	1.55E-03	1.05E+00	5.13E-02	7.15E-02	5.46E-02	2.21E-01	1.74E-01	2.49E+00
Selenium	0.75	2.82E-01	1.26E+00	8.96E+00	1.02E-01	8.06E+00	5.85E+00	1.18E+02	1.85E-01	6.73E+01	3.29E+00	4.59E+00	3.50E+00	1.42E+01	1.12E+01	1.60E+02
Uranium	6.51	9.55E-03	4.25E-02	3.03E-01	3.44E-03	2.73E-01	1.98E-01	3.99E+00	6.26E-03	4.52E+01	2.21E+00	3.08E+00	2.35E+00	9.53E+00	7.49E+00	1.07E+02
Vanadium	12.51	4.71E-01	2.10E+00	1.49E+01	1.70E-01	1.34E+01	9.76E+00	1.97E+02	3.09E-01	7.17E+01	3.51E+00	4.89E+00	3.73E+00	1.51E+01	1.19E+01	1.70E+02
Zinc	0.75	4.52E-01	2.01E+00	1.43E+01	1.63E-01	1.29E+01	9.36E+00	1.88E+02	2.96E-01	3.26E+00	1.59E-01	2.22E-01	1.70E-01	6.88E-01	5.41E-01	7.74E+00
Radionuclides																
Lead-210	24.2	6.38E-02	2.84E-01	2.02E+00	2.30E-02	1.82E+00	1.32E+00	2.66E+01	4.18E-02	1.12E+01	5.47E-01	7.63E-01	5.83E-01	2.36E+00	1.86E+00	2.66E+01
Polonium-210	0.91	1.71E-02	7.62E-02	5.44E-01	6.17E-03	4.89E-01	3.55E-01	7.15E+00	1.12E-02	2.02E+01	9.88E-01	1.38E+00	1.05E+00	4.26E+00	3.35E+00	4.80E+01
Radium-226	1.11	7.10E-03	3.16E-02	2.25E-01	2.56E-03	2.03E-01	1.47E-01	2.96E+00	4.66E-03	3.08E-01	1.51E-02	2.10E-02	1.60E-02	6.50E-02	5.11E-02	7.32E-01
Thorium-230	101	8.74E-02	3.89E-01	2.78E+00	3.15E-02	2.50E+00	1.81E+00	3.65E+01	5.73E-02	9.34E+00	4.57E-01	6.37E-01	4.86E-01	1.97E+00	1.55E+00	2.22E+01
Uranium-234	6.51	9.55E-03	4.25E-02	3.03E-01	3.44E-03	2.73E-01	1.98E-01	3.99E+00	6.26E-03	4.52E+01	2.21E+00	3.08E+00	2.35E+00	9.53E+00	7.49E+00	1.07E+02
Uranium-238	6.51	9.55E-03	4.25E-02	3.03E-01	3.44E-03	2.73E-01	1.98E-01	3.99E+00	6.26E-03	4.52E+01	2.21E+00	3.08E+00	2.35E+00	9.53E+00	7.49E+00	1.07E+02

Notes

a. N288.1 Table G.8

b. For elements that are not listed in Table G.8, a surrogate element was used as follows (surrogate in parentheses): Cd (Zn); Cu (Ag); Po (Te), V (Nb).

3.7.6 Dose Coefficients for Terrestrial Animals, Birds, and Humans

Dose coefficients for all internal and external exposure routes to terrestrial animals and birds are presented in Table 3-18 and Table 3-19, respectively. The DCFs for terrestrial animals and birds follow the approach of the ICRP (2008). Progeny with half lives shorter than 10 days are included in each DCF.

Table 3-18: Internal Dose coefficients for Terrestrial Animals and Birds

COPC	DCF internal (μGy/hr)/(Bq/kg(fw animal))							
	Black Bear [a]	Canada Lynx [b]	Mink [b]	Moose [a]	Muskrat [b]	Snowshoe Hare [b]	Southern Red-backed Vole [b]	Woodland Caribou [a]
Lead-210	2.5E-04	2.4E-04	2.4E-04	2.5E-04	2.4E-04	2.4E-04	2.4E-04	2.5E-04
Polonium-210	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02
Radium-226	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01
Thorium-230	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02
Uranium-234	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02
Uranium-238	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02
COPC	American Robin [c]	Bald Eagle [c]	Canada Goose [c]	Common Loon [c]	Lesser Scaup [c]	Mallard [c]	Olive-Sided Flycatcher [c]	
Lead-210	2.5E-04	2.5E-04	2.5E-04	2.5E-04	2.5E-04	2.5E-04	2.5E-04	
Polonium-210	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02	
Radium-226	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	
Thorium-230	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02	2.7E-02	
Uranium-234	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	2.8E-02	
Uranium-238	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.4E-02	

a. DCFs are based on deer (ICRP 2008).
b. DCFs are based on rat (ICRP 2008).
c. DCFs are based on duck (ICRP 2008).
COPC = constituent of potential concern; DCF = dose coefficient.

Table 3-19: External Dose Coefficients for Terrestrial Animals and Birds

COPC	DCF external (μGy/hr)/(Bq/m^2)							
	Black Bear [a]	Canada Lynx [b]	Mink [b]	Moose [a]	Muskrat [b]	Snowshoe Hare [b]	Southern Red-backed Vole [b]	Woodland Caribou [a]
Lead-210	2.3E-09	6.3E-09	6.3E-09	2.3E-09	6.3E-09	6.3E-09	6.3E-09	2.3E-09
Polonium-210	1.4E-11	2.8E-11	2.8E-11	1.4E-11	2.8E-11	2.8E-11	2.8E-11	1.4E-11
Radium-226	2.8E-06	5.4E-06	5.4E-06	2.8E-06	5.4E-06	5.4E-06	5.4E-06	2.8E-06
Thorium-230	5.4E-10	1.3E-09	1.3E-09	5.4E-10	1.3E-09	1.3E-09	1.3E-09	5.4E-10
Uranium-234	2.8E-10	7.5E-10	7.5E-10	2.8E-10	7.5E-10	7.5E-10	7.5E-10	2.8E-10
Uranium-238	1.5E-10	4.1E-10	4.1E-10	1.5E-10	4.1E-10	4.1E-10	4.1E-10	1.5E-10

COPC	American Robin [c]	Bald Eagle [c]	Canada Goose [c]	Common Loon [c]	Lesser Scaup [c]	Mallard [c]	Olive-Sided Flycatcher [c]	
Lead-210	5.8E-09	5.8E-09	5.8E-09	5.8E-09	5.8E-09	5.8E-09	5.8E-09	
Polonium-210	2.6E-11	2.6E-11	2.6E-11	2.6E-11	2.6E-11	2.6E-11	2.6E-11	
Radium-226	5.0E-06	5.0E-06	5.0E-06	5.0E-06	5.0E-06	5.0E-06	5.0E-06	
Thorium-230	1.3E-09	1.3E-09	1.3E-09	1.3E-09	1.3E-09	1.3E-09	1.3E-09	
Uranium-234	7.1E-10	7.1E-10	7.1E-10	7.1E-10	7.1E-10	7.1E-10	7.1E-10	
Uranium-238	3.9E-10	3.9E-10	3.9E-10	3.9E-10	3.9E-10	3.9E-10	3.9E-10	

a. DCFs are based on deer (ICRP 2008).
b. DCFs are based on rat (ICRP 2008).
c. DCFs are based on duck (ICRP 2008).
COPC = constituent of potential concern; DCF = dose coefficient.

Dose coefficients for all internal and external exposure routes for humans are presented in Table 3-20. The DCFs for ingestion and inhalation by human receptors were taken from CSA N288.1-20 and are progeny inclusive.

The external DCFs used in this IMPACT model update were derived based on the methodology described in CSA N288.1-20. Uranium-238 progeny associated with each of the radionuclides, as required, were included in the external DCFs as follows:

- uranium-238 with its progeny thorium-234 and protactinium-234m;
- uranium-234 was modelled explicitly and no progeny were included in the external DCF;
- thorium-230 was modelled explicitly and no progeny were included in the external DCF;
- radium-226 with its progeny radon-222 (except for air immersion), polonium-218, lead-214, bismuth-214, and polonium-214;
- lead-210 with its progeny bismuth-210; and
- radon-222 (air immersion only) with its progeny polonium-218, lead-214, and bismuth-214.

The achievement of transient or secular equilibrium by ingrowth of progeny takes time. Therefore, the available time for ingrowth in each exposure medium must be considered in deciding whether it is reasonable to assume equilibrium. The timeframes for ingrowth of the progeny assumed for each of the external pathways were two hours for air immersion, one day for water immersion, and 40 years for exposure to soils and sediment. Details for the calculation of the external DCFs are described in CSA N288.1-20.

Table 3-20: Human Dose Coefficients for Internal and External Exposure

COPC	Ingestion DCF (Sv/Bq)	Inhalation DCF (Sv/Bq)	External Soil DCF (Sv/yr)/ (Bq/m^2)	External Water Immersion DCF (Sv/yr)/ (Bq/L)	External Sediment DCF (Sv/yr)/ (Bq/kg)	External Air Immersion DCF (Sv/yr)/ (Bq/m^3)
Adult						
Lead-210	6.9E-07	1.1E-06	1.2E-09	4.5E-09	1.8E-09	1.4E-09
Polonium-210	1.2E-06	3.3E-06	2.6E-13	2.7E-11	7.4E-12	1.2E-11
Radium-226	2.8E-07	3.5E-06	5.3E-08	9.2E-07	1.5E-06	9.0E-09
Thorium-230	2.1E-07	1.4E-05	2.4E-11	1.1E-09	2.3E-10	4.7E-10
Uranium-234	4.9E-08	3.5E-06	1.9E-11	4.4E-10	7.8E-11	1.9E-10
Uranium-238	4.5E-08	2.9E-06	3.7E-09	2.5E-09	2.2E-08	7.9E-11
1-year old						
Lead-210	3.6E-06	3.7E-06	1.5E-09	4.8E-09	2.3E-09	1.8E-09
Polonium-210	8.8E-06	1.1E-05	3.3E-13	3.5E-11	9.6E-12	1.6E-11
Radium-226	9.6E-07	1.1E-05	6.9E-08	1.2E-06	2.0E-06	1.2E-08
Thorium-230	4.1E-07	3.5E-05	2.6E-11	1.4E-09	3.0E-10	6.1E-10
Uranium-234	1.3E-07	1.1E-05	2.4E-11	5.7E-10	1.0E-10	2.5E-10
Uranium-238	1.2E-07	9.4E-06	4.8E-09	3.3E-09	2.8E-08	1.0E-10

COPC = constituent of potential concern; DCF = dose coefficient; Sv/yr = sieverts per year; Bq = becquerel.

4.0 References

Arnold TW, Fritzell EK. 1987. Food habits of prairie mink during the waterfowl breeding season. Canadian Journal of Zoology. 65, 2322–2324.

Barnett, C.L., Beresford, N.A., Walker, L.A. et al. Transfer parameters for ICRP reference animals and plants collected from a forest ecosystem. Radiat Environ Biophys 53, 125–149 (2014).

Beresford NA, Barnett CL, Howard BJ, Scott WA, Brown JE, Copplestone D. 2008. Derivation of transfer parameters for use within the ERICA Tool and the default concentration ratios for terrestrial biota. Journal of Environmental Radioactivity. 99 1393-1407.

Beyer WN, Connor E, Gerould S. 1994. Estimates of Soil Ingestion by Wildlife. Journal of Wildlife Management 58.

Brown JE, Alfonso B, Avila R, Beresford NA, Copplestone D, Prohl G, Ulanovsky A. 2008. The ERICA Tool. Journal of Environmental Radioactivity. 99 1393-1407 99, 1371–1383. September.

Cameco, 2004. Cigar Lake Project: Construction, Operation, and Decommissioning Environmental Assessment Study Report

CANDU Owners Group (COG), 2019. Derived Release Limits Guidance. COG-06-3090R4-I.

CanNorth (Canada North Environmental Services), 2000. Hatchet Lake Dietary Survey. Report Prepared for: Atomic Energy Control Board, Ottawa ON. March 2000

CanNorth (Canada North Environmental Services), 2017. English River First Nation Country Foods Study. Report Prepared for: English River First Nation, Patuanak, Saskatchewan. September 2017

Chapman PM, Allen HE, Z'Graggen MN. 1996. Evaluation of bioaccumulation factors in regulating metals. Environmental Science and Technology. 30, 448A-452A.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada.). 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus* caribou in Canada.

CSA Group (Canadian Standards Association Group). 2022. CSA N288.6-22: Environmental Risk Assessments at Nuclear Facilities and Uranium Mines and Mills.

CSA Group. 2020. CSA N288.1-20: Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne or Liquid Effluents for Normal Operation of Nuclear Facilities.

Ecometrix (Ecometrix Incorporated), 2005. Key Lake Project: Environmental Risk Assessment 2005. Report Prepared for Cameco Corporation.

Ecometrix (Ecometrix Incorporated), 2012. Key Lake IMPACT model 2011 Update. Report prepared for Cameco Corporation.

Ecometrix (Ecometrix Incorporated), 2013a. Key Lake Extension Project - Ecological and Human Health Risk Assessment. Report prepared for Cameco Corporation. In: Cameco. 2013. Key Lake Extension Project Environmental Impact Statement, Annex VII.

Ecometrix (Ecometrix Incorporated), 2013b. Millennium Project - Ecological and Human Health Risk Assessment. Report prepared for Cameco Corporation. In: Cameco. 2013. Millennium Project Environmental Impact Statement, Annex J.

Ecometrix (Ecometrix Incorporated), 2013c. Millennium IMPACT Model 2012. Report prepared for Cameco Corporation. In: Cameco. 2013. Millennium Project Environmental Impact Statement, Annex K.

Ecometrix (Ecometrix Incorporated), 2013d. McArthur River – IMPACT Model 2013 Update. Report prepared for Cameco Corporation. December 2013.

Ecometrix (Ecometrix Incorporated), 2020a. Wheeler River Project: Baseline Aquatic Environment Study. Report prepared for Denison Mines Corporation.

Ecometrix (Ecometrix Incorporated), 2020b. Wheeler River Project: Baseline Hydrology Summary Report. Report prepared for Denison Mines Corporation.

Environment Canada, 2015. Recovery Strategy for Olive-sided Flycatcher (*Contopus cooperi*) in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. vi + 51 pp.

FCSAP (Federal Contaminated Sites Action Plan), 2012. Ecological Risk Assessment Guidance, Module 3: Standardization of Wildlife Receptor Characteristics. Prepared for: Environment Canada (Government of Canada), Vancouver, BC. March.

Franzmann AW. 1981. *Alces alces*. Mammalian Species. 154:1–7. May.

Hamilton SJ, Mehrle PM. 1986. Metallothionein in fish: review of its importance in assessing stress from metal contaminants. Transactions of the American Fisheries Society 115, 596–609.

Hart D. 2019. Derived Release Limits. Report No. COG-06-3090-R4-I.

Health Canada, 2000. Food and Nutrition. Dietary Intakes of Contaminants and other Chemicals for Different Age-sex Groups of Canadians (1993 to 1999).

Health Canada, 2010a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. Contaminated Sites Program. September.

Health Canada, 2010b. Federal Contaminated Site Risk Assessment in Canada. Part VI: Guidance on Human Health Detailed Quantitative Radiological Risk Assessment (DQRARAD). September.

Health Canada, 2011. Food and Nutrition. Dietary Intakes of Contaminants and other Chemicals for Different Age-sex Groups of Canadians (2000 to 2011).

Health Canada, 2018. Guidance for Evaluating Human Health Impacts in Environmental Assessment: Country Foods. Report No. H129- 54/5-2018. May.

Health Canada, 2020. Canadian Total Diet Study - Trace Elements 1993-2018. Available at **https://open.canada.ca/data/en/dataset/83934503-cfae-4773-b258-e336896c2c53**

Hinterland Who's Who, 2007. Profile on the Black Bear. Available at **http://www.hww.ca/en/wildlife/mammals/black-bear.html**

IAEA (International Atomic Energy Agency), 2010. Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments. Technical Report Series No. 472.

IEC (Independent Environmental Consultants), 2024. Atmospheric Environment: Air Quality Impact Assessment, Denison Mines Corp. – Wheeler River Project. Report prepared for Denison Mines Corporation. January.

ICRP (International Commission on Radiological Protection), 2008. Environmental Protection - the Concept and Use of Reference Animals and Plants. ICRP Publication 108.

Livingston, S.A., C.S. Todd, W.B. Krohn and R.B. Owen, Jr. 1990. Habitat models for nesting bald eagles in Maine. J. Wildl. Manage. 54(4):644-653.

McLoughlin PD, Stewart K, Superbie C, Perry T, Tomchuk P, Greuel R, Singh K, Truchon-Savard A, Henkelman J, Johnstone JF (Department of Biology, University of Saskatchewan). 2016. Population dynamics and critical habitat of woodland caribou in the Saskatchewan Boreal Shield. Interim Project Report, 2013-2016.

McLoughlin PD, Superbie CM, Stewart K, Tomchuk P, Neufeld B, Barks D, Perry T, Greuel R, Regan C, Truchon-Savard A, Hart S, Henkelman J, Johnstone JF (Department of Biology, University of Saskatchewan). 2019. Population and habitat ecology of boreal caribou and their predators in the Saskatchewan Boreal Shield. Final Report.

NCRP (National Council on Radiation Protection and Measurements). 1996. Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground - Vol. I and Vol. II. Report No. 123.

NewFields (NewFields Canada Mining & Environment), 2021. Hydrological Effects Assessment Report for Denison Mines Wheeler River Project. Report prepared for Ecometrix Incorporated. July 2021.

Newman MC, Unger MA. 2002. Fundamentals of Ecotoxicology, 2nd ed. CRC/Lewis Press, Boca Raton, FL.

Omnia (Omnia Ecological Services), 2020. Denison Mines Corporation Wheeler River Project - Terrestrial Environment Wildlife and Vegetation Baseline Inventory.

Richardson GM. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates.

Sample BE, Beauchamp JJ, Efroymson RA, Suter GW, Ashwood TL. 1998. Development and Validation of Bioaccumulation Models for Earthworms. Report No. ES/ER/TM-220.

Sheppard, S.C., Long, J. and Sanipelli, B. 2009. Field measurements of the transfer factors for iodine and other trace elements. NWMO TR-2009-35

Species at Risk Act. SC. 2002, c 29. Last amended 12 August 2021. Available at: **https://laws-lois.justice.gc.ca/eng/acts/s-15.3/**

Thomann RV, Mueller JA. 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row, Publishers, New York.

Thompson, S.E., C.A. Burton, D.J. Quinn and Y.C. Ng. 1972. Concentration factors of chemical elements in edible aquatic organisms. Lawrence Livermore Laboratory, University of California. Rep. UCRL-50564 Rev. 1.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). 2000. Volume 1, Annex B: Exposures from Natural Radiation Sources and Effects of Ionizing Radiation, Report to the General Assembly with Scientific Annexes.

US EPA (United States Environmental Protection Agency). 1986. Standard for Radon-222 Emissions from Licensed Uranium Mill Tailings. Report No. EPA 520/1-86-009.

US EPA. 1993. Wildlife Exposure Factors Handbook. Report No. EPA/600/R-93/187.

US EPA. 2007. Attachment 4-1 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLsd

U.S. FWS (Fish and Wildlife Service), 2002. **https://www.fws.gov/r5gomp/gom/habitatstudy/metadata/bald_eagle_model.htm**

U.S. FWS (Fish and Wildlife Service), 2017. Species Status Assessment for the Canada Lynx (Lynx canadensis), Contiguous United States Distinct Population Segment. Version 1.0 - Final, October 2017.

Wilson D, Ruff S. 1999. The Smithsonian Book of North American Mammals. Smithsonian Institution Press, Washington.

Wood CM, Port P. 2000. Intracellular pH regulation and buffer capacity in CO_2/HCO_3-buffered media in cultured epithelial cells from rainbow trout gills. Journal of Comparative Physiology. 170, 175–184.

Appendix B Model Results in Support of the ERA

Table B.1: Maximum Concentration of Non-radionuclides in Environmental Media during Project Phases

Environmental Media	Location	Maximum Concentration of Non-radionuclides during Project Phases											
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Water (mg/L)	Kratchkowsky Lake	1.19E-04	2.38E-05	3.22E-01	1.01E-04	5.30E-04	6.22E-04	1.07E-04	6.87E-01	3.35E-05	3.12E-05	1.67E-04	7.00E-04
	Whitefish Lake North	1.10E-04	2.34E-05	3.22E-01	1.01E-04	5.24E-04	6.20E-04	1.07E-04	6.87E-01	3.28E-05	3.05E-05	1.55E-04	6.89E-04
	Whitefish Lake Middle	1.46E-04	3.97E-05	6.14E+00	1.29E-04	7.46E-04	8.22E-04	2.43E-02	3.87E+01	4.33E-04	5.74E-04	6.70E-04	1.06E-03
	Whitefish Lake South	1.49E-04	3.86E-05	6.11E+00	1.28E-04	7.30E-04	8.17E-04	2.40E-02	3.85E+01	4.12E-04	5.47E-04	5.64E-04	1.03E-03
	McGowan Lake	1.26E-04	3.28E-05	4.20E+00	1.19E-04	6.54E-04	7.50E-04	1.58E-02	2.60E+01	2.59E-04	3.38E-04	3.28E-04	9.01E-04
	Icelander River	1.26E-04	3.26E-05	4.16E+00	1.19E-04	6.52E-04	7.49E-04	1.56E-02	2.57E+01	2.56E-04	3.34E-04	3.26E-04	8.99E-04
	Russell Lake Inlet	1.22E-04	3.01E-05	3.26E+00	1.14E-04	6.17E-04	7.17E-04	1.18E-02	1.99E+01	1.95E-04	2.52E-04	2.69E-04	8.40E-04
Sediment (mg/kg dw)	Kratchkowsky Lake	8.35E+00	3.38E-01	-	2.52E-01	5.86E+00	1.85E+00	3.37E-01	-	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake North	8.35E+00	3.38E-01	-	2.52E-01	5.86E+00	1.85E+00	3.37E-01	-	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake Middle	1.10E+01	4.97E-01	-	3.05E-01	7.59E+00	2.31E+00	5.72E+01	-	5.48E+00	7.18E+00	3.72E+01	1.36E+01
	Whitefish Lake South	1.05E+01	4.90E-01	-	3.04E-01	7.53E+00	2.30E+00	5.62E+01	-	5.26E+00	6.87E+00	3.33E+01	1.35E+01
	McGowan Lake	9.47E+00	4.43E-01	-	2.90E-01	7.03E+00	2.18E+00	4.11E+01	-	3.71E+00	4.78E+00	2.22E+01	1.24E+01
	Russell Lake Inlet	9.04E+00	4.15E-01	-	2.81E-01	6.73E+00	2.10E+00	3.13E+01	-	2.88E+00	3.64E+00	1.82E+01	1.17E+01
Air (mg/m^3)	Kratchkowsky Lake	7.00E-07	7.44E-08	-	7.07E-07	1.49E-07	6.30E-05	7.19E-07	-	1.54E-07	6.00E-07	1.43E-06	2.16E-04
	Whitefish Lake South	7.05E-07	7.58E-08	-	7.14E-07	1.68E-07	6.33E-05	7.25E-07	-	1.57E-07	1.77E-05	1.46E-06	2.16E-04
	Whitefish Lake Middle	7.12E-07	7.75E-08	-	7.22E-07	1.93E-07	6.38E-05	7.34E-07	-	1.61E-07	3.45E-05	1.51E-06	2.16E-04
	McGowan Lake	7.01E-07	7.47E-08	-	7.08E-07	1.54E-07	6.31E-05	7.20E-07	-	1.55E-07	5.05E-06	1.43E-06	2.16E-04
	Russell Lake Inlet	7.00E-07	7.45E-08	-	7.07E-07	1.50E-07	6.30E-05	7.19E-07	-	1.54E-07	1.79E-06	1.43E-06	2.16E-04
Soil (mg/kg dw)	Kratchkowsky Lake	6.16E-01	3.61E-01	-	2.65E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	3.82E-01	4.81E+00	5.31E+00
	Whitefish Lake South	6.16E-01	3.61E-01	-	2.66E-01	3.31E+00	1.48E+00	1.15E-01	-	1.07E-01	1.68E+00	4.82E+00	5.32E+00
	Whitefish Lake Middle	6.16E-01	3.61E-01	-	2.67E-01	3.31E+00	1.51E+00	1.15E-01	-	1.08E-01	2.89E+00	4.82E+00	5.33E+00
	McGowan Lake	6.16E-01	3.61E-01	-	2.65E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	7.12E-01	4.81E+00	5.31E+00
	Russell Lake Inlet	6.16E-01	3.61E-01	-	2.65E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	4.70E-01	4.81E+00	5.31E+00

Table B.2: Maximum Concentration of Non-radionuclides in Environmental Media during Future Centuries

Environmental Media	Location	Maximum Concentration of Non-radionuclides during Future Centuries											
		Arsenic	Cadmium	Chloride	Cobalt	Chromium	Copper	Molybdenum	Sulphate	Selenium	Uranium	Vanadium	Zinc
Water (mg/L)	Kratchkowsky Lake	1.03E-04	2.32E-05	3.22E-01	1.01E-04	5.19E-04	6.18E-04	1.07E-04	6.87E-01	3.23E-05	3.01E-05	1.46E-04	6.81E-04
	Whitefish Lake North	1.03E-04	2.32E-05	3.22E-01	1.01E-04	5.19E-04	6.18E-04	1.07E-04	6.87E-01	3.23E-05	3.01E-05	1.46E-04	6.81E-04
	Whitefish Lake Middle	1.07E-04	2.33E-05	4.15E-01	1.06E-04	5.26E-04	6.26E-04	1.16E-04	7.21E-01	4.30E-05	3.68E-05	1.47E-04	7.40E-04
	Whitefish Lake South	1.07E-04	2.33E-05	4.14E-01	1.06E-04	5.26E-04	6.26E-04	1.16E-04	7.20E-01	4.26E-05	3.65E-05	1.47E-04	7.37E-04
	McGowan Lake	1.05E-04	2.33E-05	3.93E-01	1.05E-04	5.24E-04	6.24E-04	1.14E-04	7.13E-01	3.94E-05	3.45E-05	1.46E-04	7.21E-04
	Icelander River	1.05E-04	2.33E-05	3.92E-01	1.05E-04	5.24E-04	6.24E-04	1.14E-04	7.13E-01	3.94E-05	3.45E-05	1.46E-04	7.21E-04
	Russell Lake Inlet	1.04E-04	2.32E-05	3.76E-01	1.04E-04	5.23E-04	6.23E-04	1.12E-04	7.07E-01	3.76E-05	3.33E-05	1.46E-04	7.11E-04
Sediment (mg/kg dw)	Kratchkowsky Lake	8.35E+00	3.38E-01	-	2.52E-01	5.86E+00	1.85E+00	3.37E-01	-	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake North	8.35E+00	3.38E-01	-	2.52E-01	5.86E+00	1.85E+00	3.37E-01	-	6.22E-01	5.78E-01	1.12E+01	9.93E+00
	Whitefish Lake Middle	8.66E+00	3.40E-01	-	2.65E-01	5.94E+00	1.87E+00	3.68E-01	-	8.28E-01	7.07E-01	1.13E+01	1.08E+01
	Whitefish Lake South	8.62E+00	3.40E-01	-	2.65E-01	5.93E+00	1.87E+00	3.67E-01	-	8.19E-01	7.02E-01	1.13E+01	1.08E+01
	McGowan Lake	8.48E+00	3.39E-01	-	2.62E-01	5.91E+00	1.87E+00	3.60E-01	-	7.59E-01	6.64E-01	1.13E+01	1.05E+01
	Russell Lake Inlet	8.43E+00	3.39E-01	-	2.59E-01	5.90E+00	1.86E+00	3.55E-01	-	7.22E-01	6.41E-01	1.12E+01	1.04E+01
Air (mg/m^3)	Kratchkowsky Lake	7.00E-07	7.44E-08	-	7.07E-07	1.49E-07	6.30E-05	7.19E-07	-	1.54E-07	6.00E-07	1.43E-06	2.16E-04
	Whitefish Lake South	7.00E-07	7.44E-08	-	7.07E-07	1.49E-07	6.30E-05	7.19E-07	-	1.54E-07	6.00E-07	1.43E-06	2.16E-04
	Whitefish Lake Middle	7.00E-07	7.44E-08	-	7.07E-07	1.49E-07	6.30E-05	7.19E-07	-	1.54E-07	6.00E-07	1.43E-06	2.16E-04
	McGowan Lake	7.00E-07	7.44E-08	-	7.07E-07	1.49E-07	6.30E-05	7.19E-07	-	1.54E-07	6.00E-07	1.43E-06	2.16E-04
	Russell Lake Inlet	7.00E-07	7.44E-08	-	7.07E-07	1.49E-07	6.30E-05	7.19E-07	-	1.54E-07	6.00E-07	1.43E-06	2.16E-04
Soil (mg/kg dw)	Kratchkowsky Lake	6.16E-01	3.61E-01	-	2.65E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	3.82E-01	4.81E+00	5.31E+00
	Whitefish Lake South	6.16E-01	3.61E-01	-	2.66E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	4.55E-01	4.81E+00	5.31E+00
	Whitefish Lake Middle	6.16E-01	3.61E-01	-	2.66E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	5.25E-01	4.81E+00	5.31E+00
	McGowan Lake	6.16E-01	3.61E-01	-	2.65E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	4.01E-01	4.81E+00	5.31E+00
	Russell Lake Inlet	6.16E-01	3.61E-01	-	2.65E-01	3.31E+00	1.46E+00	1.15E-01	-	1.07E-01	3.87E-01	4.81E+00	5.31E+00

Table B.3: Maximum Concentration of Radionuclides in Environmental Media during Project Phases

Environmental Media	Location	Maximum Concentration of Radionuclides during Project Phases						
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Radon-222	Lead-210	Polonium-210
Water (Bq/L)	Kratchkowsky Lake	3.85E-04	3.85E-04	1.01E-02	5.70E-03	-	6.22E-03	6.33E-03
	Whitefish Lake North	3.77E-04	3.77E-04	1.01E-02	5.63E-03	-	5.68E-03	5.78E-03
	Whitefish Lake Middle	7.05E-03	7.05E-03	1.87E-02	6.87E-03	-	8.36E-03	6.71E-03
	Whitefish Lake South	6.72E-03	6.72E-03	1.85E-02	6.73E-03	-	8.25E-03	7.22E-03
	McGowan Lake	4.15E-03	4.15E-03	1.57E-02	6.33E-03	-	6.68E-03	6.23E-03
	Icelander River	4.11E-03	4.11E-03	1.56E-02	6.32E-03	-	6.66E-03	6.20E-03
	Russell Lake Inlet	3.09E-03	3.09E-03	1.43E-02	6.14E-03	-	6.41E-03	6.16E-03
Sediment (Bq/kg dw)	Kratchkowsky Lake	7.14E+00	7.14E+00	2.32E+01	6.51E+01	-	3.74E+02	3.80E+02
	Whitefish Lake North	7.14E+00	7.14E+00	2.32E+01	6.51E+01	-	3.74E+02	3.80E+02
	Whitefish Lake Middle	8.82E+01	8.82E+01	3.83E+01	7.57E+01	-	5.57E+02	5.58E+02
	Whitefish Lake South	8.44E+01	8.44E+01	3.80E+01	7.52E+01	-	5.19E+02	5.22E+02
	McGowan Lake	5.87E+01	5.87E+01	3.41E+01	7.23E+01	-	4.42E+02	4.47E+02
	Russell Lake Inlet	4.48E+01	4.48E+01	3.15E+01	7.04E+01	-	4.14E+02	4.20E+02
Air (Bq/m^3)	Kratchkowsky Lake	7.41E-06	7.41E-06	-	-	0.00E+00	-	-
	Whitefish Lake South	2.19E-04	2.19E-04	-	-	1.24E+01	-	-
	Whitefish Lake Middle	4.26E-04	4.26E-04	-	-	3.61E+01	-	-
	McGowan Lake	6.23E-05	6.23E-05	-	-	2.50E+00	-	-
	Russell Lake Inlet	2.21E-05	2.21E-05	-	-	5.92E-01	-	-
Soil (Bq/kg dw)	Kratchkowsky Lake	4.72E+00	4.72E+00	2.00E+01	1.52E+01	-	7.29E+01	6.55E+01
	Whitefish Lake South	2.08E+01	2.08E+01	2.00E+01	1.52E+01	-	7.29E+01	6.55E+01
	Whitefish Lake Middle	3.57E+01	3.57E+01	2.00E+01	1.52E+01	-	7.29E+01	6.55E+01
	McGowan Lake	8.79E+00	8.79E+00	2.00E+01	1.52E+01	-	7.29E+01	6.55E+01
	Russell Lake Inlet	5.81E+00	5.81E+00	2.00E+01	1.52E+01	-	7.29E+01	6.55E+01

Table B.4: Maximum Concentration of Radionuclides in Environmental Media during Future Centuries

Environmental Media	Location	Maximum Concentration of Radionuclides during Future Centuries					
		Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Water (Bq/L)	Kratchkowsky Lake	3.71E-04	3.71E-04	1.01E-02	5.57E-03	5.27E-03	5.36E-03
	Whitefish Lake North	3.71E-04	3.71E-04	1.01E-02	5.57E-03	5.27E-03	5.36E-03
	Whitefish Lake Middle	4.54E-04	4.54E-04	1.04E-02	6.39E-03	6.05E-03	6.15E-03
	Whitefish Lake South	4.51E-04	4.51E-04	1.04E-02	6.37E-03	5.92E-03	6.02E-03
	McGowan Lake	4.26E-04	4.26E-04	1.03E-02	6.15E-03	5.57E-03	5.66E-03
	Icelander River	4.26E-04	4.26E-04	1.03E-02	6.14E-03	5.56E-03	5.64E-03
	Russell Lake Inlet	4.12E-04	4.12E-04	1.03E-02	6.00E-03	5.45E-03	5.53E-03
Sediment (Bq/kg dw)	Kratchkowsky Lake	7.14E+00	7.14E+00	2.32E+01	6.51E+01	3.74E+02	3.80E+02
	Whitefish Lake North	7.14E+00	7.14E+00	2.32E+01	6.51E+01	3.74E+02	3.80E+02
	Whitefish Lake Middle	8.74E+00	8.74E+00	2.38E+01	7.47E+01	4.29E+02	4.36E+02
	Whitefish Lake South	8.67E+00	8.67E+00	2.38E+01	7.44E+01	4.19E+02	4.27E+02
	McGowan Lake	8.20E+00	8.20E+00	2.36E+01	7.18E+01	3.95E+02	4.01E+02
	Russell Lake Inlet	7.92E+00	7.92E+00	2.35E+01	7.01E+01	3.86E+02	3.93E+02
Air (Bq/m^3)	Kratchkowsky Lake	7.41E-06	7.41E-06	-	-	-	-
	Whitefish Lake South	7.41E-06	7.41E-06	-	-	-	-
	Whitefish Lake Middle	7.41E-06	7.41E-06	-	-	-	-
	McGowan Lake	7.41E-06	7.41E-06	-	-	-	-
	Russell Lake Inlet	7.41E-06	7.41E-06	-	-	-	-
Soil (Bq/kg dw)	Kratchkowsky Lake	4.72E+00	4.72E+00	2.00E+01	1.52E+01	7.29E+01	6.55E+01
	Whitefish Lake South	5.63E+00	5.63E+00	2.00E+01	1.52E+01	7.29E+01	6.55E+01
	Whitefish Lake Middle	6.48E+00	6.48E+00	2.00E+01	1.52E+01	7.29E+01	6.55E+01
	McGowan Lake	4.95E+00	4.95E+00	2.00E+01	1.52E+01	7.29E+01	6.55E+01
	Russell Lake Inlet	4.78E+00	4.78E+00	2.00E+01	1.52E+01	7.29E+01	6.55E+01

Table B.5: Maximum Concentration of Non-radionuclides for Ecological Receptors during Project Phases

Biota		Location	Maximum Concentration of Non-radionuclides during Project Phases (mg/kg fw)									
			Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Aquatic Plants	Macrophytes	Reference (Kratchkowsky Lake)	2.05E-02	1.56E-03	1.60E-02	5.30E-03	1.35E-01	7.31E-04	5.95E-03	1.57E-03	5.43E-02	3.93E-01
		Whitefish Lake North	1.89E-02	1.53E-03	1.60E-02	5.24E-03	1.34E-01	7.28E-04	5.82E-03	1.54E-03	5.03E-02	3.87E-01
		Whitefish Lake Middle	2.52E-02	2.59E-03	2.03E-02	7.46E-03	1.78E-01	1.65E-01	7.68E-02	2.89E-02	2.18E-01	5.97E-01
		Whitefish Lake South	2.56E-02	2.52E-03	2.02E-02	7.30E-03	1.77E-01	1.63E-01	7.32E-02	2.76E-02	1.83E-01	5.81E-01
		McGowan Lake	2.17E-02	2.14E-03	1.88E-02	6.54E-03	1.63E-01	1.07E-01	4.59E-02	1.70E-02	1.07E-01	5.06E-01
		Russell Lake Inlet	2.10E-02	1.97E-03	1.81E-02	6.17E-03	1.56E-01	8.06E-02	3.47E-02	1.27E-02	8.73E-02	4.72E-01
	Phytoplankton	Reference (Kratchkowsky Lake)	2.05E-02	1.56E-03	1.60E-02	5.30E-03	1.35E-01	7.31E-04	5.95E-03	1.57E-03	5.43E-02	3.93E-01
		Whitefish Lake North	1.89E-02	1.53E-03	1.60E-02	5.24E-03	1.34E-01	7.28E-04	5.82E-03	1.54E-03	5.03E-02	3.87E-01
		Whitefish Lake Middle	2.52E-02	2.59E-03	2.03E-02	7.46E-03	1.78E-01	1.65E-01	7.68E-02	2.89E-02	2.18E-01	5.97E-01
		Whitefish Lake South	2.56E-02	2.52E-03	2.02E-02	7.30E-03	1.77E-01	1.63E-01	7.32E-02	2.76E-02	1.83E-01	5.81E-01
		McGowan Lake	2.17E-02	2.14E-03	1.88E-02	6.54E-03	1.63E-01	1.07E-01	4.59E-02	1.70E-02	1.07E-01	5.06E-01
		Russell Lake Inlet	2.10E-02	1.97E-03	1.81E-02	6.17E-03	1.56E-01	8.06E-02	3.47E-02	1.27E-02	8.73E-02	4.72E-01
Aquatic Animals	Benthic Invertebrate	Reference (Kratchkowsky Lake)	4.68E-02	5.84E-03	2.01E-02	1.98E-01	4.79E+00	1.72E-02	3.32E-02	2.89E-03	4.80E-02	2.84E+00
		Whitefish Lake North	4.67E-02	5.84E-03	2.01E-02	1.98E-01	4.79E+00	1.72E-02	3.32E-02	2.89E-03	4.80E-02	2.84E+00
		Whitefish Lake Middle	6.18E-02	8.59E-03	2.43E-02	2.56E-01	5.99E+00	2.91E+00	2.93E-01	3.59E-02	1.59E-01	3.90E+00
		Whitefish Lake South	5.91E-02	8.48E-03	2.42E-02	2.54E-01	5.96E+00	2.86E+00	2.81E-01	3.43E-02	1.43E-01	3.85E+00
		McGowan Lake	5.31E-02	7.66E-03	2.31E-02	2.37E-01	5.65E+00	2.10E+00	1.99E-01	2.39E-02	9.51E-02	3.54E+00
		Russell Lake Inlet	5.06E-02	7.18E-03	2.24E-02	2.27E-01	5.44E+00	1.59E+00	1.54E-01	1.82E-02	7.79E-02	3.35E+00
	Northern pike	Reference (Kratchkowsky Lake)	3.58E-02	7.15E-05	1.22E-03	2.92E-02	3.11E-01	1.07E-05	1.89E-01	6.24E-04	1.62E-02	1.40E+00
		Whitefish Lake North	3.30E-02	7.03E-05	1.21E-03	2.88E-02	3.10E-01	1.07E-05	1.86E-01	6.11E-04	1.50E-02	1.38E+00
		Whitefish Lake Middle	4.39E-02	1.19E-04	1.54E-03	4.10E-02	4.11E-01	2.43E-03	1.57E+00	1.15E-02	6.50E-02	2.13E+00
		Whitefish Lake South	4.47E-02	1.16E-04	1.54E-03	4.01E-02	4.08E-01	2.40E-03	1.51E+00	1.09E-02	5.47E-02	2.07E+00
		McGowan Lake	3.78E-02	9.83E-05	1.43E-03	3.60E-02	3.75E-01	1.58E-03	1.02E+00	6.76E-03	3.18E-02	1.80E+00
		Russell Lake Inlet	3.66E-02	9.04E-05	1.37E-03	3.40E-02	3.58E-01	1.18E-03	8.12E-01	5.03E-03	2.61E-02	1.68E+00
	White sucker	Reference (Kratchkowsky Lake)	3.33E-02	7.04E-05	1.21E-03	2.88E-02	3.10E-01	1.07E-05	1.46E-01	6.12E-04	1.51E-02	1.38E+00
		Whitefish Lake North	3.12E-02	6.96E-05	1.21E-03	2.86E-02	3.09E-01	1.07E-05	1.43E-01	6.02E-04	1.42E-02	1.36E+00
		Whitefish Lake Middle	4.15E-02	1.14E-04	1.52E-03	3.98E-02	4.04E-01	2.27E-03	1.74E+00	1.04E-02	5.86E-02	2.05E+00
		Whitefish Lake South	4.17E-02	1.11E-04	1.51E-03	3.90E-02	4.02E-01	2.24E-03	1.66E+00	9.91E-03	4.99E-02	2.00E+00
		McGowan Lake	3.57E-02	9.57E-05	1.42E-03	3.53E-02	3.72E-01	1.50E-03	1.06E+00	6.25E-03	2.97E-02	1.76E+00
		Russell Lake Inlet	3.45E-02	8.84E-05	1.37E-03	3.35E-02	3.56E-01	1.13E-03	8.06E-01	4.68E-03	2.44E-02	1.65E+00
	Zooplankton	Reference (Kratchkowsky Lake)	6.44E-02	6.19E-03	2.03E-02	2.07E-01	4.85E+00	1.74E-02	3.59E-02	3.12E-03	6.52E-02	3.01E+00
		Whitefish Lake North	5.94E-02	6.09E-03	2.02E-02	2.04E-01	4.83E+00	1.74E-02	3.51E-02	3.05E-03	6.03E-02	2.96E+00
		Whitefish Lake Middle	7.91E-02	1.03E-02	2.57E-02	2.91E-01	6.41E+00	3.94E+00	4.63E-01	5.74E-02	2.61E-01	4.57E+00
		Whitefish Lake South	8.04E-02	1.00E-02	2.56E-02	2.85E-01	6.37E+00	3.88E+00	4.41E-01	5.47E-02	2.20E-01	4.44E+00
		McGowan Lake	6.81E-02	8.52E-03	2.38E-02	2.55E-01	5.85E+00	2.55E+00	2.77E-01	3.38E-02	1.28E-01	3.87E+00
		Russell Lake Inlet	6.59E-02	7.83E-03	2.29E-02	2.41E-01	5.59E+00	1.92E+00	2.09E-01	2.52E-02	1.05E-01	3.61E+00
	Blueberries	Reference (Kratchkowsky Lake)	1.43E-01	8.53E-03	8.06E-02	1.42E-02	5.58E+00	6.60E-02	5.71E-02	3.43E-02	6.00E-03	1.35E+01
		Whitefish Lake	1.43E-01	8.56E-03	8.10E-02	1.43E-02	5.78E+00	6.64E-02	5.74E-02	2.85E-01	6.08E-03	1.35E+01
		McGowan Lake	1.43E-01	8.53E-03	8.07E-02	1.42E-02	5.60E+00	6.60E-02	5.71E-02	6.72E-02	6.01E-03	1.35E+01
		Russell Lake Inlet	1.43E-01	8.53E-03	8.06E-02	1.42E-02	5.58E+00	6.60E-02	5.71E-02	4.31E-02	6.00E-03	1.35E+01

Biota		Location	Maximum Concentration of Non-radionuclides during Project Phases (mg/kg fw)									
			Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Terrestrial Plants	Browse	Reference (Kratchkowsky Lake)	7.16E-02	5.83E-02	5.00E-02	9.48E-03	3.65E+00	4.26E-02	2.56E-02	2.93E-02	4.07E-02	1.03E+01
		Whitefish Lake	7.19E-02	5.84E-02	5.06E-02	1.07E-02	3.75E+00	4.31E-02	2.59E-02	1.04E+00	4.29E-02	1.04E+01
		McGowan Lake	7.16E-02	5.83E-02	5.01E-02	9.62E-03	3.66E+00	4.26E-02	2.57E-02	1.62E-01	4.09E-02	1.04E+01
		Russell Lake Inlet	7.16E-02	5.83E-02	5.01E-02	9.52E-03	3.65E+00	4.26E-02	2.56E-02	6.47E-02	4.08E-02	1.04E+01
	Labrador Tea	Reference (Kratchkowsky Lake)	2.34E-01	7.56E-02	2.14E-01	4.41E-02	1.83E+01	2.10E-01	6.14E-02	1.69E-01	3.72E-01	6.05E+01
		Whitefish Lake	2.37E-01	7.64E-02	2.18E-01	5.55E-02	1.86E+01	2.14E-01	6.33E-02	9.05E+00	3.93E-01	6.06E+01
		McGowan Lake	2.34E-01	7.57E-02	2.15E-01	4.54E-02	1.83E+01	2.10E-01	6.16E-02	1.33E+00	3.74E-01	6.05E+01
		Russell Lake Inlet	2.34E-01	7.56E-02	2.14E-01	4.44E-02	1.83E+01	2.10E-01	6.15E-02	4.80E-01	3.73E-01	6.05E+01
	Lichen	Reference (Kratchkowsky Lake)	1.09E-01	6.75E-02	1.14E-01	1.49E+00	1.30E+00	8.10E-02	9.14E-02	8.89E-02	6.56E-01	1.28E+01
		Whitefish Lake	1.27E-01	7.22E-02	1.37E-01	1.55E+00	2.43E+00	1.03E-01	1.02E-01	5.05E+01	7.76E-01	1.32E+01
		McGowan Lake	1.10E-01	6.80E-02	1.17E-01	1.49E+00	1.42E+00	8.22E-02	9.26E-02	6.71E+00	6.69E-01	1.28E+01
		Russell Lake Inlet	1.09E-01	6.77E-02	1.15E-01	1.49E+00	1.33E+00	8.12E-02	9.17E-02	1.86E+00	6.60E-01	1.28E+01
	Terrestrial Invertebrate	Reference (Kratchkowsky Lake)	4.25E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	1.97E-02	7.32E-02	8.78E+00
		Whitefish Lake	4.29E-02	7.60E-01	2.13E-02	1.78E-01	1.87E+00	5.02E-02	1.64E-01	9.66E-01	7.55E-02	8.80E+00
		McGowan Lake	4.26E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	1.44E-01	7.35E-02	8.78E+00
		Russell Lake Inlet	4.25E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	5.29E-02	7.33E-02	8.78E+00
	Black Bear	Reference (Kratchkowsky Lake)	6.26E-02	1.63E-03	6.84E-04	1.79E-02	1.06E+00	1.26E-03	2.60E-01	3.00E-04	1.87E-02	4.19E+01
		Whitefish Lake	6.27E-02	1.63E-03	6.84E-04	1.82E-02	1.06E+00	1.48E-03	6.37E-01	5.10E-04	1.94E-02	4.22E+01
	Lynx	Reference (Kratchkowsky Lake)	7.55E-02	3.40E-03	5.69E-05	1.68E-02	7.93E-01	1.29E-04	6.74E-01	5.33E-05	2.40E-02	5.35E+02
		Whitefish Lake	7.57E-02	3.41E-03	5.75E-05	1.71E-02	8.16E-01	5.69E-04	6.81E-01	5.95E-04	2.44E-02	5.37E+02
		McGowan Lake	7.55E-02	3.40E-03	5.71E-05	1.69E-02	7.95E-01	4.14E-04	6.75E-01	1.26E-04	2.40E-02	5.35E+02
		Russell Lake Inlet	7.55E-02	3.40E-03	5.70E-05	1.69E-02	7.94E-01	3.42E-04	6.75E-01	7.35E-05	2.40E-02	5.35E+02
	Mink	Reference (Kratchkowsky Lake)	2.55E-02	5.45E-04	5.43E-05	1.83E-02	1.78E-01	7.82E-05	1.75E-01	3.34E-05	1.69E-02	6.18E+00
		Whitefish Lake	3.25E-02	6.64E-04	6.27E-05	2.24E-02	2.23E-01	1.06E-02	1.54E+00	3.13E-04	4.15E-02	9.00E+00
		McGowan Lake	2.82E-02	6.22E-04	6.02E-05	2.10E-02	2.10E-01	7.58E-03	1.00E+00	1.41E-04	2.66E-02	7.83E+00
		Russell Lake Inlet	2.71E-02	6.01E-04	5.88E-05	2.03E-02	2.02E-01	5.76E-03	7.86E-01	1.04E-04	2.30E-02	7.35E+00
	Moose	Reference (Kratchkowsky Lake)	7.41E-02	1.45E-02	9.87E-04	1.44E-02	1.53E+00	1.81E-03	1.17E-01	5.16E-04	3.64E-02	6.93E+01
		Whitefish Lake	7.79E-02	1.47E-02	1.02E-03	1.61E-02	1.57E+00	7.15E-03	2.17E-01	1.72E-02	6.68E-02	6.98E+01
		McGowan Lake	7.55E-02	1.46E-02	1.00E-03	1.53E-02	1.53E+00	5.46E-03	1.75E-01	2.81E-03	4.74E-02	6.96E+01
		Russell Lake Inlet	7.49E-02	1.46E-02	9.97E-04	1.50E-02	1.53E+00	4.57E-03	1.59E-01	1.19E-03	4.34E-02	6.95E+01
	Moose Organs	Reference (Kratchkowsky Lake)	6.30E-01	5.01E-03	2.29E-01	6.56E-03	6.11E+01	1.81E-01	1.17E-01	9.13E-04	3.62E-05	8.67E-01
		McGowan Lake	6.42E-01	5.03E-03	2.33E-01	6.94E-03	6.14E+01	5.46E-01	1.75E-01	4.96E-03	4.73E-05	8.70E-01
		Russell Lake Inlet	6.37E-01	5.03E-03	2.32E-01	6.84E-03	6.12E+01	4.57E-01	1.59E-01	2.10E-03	4.32E-05	8.69E-01
	Muskrat	Reference (Kratchkowsky Lake)	6.44E-02	8.86E-04	2.43E-04	2.19E-02	4.69E-02	1.29E-04	3.74E-02	8.91E-05	5.12E-02	2.41E+00
		Whitefish Lake	8.40E-02	1.35E-03	3.06E-04	2.85E-02	6.15E-02	2.31E-02	4.03E-01	1.21E-03	1.80E-01	3.58E+00
		McGowan Lake	7.21E-02	1.18E-03	2.84E-04	2.63E-02	5.63E-02	1.62E-02	2.54E-01	7.77E-04	1.01E-01	3.07E+00
		Russell Lake Inlet	6.91E-02	1.10E-03	2.74E-04	2.51E-02	5.39E-02	1.23E-02	1.94E-01	5.90E-04	8.25E-02	2.88E+00

Biota		Location	Maximum Concentration of Non-radionuclides during Project Phases (mg/kg fw)									
			Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Terrestrial Animals	Snowshoe Hare	Reference (Kratchkowsky Lake)	6.22E-02	1.21E-02	8.82E-04	1.58E-02	1.43E+00	1.70E-03	1.10E-01	4.79E-04	2.92E-02	6.34E+01
		Whitefish Lake	6.24E-02	1.22E-02	8.91E-04	1.63E-02	1.47E+00	2.04E-03	1.12E-01	1.43E-02	3.00E-02	6.36E+01
		McGowan Lake	6.22E-02	1.21E-02	8.83E-04	1.58E-02	1.43E+00	1.91E-03	1.10E-01	2.29E-03	2.93E-02	6.34E+01
		Russell Lake Inlet	6.22E-02	1.21E-02	8.82E-04	1.58E-02	1.43E+00	1.86E-03	1.10E-01	9.63E-04	2.92E-02	6.34E+01
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	3.68E-01	2.69E-02	4.74E-03	2.80E-02	7.71E+00	9.11E-03	7.15E-01	2.05E-03	4.01E-02	3.14E+02
		Whitefish Lake	3.69E-01	2.69E-02	4.77E-03	2.89E-02	7.96E+00	9.35E-03	7.20E-01	3.69E-02	4.16E-02	3.15E+02
		McGowan Lake	3.68E-01	2.69E-02	4.74E-03	2.81E-02	7.74E+00	9.22E-03	7.16E-01	6.63E-03	4.03E-02	3.14E+02
		Russell Lake Inlet	3.68E-01	2.69E-02	4.74E-03	2.80E-02	7.72E+00	9.19E-03	7.16E-01	3.27E-03	4.01E-02	3.14E+02
	WoodLand Caribou	Reference (Kratchkowsky Lake)	6.56E-02	8.32E-03	7.07E-04	1.21E-01	6.06E-01	1.16E-03	1.06E-01	4.66E-04	8.70E-02	3.58E+01
		Whitefish Lake	6.74E-02	8.39E-03	7.19E-04	1.22E-01	6.14E-01	5.17E-03	1.50E-01	1.14E-02	9.81E-02	3.60E+01
	Canada Goose	Reference (Kratchkowsky Lake)	7.12E-03	7.93E-03	3.84E-03	4.32E-03	1.65E-01	5.82E-04	1.93E-02	1.94E-03	5.42E-03	3.56E-01
		Whitefish Lake	7.14E-03	7.94E-03	3.87E-03	4.36E-03	1.69E-01	5.87E-04	1.95E-02	5.90E-02	5.51E-03	3.56E-01
		McGowan Lake	7.13E-03	7.93E-03	3.84E-03	4.34E-03	1.66E-01	8.35E-04	1.95E-02	9.45E-03	5.44E-03	3.56E-01
		Russell Lake Inlet	7.12E-03	7.93E-03	3.84E-03	4.33E-03	1.65E-01	7.71E-04	1.94E-02	3.96E-03	5.42E-03	3.56E-01
	Eagle	Reference (Kratchkowsky Lake)	3.16E-02	1.48E-02	6.75E-03	8.14E-02	1.01E-01	4.95E-04	5.52E-01	6.88E-03	7.31E-02	2.34E-01
		Whitefish Lake	3.17E-02	1.48E-02	6.76E-03	8.16E-02	1.03E-01	6.78E-04	7.75E-01	7.77E-03	7.34E-02	2.39E-01
	Flycatcher	Reference (Kratchkowsky Lake)	6.25E-02	1.18E+00	2.40E-02	2.09E-01	1.31E+00	8.68E-03	1.47E+00	1.80E-02	8.95E-02	3.89E+00
		Whitefish Lake	6.43E-02	1.18E+00	2.47E-02	2.15E-01	1.39E+00	5.45E-02	1.70E+00	6.91E-01	9.61E-02	3.94E+00
		McGowan Lake	6.32E-02	1.18E+00	2.43E-02	2.13E-01	1.36E+00	4.19E-02	1.61E+00	1.07E-01	9.21E-02	3.92E+00
		Russell Lake Inlet	6.29E-02	1.18E+00	2.42E-02	2.12E-01	1.35E+00	3.39E-02	1.58E+00	4.24E-02	9.11E-02	3.91E+00
	Loon	Reference (Kratchkowsky Lake)	1.36E-02	3.41E-04	9.31E-04	1.30E-02	1.44E-01	9.70E-05	5.16E-01	1.99E-04	3.71E-03	2.22E-01
		Whitefish Lake	1.68E-02	5.08E-04	1.15E-03	1.77E-02	1.84E-01	1.65E-02	4.28E+00	3.25E-03	1.42E-02	3.31E-01
		McGowan Lake	1.45E-02	4.48E-04	1.08E-03	1.58E-02	1.71E-01	1.19E-02	2.80E+00	1.96E-03	7.27E-03	2.84E-01
		Russell Lake Inlet	1.40E-02	4.20E-04	1.04E-03	1.50E-02	1.65E-01	9.01E-03	2.22E+00	1.47E-03	5.96E-03	2.66E-01
	Mallard	Reference (Kratchkowsky Lake)	4.84E-02	4.75E-03	7.57E-03	6.72E-02	8.31E-01	1.05E-03	1.13E-01	2.04E-03	3.26E-02	4.00E-01
		Whitefish Lake	6.39E-02	7.02E-03	9.24E-03	8.71E-02	1.04E+00	1.79E-01	1.01E+00	2.58E-02	1.10E-01	5.50E-01
		McGowan Lake	5.48E-02	6.24E-03	8.74E-03	8.07E-02	9.81E-01	1.29E-01	6.80E-01	1.70E-02	6.46E-02	4.99E-01
		Russell Lake Inlet	5.23E-02	5.85E-03	8.46E-03	7.72E-02	9.45E-01	9.79E-02	5.26E-01	1.30E-02	5.27E-02	4.72E-01
	Robin	Reference (Kratchkowsky Lake)	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.75E+00	2.13E-02	1.87E+00	6.05E-02	2.56E-01	1.03E+01
		Whitefish Lake	2.82E-01	1.02E+00	1.21E-01	3.59E-01	4.90E+00	2.15E-02	1.88E+00	9.34E-01	2.58E-01	1.03E+01
		McGowan Lake	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.77E+00	2.17E-02	1.87E+00	1.75E-01	2.56E-01	1.03E+01
		Russell Lake Inlet	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.76E+00	2.16E-02	1.87E+00	9.11E-02	2.56E-01	1.03E+01
	Scaup	Reference (Kratchkowsky Lake)	7.77E-02	8.03E-03	1.72E-02	1.05E-01	1.35E+00	1.68E-03	1.95E-01	3.31E-03	5.80E-02	6.98E-01
		Whitefish Lake	1.02E-01	1.20E-02	2.12E-02	1.36E-01	1.70E+00	2.88E-01	1.82E+00	4.43E-02	2.03E-01	9.69E-01
		McGowan Lake	8.73E-02	1.06E-02	1.99E-02	1.26E-01	1.60E+00	2.06E-01	1.20E+00	2.86E-02	1.14E-01	8.72E-01
		Russell Lake Inlet	8.35E-02	9.89E-03	1.93E-02	1.21E-01	1.54E+00	1.57E-01	9.30E-01	2.17E-02	9.36E-02	8.25E-01

Table B.6: Maximum Concentration of Non-radionuclides in Ecological Receptors during Future Centuries

Biota		Location	Maximum Concentration of Non-radionuclides during Future Centuries (mg/kg fw)									
			Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Aquatic Plants	Macrophytes	Reference (Kratchkowsky Lake)	1.78E-02	1.51E-03	1.60E-02	5.19E-03	1.34E-01	7.27E-04	5.73E-03	1.51E-03	4.73E-02	3.82E-01
		Whitefish Lake North	1.78E-02	1.51E-03	1.60E-02	5.19E-03	1.34E-01	7.27E-04	5.73E-03	1.51E-03	4.73E-02	3.82E-01
		Whitefish Lake Middle	1.84E-02	1.52E-03	1.68E-02	5.26E-03	1.36E-01	7.92E-04	7.64E-03	1.85E-03	4.77E-02	4.16E-01
		Whitefish Lake South	1.83E-02	1.52E-03	1.68E-02	5.26E-03	1.36E-01	7.91E-04	7.56E-03	1.84E-03	4.77E-02	4.14E-01
		McGowan Lake	1.81E-02	1.52E-03	1.66E-02	5.24E-03	1.35E-01	7.76E-04	7.00E-03	1.74E-03	4.75E-02	4.05E-01
		Russell Lake Inlet	1.79E-02	1.52E-03	1.64E-02	5.23E-03	1.35E-01	7.64E-04	6.66E-03	1.68E-03	4.74E-02	3.99E-01
	Phytoplankton	Reference (Kratchkowsky Lake)	1.78E-02	1.51E-03	1.60E-02	5.19E-03	1.34E-01	7.27E-04	5.73E-03	1.51E-03	4.73E-02	3.82E-01
		Whitefish Lake North	1.78E-02	1.51E-03	1.60E-02	5.19E-03	1.34E-01	7.27E-04	5.73E-03	1.51E-03	4.73E-02	3.82E-01
		Whitefish Lake Middle	1.84E-02	1.52E-03	1.68E-02	5.26E-03	1.36E-01	7.92E-04	7.64E-03	1.85E-03	4.77E-02	4.16E-01
		Whitefish Lake South	1.83E-02	1.52E-03	1.68E-02	5.26E-03	1.36E-01	7.91E-04	7.56E-03	1.84E-03	4.77E-02	4.14E-01
		McGowan Lake	1.81E-02	1.52E-03	1.66E-02	5.24E-03	1.35E-01	7.76E-04	7.00E-03	1.74E-03	4.75E-02	4.05E-01
		Russell Lake Inlet	1.79E-02	1.52E-03	1.64E-02	5.23E-03	1.35E-01	7.64E-04	6.66E-03	1.68E-03	4.74E-02	3.99E-01
Aquatic Animals	Benthic Invertebrate	Reference (Kratchkowsky Lake)	4.67E-02	5.84E-03	2.01E-02	1.98E-01	4.79E+00	1.72E-02	3.32E-02	2.89E-03	4.80E-02	2.84E+00
		Whitefish Lake North	4.67E-02	5.84E-03	2.01E-02	1.98E-01	4.79E+00	1.72E-02	3.32E-02	2.89E-03	4.80E-02	2.84E+00
		Whitefish Lake Middle	4.85E-02	5.88E-03	2.11E-02	2.00E-01	4.85E+00	1.87E-02	4.43E-02	3.53E-03	4.85E-02	3.09E+00
		Whitefish Lake South	4.83E-02	5.88E-03	2.11E-02	2.00E-01	4.85E+00	1.87E-02	4.38E-02	3.51E-03	4.84E-02	3.08E+00
		McGowan Lake	4.75E-02	5.87E-03	2.09E-02	2.00E-01	4.84E+00	1.83E-02	4.06E-02	3.32E-03	4.82E-02	3.01E+00
		Russell Lake Inlet	4.72E-02	5.86E-03	2.07E-02	1.99E-01	4.82E+00	1.81E-02	3.86E-02	3.20E-03	4.82E-02	2.97E+00
	Northern pike	Reference (Kratchkowsky Lake)	3.10E-02	6.95E-05	1.21E-03	2.85E-02	3.09E-01	1.07E-05	1.83E-01	6.01E-04	1.41E-02	1.36E+00
		Whitefish Lake North	3.10E-02	6.95E-05	1.21E-03	2.85E-02	3.09E-01	1.07E-05	1.83E-01	6.01E-04	1.41E-02	1.36E+00
		Whitefish Lake Middle	3.22E-02	6.99E-05	1.28E-03	2.89E-02	3.13E-01	1.16E-05	2.33E-01	7.35E-04	1.43E-02	1.48E+00
		Whitefish Lake South	3.20E-02	6.99E-05	1.28E-03	2.89E-02	3.13E-01	1.16E-05	2.31E-01	7.30E-04	1.42E-02	1.47E+00
		McGowan Lake	3.15E-02	6.98E-05	1.26E-03	2.88E-02	3.12E-01	1.14E-05	2.16E-01	6.90E-04	1.42E-02	1.44E+00
		Russell Lake Inlet	3.13E-02	6.97E-05	1.25E-03	2.87E-02	3.11E-01	1.12E-05	2.08E-01	6.67E-04	1.42E-02	1.42E+00
	White sucker	Reference (Kratchkowsky Lake)	2.97E-02	6.90E-05	1.21E-03	2.84E-02	3.09E-01	1.07E-05	1.42E-01	5.95E-04	1.36E-02	1.35E+00
		Whitefish Lake North	2.97E-02	6.90E-05	1.21E-03	2.84E-02	3.09E-01	1.07E-05	1.42E-01	5.95E-04	1.36E-02	1.35E+00
		Whitefish Lake Middle	3.09E-02	6.94E-05	1.27E-03	2.87E-02	3.13E-01	1.16E-05	1.89E-01	7.28E-04	1.37E-02	1.47E+00
		Whitefish Lake South	3.07E-02	6.94E-05	1.27E-03	2.87E-02	3.13E-01	1.16E-05	1.87E-01	7.23E-04	1.37E-02	1.46E+00
		McGowan Lake	3.02E-02	6.92E-05	1.26E-03	2.86E-02	3.12E-01	1.14E-05	1.73E-01	6.84E-04	1.36E-02	1.43E+00
		Russell Lake Inlet	3.00E-02	6.92E-05	1.25E-03	2.86E-02	3.11E-01	1.12E-05	1.65E-01	6.60E-04	1.36E-02	1.41E+00
	Zooplankton	Reference (Kratchkowsky Lake)	5.58E-02	6.02E-03	2.02E-02	2.02E-01	4.82E+00	1.73E-02	3.46E-02	3.01E-03	5.68E-02	2.93E+00
		Whitefish Lake North	5.58E-02	6.02E-03	2.02E-02	2.02E-01	4.82E+00	1.73E-02	3.46E-02	3.01E-03	5.68E-02	2.93E+00
		Whitefish Lake Middle	5.79E-02	6.06E-03	2.13E-02	2.05E-01	4.89E+00	1.89E-02	4.61E-02	3.68E-03	5.73E-02	3.18E+00
		Whitefish Lake South	5.76E-02	6.06E-03	2.13E-02	2.05E-01	4.89E+00	1.88E-02	4.56E-02	3.65E-03	5.72E-02	3.17E+00
		McGowan Lake	5.67E-02	6.05E-03	2.10E-02	2.04E-01	4.87E+00	1.85E-02	4.22E-02	3.45E-03	5.70E-02	3.10E+00
		Russell Lake Inlet	5.63E-02	6.04E-03	2.08E-02	2.04E-01	4.86E+00	1.82E-02	4.02E-02	3.33E-03	5.69E-02	3.06E+00
	Blueberries	Reference (Kratchkowsky Lake)	1.43E-01	8.53E-03	8.06E-02	1.42E-02	5.58E+00	6.60E-02	5.71E-02	3.43E-02	6.00E-03	1.35E+01
		Whitefish Lake	1.43E-01	8.53E-03	8.08E-02	1.42E-02	5.59E+00	6.60E-02	5.71E-02	4.69E-02	6.00E-03	1.35E+01
		McGowan Lake	1.43E-01	8.53E-03	8.07E-02	1.42E-02	5.58E+00	6.60E-02	5.71E-02	3.59E-02	6.00E-03	1.35E+01
		Russell Lake Inlet	1.43E-01	8.53E-03	8.06E-02	1.42E-02	5.58E+00	6.60E-02	5.71E-02	3.47E-02	6.00E-03	1.35E+01

Biota		Location	Maximum Concentration of Non-radionuclides during Future Centuries (mg/kg fw)									
			Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Terrestrial Plants	**Browse**	Reference (Kratchkowsky Lake)	7.16E-02	5.83E-02	5.00E-02	9.48E-03	3.65E+00	4.26E-02	2.56E-02	2.93E-02	4.07E-02	1.03E+01
		Whitefish Lake	7.16E-02	5.83E-02	5.01E-02	9.48E-03	3.65E+00	4.26E-02	2.56E-02	3.42E-02	4.07E-02	1.04E+01
		McGowan Lake	7.16E-02	5.83E-02	5.01E-02	9.48E-03	3.65E+00	4.26E-02	2.56E-02	3.00E-02	4.07E-02	1.03E+01
		Russell Lake Inlet	7.16E-02	5.83E-02	5.00E-02	9.48E-03	3.65E+00	4.26E-02	2.56E-02	2.95E-02	4.07E-02	1.03E+01
	Labrador Tea	Reference (Kratchkowsky Lake)	2.34E-01	7.56E-02	2.14E-01	4.41E-02	1.83E+01	2.10E-01	6.14E-02	1.69E-01	3.72E-01	6.05E+01
		Whitefish Lake	2.34E-01	7.56E-02	2.14E-01	4.41E-02	1.83E+01	2.10E-01	6.14E-02	1.74E-01	3.72E-01	6.05E+01
		McGowan Lake	2.34E-01	7.56E-02	2.14E-01	4.41E-02	1.83E+01	2.10E-01	6.14E-02	1.69E-01	3.72E-01	6.05E+01
		Russell Lake Inlet	2.34E-01	7.56E-02	2.14E-01	4.41E-02	1.83E+01	2.10E-01	6.14E-02	1.69E-01	3.72E-01	6.05E+01
	Lichen	Reference (Kratchkowsky Lake)	1.09E-01	6.75E-02	1.14E-01	1.49E+00	1.30E+00	8.10E-02	9.14E-02	8.89E-02	6.56E-01	1.28E+01
		Whitefish Lake	1.09E-01	6.75E-02	1.14E-01	1.49E+00	1.30E+00	8.10E-02	9.14E-02	8.89E-02	6.56E-01	1.28E+01
		McGowan Lake	1.09E-01	6.75E-02	1.14E-01	1.49E+00	1.30E+00	8.10E-02	9.14E-02	8.89E-02	6.56E-01	1.28E+01
		Russell Lake Inlet	1.09E-01	6.75E-02	1.14E-01	1.49E+00	1.30E+00	8.10E-02	9.14E-02	8.89E-02	6.56E-01	1.28E+01
	Terrestrial Invertebrate	Reference (Kratchkowsky Lake)	4.25E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	1.97E-02	7.32E-02	8.78E+00
		Whitefish Lake	4.25E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	2.10E-02	7.32E-02	8.78E+00
		McGowan Lake	4.25E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	1.99E-02	7.32E-02	8.78E+00
		Russell Lake Inlet	4.25E-02	7.59E-01	2.09E-02	1.76E-01	1.85E+00	4.97E-02	1.63E-01	1.98E-02	7.32E-02	8.78E+00
	Black Bear	Reference (Kratchkowsky Lake)	6.18E-02	1.63E-03	6.84E-04	1.79E-02	1.06E+00	1.26E-03	2.55E-01	3.00E-04	1.86E-02	4.19E+01
		Whitefish Lake	6.18E-02	1.63E-03	6.84E-04	1.79E-02	1.06E+00	1.26E-03	2.70E-01	3.10E-04	1.86E-02	4.19E+01
	Lynx	Reference (Kratchkowsky Lake)	7.55E-02	3.40E-03	5.69E-05	1.68E-02	7.93E-01	1.29E-04	6.74E-01	5.33E-05	2.39E-02	5.35E+02
		Whitefish Lake	7.55E-02	3.40E-03	5.71E-05	1.68E-02	7.94E-01	1.29E-04	6.74E-01	7.16E-05	2.40E-02	5.35E+02
		McGowan Lake	7.55E-02	3.40E-03	5.70E-05	1.68E-02	7.93E-01	1.29E-04	6.74E-01	5.56E-05	2.39E-02	5.35E+02
		Russell Lake Inlet	7.55E-02	3.40E-03	5.70E-05	1.68E-02	7.93E-01	1.29E-04	6.74E-01	5.39E-05	2.39E-02	5.35E+02
	Mink	Reference (Kratchkowsky Lake)	2.47E-02	5.44E-04	5.43E-05	1.83E-02	1.78E-01	7.82E-05	1.71E-01	3.34E-05	1.66E-02	6.08E+00
		Whitefish Lake	2.55E-02	5.46E-04	5.64E-05	1.85E-02	1.80E-01	8.38E-05	2.21E-01	4.20E-05	1.67E-02	6.59E+00
		McGowan Lake	2.50E-02	5.45E-04	5.58E-05	1.84E-02	1.79E-01	8.24E-05	2.04E-01	3.57E-05	1.66E-02	6.43E+00
		Russell Lake Inlet	2.49E-02	5.45E-04	5.55E-05	1.84E-02	1.79E-01	8.14E-05	1.95E-01	3.48E-05	1.66E-02	6.34E+00
	Moose	Reference (Kratchkowsky Lake)	7.35E-02	1.45E-02	9.86E-04	1.44E-02	1.53E+00	1.81E-03	1.17E-01	5.16E-04	3.56E-02	6.93E+01
		Whitefish Lake	7.40E-02	1.45E-02	9.91E-04	1.45E-02	1.53E+00	1.81E-03	1.20E-01	6.03E-04	3.57E-02	6.94E+01
		McGowan Lake	7.37E-02	1.45E-02	9.89E-04	1.44E-02	1.53E+00	1.81E-03	1.19E-01	5.28E-04	3.57E-02	6.94E+01
		Russell Lake Inlet	7.37E-02	1.45E-02	9.89E-04	1.44E-02	1.53E+00	1.81E-03	1.18E-01	5.20E-04	3.57E-02	6.93E+01
	Moose Organs	Reference (Kratchkowsky Lake)	6.25E-01	5.01E-03	2.29E-01	6.55E-03	6.11E+01	1.81E-01	1.17E-01	9.13E-04	3.55E-05	8.67E-01
		McGowan Lake	6.27E-01	5.01E-03	2.30E-01	6.57E-03	6.11E+01	1.81E-01	1.19E-01	9.35E-04	3.55E-05	8.67E-01
		Russell Lake Inlet	6.26E-01	5.01E-03	2.30E-01	6.56E-03	6.11E+01	1.81E-01	1.18E-01	9.20E-04	3.55E-05	8.67E-01
	Muskrat	Reference (Kratchkowsky Lake)	6.28E-02	8.78E-04	2.42E-04	2.19E-02	4.66E-02	1.28E-04	3.68E-02	8.84E-05	4.91E-02	2.35E+00
		Whitefish Lake	6.52E-02	8.84E-04	2.55E-04	2.21E-02	4.72E-02	1.40E-04	4.90E-02	1.08E-04	4.95E-02	2.56E+00
		McGowan Lake	6.39E-02	8.82E-04	2.52E-04	2.20E-02	4.71E-02	1.37E-04	4.49E-02	1.02E-04	4.93E-02	2.49E+00
		Russell Lake Inlet	6.35E-02	8.81E-04	2.50E-04	2.20E-02	4.70E-02	1.35E-04	4.28E-02	9.80E-05	4.92E-02	2.46E+00

Biota		Location	Maximum Concentration of Non-radionuclides during Future Centuries (mg/kg fw)									
			Arsenic	Cadmium	Cobalt	Chromium	Copper	Molybdenum	Selenium	Uranium	Vanadium	Zinc
Terrestrial Animals	Snowshoe Hare	Reference (Kratchkowsky Lake)	6.22E-02	1.21E-02	8.82E-04	1.58E-02	1.43E+00	1.70E-03	1.10E-01	4.79E-04	2.92E-02	6.34E+01
		Whitefish Lake	6.22E-02	1.21E-02	8.83E-04	1.58E-02	1.43E+00	1.70E-03	1.10E-01	5.78E-04	2.92E-02	6.34E+01
		McGowan Lake	6.22E-02	1.21E-02	8.82E-04	1.58E-02	1.43E+00	1.70E-03	1.10E-01	4.92E-04	2.92E-02	6.34E+01
		Russell Lake Inlet	6.22E-02	1.21E-02	8.82E-04	1.58E-02	1.43E+00	1.70E-03	1.10E-01	4.82E-04	2.92E-02	6.34E+01
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	3.68E-01	2.69E-02	4.74E-03	2.80E-02	7.71E+00	9.11E-03	7.15E-01	2.05E-03	4.01E-02	3.14E+02
		Whitefish Lake	3.68E-01	2.69E-02	4.74E-03	2.80E-02	7.72E+00	9.11E-03	7.15E-01	2.65E-03	4.01E-02	3.14E+02
		McGowan Lake	3.68E-01	2.69E-02	4.74E-03	2.80E-02	7.72E+00	9.11E-03	7.15E-01	2.13E-03	4.01E-02	3.14E+02
		Russell Lake Inlet	3.68E-01	2.69E-02	4.74E-03	2.80E-02	7.71E+00	9.11E-03	7.15E-01	2.07E-03	4.01E-02	3.14E+02
	WoodLand Caribou	Reference (Kratchkowsky Lake)	6.51E-02	8.32E-03	7.06E-04	1.21E-01	6.06E-01	1.16E-03	1.06E-01	4.66E-04	8.65E-02	3.58E+01
		Whitefish Lake	6.54E-02	8.32E-03	7.08E-04	1.21E-01	6.06E-01	1.17E-03	1.08E-01	4.72E-04	8.65E-02	3.58E+01
	Canada Goose	Reference (Kratchkowsky Lake)	7.12E-03	7.93E-03	3.84E-03	4.32E-03	1.65E-01	5.82E-04	1.93E-02	1.94E-03	5.41E-03	3.56E-01
		Whitefish Lake	7.11E-03	7.92E-03	3.83E-03	4.28E-03	1.65E-01	5.80E-04	1.93E-02	2.33E-03	5.41E-03	3.56E-01
		McGowan Lake	7.12E-03	7.93E-03	3.84E-03	4.32E-03	1.65E-01	5.82E-04	1.93E-02	1.99E-03	5.41E-03	3.56E-01
		Russell Lake Inlet	7.12E-03	7.93E-03	3.84E-03	4.32E-03	1.65E-01	5.82E-04	1.93E-02	1.95E-03	5.41E-03	3.56E-01
	Eagle	Reference (Kratchkowsky Lake)	3.01E-02	1.48E-02	6.74E-03	8.12E-02	1.01E-01	4.95E-04	5.38E-01	6.87E-03	7.27E-02	2.30E-01
		Whitefish Lake	3.01E-02	1.48E-02	6.75E-03	8.12E-02	1.01E-01	4.95E-04	5.47E-01	6.92E-03	7.27E-02	2.31E-01
	Flycatcher	Kratchkowsky Lake	6.25E-02	1.18E+00	2.40E-02	2.09E-01	1.31E+00	8.68E-03	1.47E+00	1.80E-02	8.95E-02	3.89E+00
		Whitefish Lake	6.27E-02	1.18E+00	2.41E-02	2.10E-01	1.31E+00	8.71E-03	1.48E+00	2.05E-02	8.95E-02	3.90E+00
		McGowan Lake	6.26E-02	1.18E+00	2.41E-02	2.10E-01	1.31E+00	8.70E-03	1.48E+00	1.83E-02	8.95E-02	3.90E+00
		Russell Lake Inlet	6.26E-02	1.18E+00	2.41E-02	2.10E-01	1.31E+00	8.70E-03	1.48E+00	1.81E-02	8.95E-02	3.90E+00
	Loon	Reference (Kratchkowsky Lake)	1.20E-02	3.40E-04	9.29E-04	1.29E-02	1.44E-01	9.69E-05	5.00E-01	1.95E-04	3.35E-03	2.17E-01
		Whitefish Lake	1.24E-02	3.42E-04	9.79E-04	1.30E-02	1.46E-01	1.06E-04	6.35E-01	2.38E-04	3.38E-03	2.36E-01
		McGowan Lake	1.22E-02	3.42E-04	9.66E-04	1.30E-02	1.45E-01	1.03E-04	5.90E-01	2.23E-04	3.36E-03	2.30E-01
		Russell Lake Inlet	1.21E-02	3.41E-04	9.58E-04	1.29E-02	1.45E-01	1.02E-04	5.67E-01	2.16E-04	3.35E-03	2.27E-01
	Mallard	Reference (Kratchkowsky Lake)	4.82E-02	4.75E-03	7.56E-03	6.72E-02	8.31E-01	1.05E-03	1.13E-01	2.04E-03	3.23E-02	4.00E-01
		Whitefish Lake	5.00E-02	4.78E-03	7.96E-03	6.81E-02	8.42E-01	1.15E-03	1.50E-01	2.49E-03	3.25E-02	4.34E-01
		McGowan Lake	4.90E-02	4.77E-03	7.86E-03	6.78E-02	8.39E-01	1.13E-03	1.38E-01	2.34E-03	3.24E-02	4.23E-01
		Russell Lake Inlet	4.87E-02	4.76E-03	7.79E-03	6.77E-02	8.37E-01	1.11E-03	1.31E-01	2.26E-03	3.23E-02	4.17E-01
	Robin	Reference (Kratchkowsky Lake)	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.75E+00	2.13E-02	1.87E+00	6.05E-02	2.56E-01	1.03E+01
		Whitefish Lake	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.76E+00	2.13E-02	1.87E+00	7.95E-02	2.56E-01	1.03E+01
		McGowan Lake	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.75E+00	2.13E-02	1.87E+00	6.30E-02	2.56E-01	1.03E+01
		Russell Lake Inlet	2.82E-01	1.02E+00	1.21E-01	3.58E-01	4.75E+00	2.13E-02	1.87E+00	6.12E-02	2.56E-01	1.03E+01
	Scaup	Reference (Kratchkowsky Lake)	7.62E-02	8.00E-03	1.71E-02	1.05E-01	1.35E+00	1.68E-03	1.94E-01	3.29E-03	5.59E-02	6.96E-01
		Whitefish Lake	7.91E-02	8.04E-03	1.81E-02	1.06E-01	1.37E+00	1.83E-03	2.58E-01	4.03E-03	5.65E-02	7.56E-01
		McGowan Lake	7.74E-02	8.03E-03	1.78E-02	1.06E-01	1.37E+00	1.79E-03	2.37E-01	3.78E-03	5.62E-02	7.37E-01
		Russell Lake Inlet	7.70E-02	8.02E-03	1.77E-02	1.06E-01	1.37E+00	1.76E-03	2.26E-01	3.65E-03	5.61E-02	7.26E-01

Table B.7: Maximum Concentration of Radionuclides for Ecological Receptors during Project Phases

Biota		Location	Maximum Concentration of Radionuclides duting Project Phases (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Aquatic Plants	Macrophytes	Reference (Kratchkowsky Lake)	1.94E-02	1.94E-02	2.35E+00	9.29E-01	1.18E+01	1.85E+00
		Whitefish Lake North	1.90E-02	1.90E-02	2.35E+00	9.17E-01	1.08E+01	1.69E+00
		Whitefish Lake Middle	3.56E-01	3.56E-01	4.33E+00	1.12E+00	1.59E+01	1.96E+00
		Whitefish Lake South	3.39E-01	3.39E-01	4.30E+00	1.10E+00	1.57E+01	2.11E+00
		McGowan Lake	2.09E-01	2.09E-01	3.64E+00	1.03E+00	1.27E+01	1.82E+00
		Russell Lake Inlet	1.56E-01	1.56E-01	3.32E+00	1.00E+00	1.22E+01	1.80E+00
	Phytoplankton	Reference (Kratchkowsky Lake)	1.94E-02	1.94E-02	2.35E+00	9.29E-01	1.18E+01	1.85E+00
		Whitefish Lake North	1.90E-02	1.90E-02	2.35E+00	9.17E-01	1.08E+01	1.69E+00
		Whitefish Lake Middle	3.56E-01	3.56E-01	4.33E+00	1.12E+00	1.59E+01	1.96E+00
		Whitefish Lake South	3.39E-01	3.39E-01	4.30E+00	1.10E+00	1.57E+01	2.11E+00
		McGowan Lake	2.09E-01	2.09E-01	3.64E+00	1.03E+00	1.27E+01	1.82E+00
		Russell Lake Inlet	1.56E-01	1.56E-01	3.32E+00	1.00E+00	1.22E+01	1.80E+00
Aquatic Animals	Benthic Invertebrate	Reference (Kratchkowsky Lake)	3.57E-02	3.57E-02	5.02E+00	1.36E+00	7.17E+00	5.00E+01
		Whitefish Lake North	3.57E-02	3.57E-02	5.02E+00	1.36E+00	7.16E+00	5.00E+01
		Whitefish Lake Middle	4.41E-01	4.41E-01	8.28E+00	1.58E+00	1.07E+01	7.34E+01
		Whitefish Lake South	4.22E-01	4.22E-01	8.23E+00	1.57E+00	9.96E+00	6.86E+01
		McGowan Lake	2.93E-01	2.93E-01	7.38E+00	1.50E+00	8.47E+00	5.88E+01
		Russell Lake Inlet	2.24E-01	2.24E-01	6.82E+00	1.47E+00	7.94E+00	5.52E+01
	Northern pike	Reference (Kratchkowsky Lake)	7.71E-03	7.71E-03	6.09E-02	6.84E-02	3.73E-01	9.50E-01
		Whitefish Lake North	7.54E-03	7.54E-03	6.07E-02	6.75E-02	3.41E-01	8.67E-01
		Whitefish Lake Middle	1.41E-01	1.41E-01	1.12E-01	8.24E-02	5.01E-01	1.01E+00
		Whitefish Lake South	1.34E-01	1.34E-01	1.11E-01	8.07E-02	4.95E-01	1.08E+00
		McGowan Lake	8.30E-02	8.30E-02	9.41E-02	7.59E-02	4.01E-01	9.34E-01
		Russell Lake Inlet	6.18E-02	6.18E-02	8.58E-02	7.37E-02	3.85E-01	9.24E-01
	White sucker	Reference (Kratchkowsky Lake)	7.56E-03	7.56E-03	6.07E-02	6.76E-02	3.27E-01	8.31E-01
		Whitefish Lake North	7.44E-03	7.44E-03	6.06E-02	6.69E-02	3.02E-01	7.69E-01
		Whitefish Lake Middle	1.28E-01	1.28E-01	1.09E-01	8.07E-02	4.45E-01	9.29E-01
		Whitefish Lake South	1.22E-01	1.22E-01	1.08E-01	7.93E-02	4.36E-01	9.75E-01
		McGowan Lake	7.67E-02	7.67E-02	9.27E-02	7.50E-02	3.56E-01	8.40E-01
		Russell Lake Inlet	5.75E-02	5.75E-02	8.48E-02	7.28E-02	3.40E-01	8.24E-01

Biota		Location	Maximum Concentration of Radionuclides duting Project Phases (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
	Zooplankton	Reference (Kratchkowsky Lake)	3.85E-02	3.85E-02	5.07E+00	1.43E+00	1.43E+01	9.99E+01
		Whitefish Lake North	3.77E-02	3.77E-02	5.06E+00	1.41E+00	1.31E+01	9.12E+01
		Whitefish Lake Middle	7.05E-01	7.05E-01	9.34E+00	1.72E+00	1.92E+01	1.06E+02
		Whitefish Lake South	6.72E-01	6.72E-01	9.27E+00	1.68E+00	1.90E+01	1.14E+02
		McGowan Lake	4.15E-01	4.15E-01	7.84E+00	1.58E+00	1.54E+01	9.83E+01
		Russell Lake Inlet	3.09E-01	3.09E-01	7.15E+00	1.53E+00	1.47E+01	9.72E+01
Terrestrial Plants	Blueberries	Reference (Kratchkowsky Lake)	4.24E-01	4.24E-01	3.24E-01	4.73E+00	1.00E+01	1.31E+01
		Whitefish Lake	3.52E+00	3.52E+00	3.25E-01	4.73E+00	1.00E+01	1.31E+01
		McGowan Lake	8.30E-01	8.30E-01	3.24E-01	4.73E+00	1.00E+01	1.31E+01
		Russell Lake Inlet	5.32E-01	5.32E-01	3.24E-01	4.73E+00	1.00E+01	1.31E+01
	Browse	Reference (Kratchkowsky Lake)	3.63E-01	3.63E-01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Whitefish Lake	1.28E+01	1.28E+01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		McGowan Lake	2.00E+00	2.00E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Russell Lake Inlet	7.99E-01	7.99E-01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
	Labrador Tea	Reference (Kratchkowsky Lake)	2.08E+00	2.08E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Whitefish Lake	1.12E+02	1.12E+02	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		McGowan Lake	1.65E+01	1.65E+01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Russell Lake Inlet	5.93E+00	5.93E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
	Lichen	Reference (Kratchkowsky Lake)	1.10E+00	1.10E+00	1.13E+00	2.72E+00	4.14E+02	2.77E+02
		Whitefish Lake	6.24E+02	6.24E+02	1.13E+00	2.72E+00	4.14E+02	2.77E+02
		McGowan Lake	8.29E+01	8.29E+01	1.13E+00	2.72E+00	4.14E+02	2.77E+02
		Russell Lake Inlet	2.29E+01	2.29E+01	1.13E+00	2.72E+00	4.14E+02	2.77E+02
	Terrestrial Invertebrate	Reference (Kratchkowsky Lake)	2.44E-01	2.44E-01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
		Whitefish Lake	1.19E+01	1.19E+01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
		McGowan Lake	1.78E+00	1.78E+00	1.77E-01	1.36E+00	2.08E+00	1.82E+00
		Russell Lake Inlet	6.53E-01	6.53E-01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
	Black Bear	Reference (Kratchkowsky Lake)	3.70E-03	3.70E-03	3.10E-03	1.58E-01	1.49E-01	1.36E+00
		Whitefish Lake	6.30E-03	6.30E-03	3.15E-03	1.58E-01	1.49E-01	1.36E+00

Biota		Location	Maximum Concentration of Radionuclides duting Project Phases (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Terrestrial Animals	Lynx	Reference (Kratchkowsky Lake)	6.58E-04	6.58E-04	1.38E-03	2.26E-02	2.02E-02	4.69E-01
		Whitefish Lake	7.36E-03	7.36E-03	1.42E-03	2.26E-02	2.03E-02	4.69E-01
		McGowan Lake	1.56E-03	1.56E-03	1.40E-03	2.26E-02	2.02E-02	4.69E-01
		Russell Lake Inlet	9.08E-04	9.08E-04	1.40E-03	2.26E-02	2.02E-02	4.69E-01
	Mink	Reference (Kratchkowsky Lake)	4.13E-04	4.13E-04	4.25E-03	1.50E-02	3.17E-02	1.22E+00
		Whitefish Lake	3.86E-03	3.86E-03	6.60E-03	1.69E-02	4.32E-02	1.75E+00
		McGowan Lake	1.74E-03	1.74E-03	5.94E-03	1.62E-02	3.58E-02	1.42E+00
		Russell Lake Inlet	1.28E-03	1.28E-03	5.53E-03	1.59E-02	3.41E-02	1.34E+00
	Moose	Reference (Kratchkowsky Lake)	6.38E-03	6.38E-03	7.88E-03	1.54E-01	2.19E-01	1.29E+00
		Whitefish Lake	2.12E-01	2.12E-01	1.28E-02	1.59E-01	2.55E-01	1.34E+00
		McGowan Lake	3.47E-02	3.47E-02	1.11E-02	1.57E-01	2.28E-01	1.30E+00
		Russell Lake Inlet	1.47E-02	1.47E-02	1.03E-02	1.56E-01	2.23E-01	1.30E+00
	Moose Organs	Reference (Kratchkowsky Lake)	1.13E-02	1.13E-02	2.16E+00	8.63E-02	6.88E+00	1.29E-02
		McGowan Lake	6.13E-02	6.13E-02	3.04E+00	8.77E-02	7.15E+00	1.30E-02
		Russell Lake Inlet	2.60E-02	2.60E-02	2.82E+00	8.73E-02	7.01E+00	1.30E-02
	Muskrat	Reference (Kratchkowsky Lake)	1.10E-03	1.10E-03	1.81E-02	8.25E-02	3.32E-01	8.73E-01
		Whitefish Lake	1.49E-02	1.49E-02	3.30E-02	9.79E-02	4.58E-01	1.17E+00
		McGowan Lake	9.54E-03	9.54E-03	2.79E-02	9.15E-02	3.66E-01	9.72E-01
		Russell Lake Inlet	7.25E-03	7.25E-03	2.54E-02	8.90E-02	3.49E-01	9.27E-01
	Snowshoe Hare	Reference (Kratchkowsky Lake)	5.92E-03	5.92E-03	2.73E-03	1.41E-01	1.32E-01	1.18E+00
		Whitefish Lake	1.76E-01	1.76E-01	2.76E-03	1.41E-01	1.32E-01	1.18E+00
		McGowan Lake	2.83E-02	2.83E-02	2.75E-03	1.41E-01	1.32E-01	1.18E+00
		Russell Lake Inlet	1.19E-02	1.19E-02	2.75E-03	1.41E-01	1.32E-01	1.18E+00
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	2.53E-02	2.53E-02	9.81E-03	9.76E-01	8.55E-01	7.96E+00
		Whitefish Lake	4.56E-01	4.56E-01	9.82E-03	9.76E-01	8.55E-01	7.96E+00
		McGowan Lake	8.19E-02	8.19E-02	9.82E-03	9.76E-01	8.55E-01	7.96E+00
		Russell Lake Inlet	4.04E-02	4.04E-02	9.81E-03	9.76E-01	8.55E-01	7.96E+00
	WoodLand Caribou	Reference (Kratchkowsky Lake)	5.76E-03	5.76E-03	9.50E-03	1.11E-01	1.79E+00	8.55E+00
		Whitefish Lake	1.41E-01	1.41E-01	1.11E-02	1.13E-01	1.80E+00	8.58E+00

Biota		Location	Maximum Concentration of Radionuclides duting Project Phases (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
	Canada Goose	Reference (Kratchkowsky Lake)	2.40E-02	2.40E-02	3.39E-04	4.52E-03	1.83E-02	1.06E+00
		Whitefish Lake	7.30E-01	7.30E-01	3.30E-04	4.50E-03	1.83E-02	1.06E+00
		McGowan Lake	1.17E-01	1.17E-01	3.44E-04	4.52E-03	1.83E-02	1.06E+00
		Russell Lake Inlet	4.89E-02	4.89E-02	3.43E-04	4.52E-03	1.83E-02	1.06E+00
	Eagle	Reference (Kratchkowsky Lake)	8.50E-02	8.50E-02	4.82E-03	1.11E-02	9.01E-02	9.67E+00
		Whitefish Lake	9.60E-02	9.60E-02	4.83E-03	1.11E-02	9.01E-02	9.75E+00
	Flycatcher	Reference (Kratchkowsky Lake)	2.22E-01	2.22E-01	9.10E-03	4.76E-02	1.82E-01	1.69E+01
		Whitefish Lake	8.54E+00	8.54E+00	1.20E-02	4.82E-02	1.97E-01	2.18E+01
		McGowan Lake	1.33E+00	1.33E+00	1.12E-02	4.80E-02	1.87E-01	1.88E+01
		Russell Lake Inlet	5.24E-01	5.24E-01	1.07E-02	4.79E-02	1.85E-01	1.80E+01
	Loon	Reference (Kratchkowsky Lake)	2.46E-03	2.46E-03	1.71E-03	1.83E-03	1.61E-02	4.30E+00
		Whitefish Lake	4.00E-02	4.00E-02	2.86E-03	2.15E-03	2.32E-02	6.05E+00
		McGowan Lake	2.41E-02	2.41E-02	2.53E-03	2.03E-03	1.85E-02	4.93E+00
		Russell Lake Inlet	1.81E-02	1.81E-02	2.33E-03	1.97E-03	1.75E-02	4.66E+00
	Mallard	Reference (Kratchkowsky Lake)	2.52E-02	2.52E-02	1.67E-02	1.98E-02	2.10E-01	3.63E+01
		Whitefish Lake	3.17E-01	3.17E-01	2.80E-02	2.31E-02	3.05E-01	5.32E+01
		McGowan Lake	2.09E-01	2.09E-01	2.48E-02	2.20E-02	2.43E-01	4.26E+01
		Russell Lake Inlet	1.59E-01	1.59E-01	2.28E-02	2.14E-02	2.29E-01	4.01E+01
	Robin	Reference (Kratchkowsky Lake)	7.47E-01	7.47E-01	1.95E-02	2.21E-01	8.98E-01	4.95E+01
		Whitefish Lake	1.15E+01	1.15E+01	1.95E-02	2.21E-01	8.98E-01	4.95E+01
		McGowan Lake	2.16E+00	2.16E+00	1.95E-02	2.21E-01	8.98E-01	4.95E+01
		Russell Lake Inlet	1.13E+00	1.13E+00	1.95E-02	2.21E-01	8.98E-01	4.95E+01
	Scaup	Reference (Kratchkowsky Lake)	4.09E-02	4.09E-02	3.45E-02	3.96E-02	5.23E-01	5.87E+01
		Whitefish Lake	5.44E-01	5.44E-01	5.92E-02	4.65E-02	7.36E-01	8.53E+01
		McGowan Lake	3.51E-01	3.51E-01	5.16E-02	4.39E-02	5.87E-01	6.87E+01
		Russell Lake Inlet	2.67E-01	2.67E-01	4.75E-02	4.27E-02	5.57E-01	6.46E+01

Table B.8: Maximum Concentration of Radionuclides for Ecological Receptors during Future Centuries

Biota		Location	Maximum Concentration of Radionuclides duting Future Centuries (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Aquatic Plants	Macrophytes	Reference (Kratchkowsky Lake)	1.87E-02	1.87E-02	2.34E+00	9.09E-01	1.00E+01	1.57E+00
		Whitefish Lake North	1.87E-02	1.87E-02	2.34E+00	9.09E-01	1.00E+01	1.57E+00
		Whitefish Lake Middle	2.29E-02	2.29E-02	2.40E+00	1.04E+00	1.15E+01	1.80E+00
		Whitefish Lake South	2.27E-02	2.27E-02	2.40E+00	1.04E+00	1.12E+01	1.76E+00
		McGowan Lake	2.15E-02	2.15E-02	2.39E+00	1.00E+00	1.06E+01	1.66E+00
		Russell Lake Inlet	2.08E-02	2.08E-02	2.38E+00	9.78E-01	1.04E+01	1.62E+00
	Phytoplankton	Reference (Kratchkowsky Lake)	1.87E-02	1.87E-02	2.34E+00	9.09E-01	1.00E+01	1.57E+00
		Whitefish Lake North	1.87E-02	1.87E-02	2.34E+00	9.09E-01	1.00E+01	1.57E+00
		Whitefish Lake Middle	2.29E-02	2.29E-02	2.40E+00	1.04E+00	1.15E+01	1.80E+00
		Whitefish Lake South	2.27E-02	2.27E-02	2.40E+00	1.04E+00	1.12E+01	1.76E+00
		McGowan Lake	2.15E-02	2.15E-02	2.39E+00	1.00E+00	1.06E+01	1.66E+00
		Russell Lake Inlet	2.08E-02	2.08E-02	2.38E+00	9.78E-01	1.04E+01	1.62E+00
Aquatic Animals	Benthic Invertebrate	Reference (Kratchkowsky Lake)	3.57E-02	3.57E-02	5.02E+00	1.36E+00	7.16E+00	5.00E+01
		Whitefish Lake North	3.57E-02	3.57E-02	5.02E+00	1.36E+00	7.16E+00	5.00E+01
		Whitefish Lake Middle	4.37E-02	4.37E-02	5.15E+00	1.55E+00	8.22E+00	5.74E+01
		Whitefish Lake South	4.33E-02	4.33E-02	5.15E+00	1.55E+00	8.04E+00	5.61E+01
		McGowan Lake	4.10E-02	4.10E-02	5.12E+00	1.50E+00	7.56E+00	5.28E+01
		Russell Lake Inlet	3.96E-02	3.96E-02	5.09E+00	1.46E+00	7.41E+00	5.17E+01
	Northern pike	Reference (Kratchkowsky Lake)	7.43E-03	7.43E-03	6.06E-02	6.69E-02	3.16E-01	8.05E-01
		Whitefish Lake North	7.43E-03	7.43E-03	6.06E-02	6.69E-02	3.16E-01	8.05E-01
		Whitefish Lake Middle	9.09E-03	9.09E-03	6.22E-02	7.67E-02	3.63E-01	9.23E-01
		Whitefish Lake South	9.02E-03	9.02E-03	6.22E-02	7.64E-02	3.55E-01	9.03E-01
		McGowan Lake	8.53E-03	8.53E-03	6.18E-02	7.38E-02	3.34E-01	8.49E-01
		Russell Lake Inlet	8.24E-03	8.24E-03	6.15E-02	7.20E-02	3.27E-01	8.30E-01
	White sucker	Reference (Kratchkowsky Lake)	7.36E-03	7.36E-03	6.05E-02	6.64E-02	2.84E-01	7.22E-01
		Whitefish Lake North	7.36E-03	7.36E-03	6.05E-02	6.64E-02	2.84E-01	7.22E-01
		Whitefish Lake Middle	9.00E-03	9.00E-03	6.21E-02	7.62E-02	3.26E-01	8.29E-01
		Whitefish Lake South	8.93E-03	8.93E-03	6.21E-02	7.59E-02	3.19E-01	8.10E-01
		McGowan Lake	8.45E-03	8.45E-03	6.17E-02	7.33E-02	3.00E-01	7.63E-01
		Russell Lake Inlet	8.16E-03	8.16E-03	6.14E-02	7.15E-02	2.94E-01	7.45E-01

Biota		Location	Maximum Concentration of Radionuclides duting Future Centuries (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
	Zooplankton	Reference (Kratchkowsky Lake)	3.71E-02	3.71E-02	5.05E+00	1.39E+00	1.21E+01	8.46E+01
		Whitefish Lake North	3.71E-02	3.71E-02	5.05E+00	1.39E+00	1.21E+01	8.46E+01
		Whitefish Lake Middle	4.54E-02	4.54E-02	5.18E+00	1.60E+00	1.39E+01	9.71E+01
		Whitefish Lake South	4.51E-02	4.51E-02	5.18E+00	1.59E+00	1.36E+01	9.50E+01
		McGowan Lake	4.26E-02	4.26E-02	5.15E+00	1.54E+00	1.28E+01	8.94E+01
		Russell Lake Inlet	4.12E-02	4.12E-02	5.13E+00	1.50E+00	1.25E+01	8.73E+01
Terrestrial Plants	Blueberries	Reference (Kratchkowsky Lake)	4.24E-01	4.24E-01	3.24E-01	4.73E+00	1.00E+01	1.31E+01
		Whitefish Lake	5.80E-01	5.80E-01	3.25E-01	4.73E+00	1.00E+01	1.31E+01
		McGowan Lake	4.44E-01	4.44E-01	3.25E-01	4.73E+00	1.00E+01	1.31E+01
		Russell Lake Inlet	4.29E-01	4.29E-01	3.24E-01	4.73E+00	1.00E+01	1.31E+01
	Browse	Reference (Kratchkowsky Lake)	3.63E-01	3.63E-01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Whitefish Lake	4.23E-01	4.23E-01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		McGowan Lake	3.70E-01	3.70E-01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Russell Lake Inlet	3.65E-01	3.65E-01	1.25E-01	1.82E+00	3.85E+00	5.06E+00
	Labrador Tea	Reference (Kratchkowsky Lake)	2.08E+00	2.08E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Whitefish Lake	2.14E+00	2.14E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		McGowan Lake	2.09E+00	2.09E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
		Russell Lake Inlet	2.09E+00	2.09E+00	1.25E-01	1.82E+00	3.85E+00	5.06E+00
	Lichen	Reference (Kratchkowsky Lake)	1.10E+00	1.10E+00	1.13E+00	2.72E+00	4.14E+02	2.77E+02
		Whitefish Lake	1.10E+00	1.10E+00	1.13E+00	2.72E+00	4.14E+02	2.77E+02
		McGowan Lake	1.10E+00	1.10E+00	1.13E+00	2.72E+00	4.14E+02	2.77E+02
		Russell Lake Inlet	1.10E+00	1.10E+00	1.13E+00	2.72E+00	4.14E+02	2.77E+02
	Terrestrial Invertebrate	Reference (Kratchkowsky Lake)	2.44E-01	2.44E-01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
		Whitefish Lake	2.59E-01	2.59E-01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
		McGowan Lake	2.46E-01	2.46E-01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
		Russell Lake Inlet	2.44E-01	2.44E-01	1.77E-01	1.36E+00	2.08E+00	1.82E+00
	Black Bear	Reference (Kratchkowsky Lake)	3.70E-03	3.70E-03	3.10E-03	1.58E-01	1.48E-01	1.35E+00
		Whitefish Lake	3.83E-03	3.83E-03	3.10E-03	1.58E-01	1.48E-01	1.35E+00

Biota		Location	Maximum Concentration of Radionuclides duting Future Centuries (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
Terrestrial Animals	Lynx	Reference (Kratchkowsky Lake)	6.58E-04	6.58E-04	1.38E-03	2.26E-02	2.02E-02	4.69E-01
		Whitefish Lake	8.85E-04	8.85E-04	1.38E-03	2.26E-02	2.02E-02	4.69E-01
		McGowan Lake	6.88E-04	6.88E-04	1.38E-03	2.26E-02	2.02E-02	4.69E-01
		Russell Lake Inlet	6.66E-04	6.66E-04	1.38E-03	2.26E-02	2.02E-02	4.69E-01
	Mink	Reference (Kratchkowsky Lake)	4.12E-04	4.12E-04	4.25E-03	1.50E-02	3.13E-02	1.22E+00
		Whitefish Lake	5.19E-04	5.19E-04	4.34E-03	1.66E-02	3.48E-02	1.39E+00
		McGowan Lake	4.41E-04	4.41E-04	4.32E-03	1.61E-02	3.26E-02	1.28E+00
		Russell Lake Inlet	4.30E-04	4.30E-04	4.30E-03	1.58E-02	3.21E-02	1.25E+00
	Moose	Reference (Kratchkowsky Lake)	6.38E-03	6.38E-03	7.86E-03	1.54E-01	2.06E-01	1.27E+00
		Whitefish Lake	7.46E-03	7.46E-03	8.01E-03	1.57E-01	2.18E-01	1.30E+00
		McGowan Lake	6.53E-03	6.53E-03	7.97E-03	1.56E-01	2.11E-01	1.28E+00
		Russell Lake Inlet	6.43E-03	6.43E-03	7.94E-03	1.56E-01	2.09E-01	1.28E+00
	Moose Organs	Reference (Kratchkowsky Lake)	1.13E-02	1.13E-02	2.15E+00	8.61E-02	6.47E+00	1.27E-02
		McGowan Lake	1.15E-02	1.15E-02	2.18E+00	8.74E-02	6.62E+00	1.28E-02
		Russell Lake Inlet	1.14E-02	1.14E-02	2.18E+00	8.70E-02	6.56E+00	1.28E-02
	Muskrat	Reference (Kratchkowsky Lake)	1.09E-03	1.09E-03	1.80E-02	8.15E-02	2.94E-01	8.31E-01
		Whitefish Lake	1.34E-03	1.34E-03	1.85E-02	9.34E-02	3.37E-01	9.53E-01
		McGowan Lake	1.25E-03	1.25E-03	1.84E-02	8.98E-02	3.11E-01	8.77E-01
		Russell Lake Inlet	1.21E-03	1.21E-03	1.83E-02	8.77E-02	3.04E-01	8.58E-01
	Snowshoe Hare	Reference (Kratchkowsky Lake)	5.92E-03	5.92E-03	2.73E-03	1.41E-01	1.32E-01	1.18E+00
		Whitefish Lake	7.14E-03	7.14E-03	2.74E-03	1.41E-01	1.32E-01	1.18E+00
		McGowan Lake	6.07E-03	6.07E-03	2.73E-03	1.41E-01	1.32E-01	1.18E+00
		Russell Lake Inlet	5.96E-03	5.96E-03	2.73E-03	1.41E-01	1.32E-01	1.18E+00
	Southern Red-Backed Vole	Reference (Kratchkowsky Lake)	2.53E-02	2.53E-02	9.81E-03	9.76E-01	8.55E-01	7.96E+00
		Whitefish Lake	3.28E-02	3.28E-02	9.81E-03	9.76E-01	8.55E-01	7.96E+00
		McGowan Lake	2.63E-02	2.63E-02	9.81E-03	9.76E-01	8.55E-01	7.96E+00
		Russell Lake Inlet	2.56E-02	2.56E-02	9.81E-03	9.76E-01	8.55E-01	7.96E+00
	WoodLand Caribou	Reference (Kratchkowsky Lake)	5.75E-03	5.75E-03	9.48E-03	1.11E-01	1.78E+00	8.54E+00
		Whitefish Lake	5.83E-03	5.83E-03	9.54E-03	1.13E-01	1.79E+00	8.55E+00

Biota		Location	Maximum Concentration of Radionuclides duting Future Centuries (Bq/kg fw)					
			Uranium-238	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210
	Canada Goose	Reference (Kratchkowsky Lake)	2.40E-02	2.40E-02	3.39E-04	4.52E-03	1.83E-02	1.06E+00
		Whitefish Lake	2.88E-02	2.88E-02	3.30E-04	4.50E-03	1.83E-02	1.06E+00
		McGowan Lake	2.46E-02	2.46E-02	3.39E-04	4.52E-03	1.83E-02	1.06E+00
		Russell Lake Inlet	2.42E-02	2.42E-02	3.39E-04	4.52E-03	1.83E-02	1.06E+00
	Eagle	Reference (Kratchkowsky Lake)	8.49E-02	8.49E-02	4.82E-03	1.11E-02	8.94E-02	9.58E+00
		Whitefish Lake	8.55E-02	8.55E-02	4.82E-03	1.11E-02	8.94E-02	9.61E+00
	Flycatcher	Reference (Kratchkowsky Lake)	2.22E-01	2.22E-01	9.10E-03	4.76E-02	1.82E-01	1.69E+01
		Whitefish Lake	2.53E-01	2.53E-01	9.20E-03	4.81E-02	1.86E-01	1.84E+01
		McGowan Lake	2.26E-01	2.26E-01	9.19E-03	4.80E-02	1.83E-01	1.75E+01
		Russell Lake Inlet	2.23E-01	2.23E-01	9.17E-03	4.79E-02	1.83E-01	1.73E+01
	Loon	Reference (Kratchkowsky Lake)	2.40E-03	2.40E-03	1.71E-03	1.81E-03	1.54E-02	4.21E+00
		Whitefish Lake	2.94E-03	2.94E-03	1.76E-03	2.08E-03	1.76E-02	4.83E+00
		McGowan Lake	2.76E-03	2.76E-03	1.75E-03	2.00E-03	1.62E-02	4.44E+00
		Russell Lake Inlet	2.66E-03	2.66E-03	1.74E-03	1.95E-03	1.59E-02	4.35E+00
	Mallard	Reference (Kratchkowsky Lake)	2.52E-02	2.52E-02	1.67E-02	1.98E-02	2.02E-01	3.63E+01
		Whitefish Lake	3.08E-02	3.08E-02	1.72E-02	2.27E-02	2.32E-01	4.16E+01
		McGowan Lake	2.89E-02	2.89E-02	1.71E-02	2.18E-02	2.14E-01	3.83E+01
		Russell Lake Inlet	2.79E-02	2.79E-02	1.70E-02	2.13E-02	2.09E-01	3.75E+01
	Robin	Reference (Kratchkowsky Lake)	7.47E-01	7.47E-01	1.95E-02	2.21E-01	8.98E-01	4.95E+01
		Whitefish Lake	9.82E-01	9.82E-01	1.95E-02	2.21E-01	8.98E-01	4.95E+01
		McGowan Lake	7.78E-01	7.78E-01	1.95E-02	2.21E-01	8.98E-01	4.95E+01
		Russell Lake Inlet	7.56E-01	7.56E-01	1.95E-02	2.21E-01	8.98E-01	4.95E+01
	Scaup	Reference (Kratchkowsky Lake)	4.07E-02	4.07E-02	3.45E-02	3.93E-02	4.79E-01	5.85E+01
		Whitefish Lake	4.97E-02	4.97E-02	3.54E-02	4.50E-02	5.50E-01	6.71E+01
		McGowan Lake	4.67E-02	4.67E-02	3.52E-02	4.33E-02	5.06E-01	6.18E+01
		Russell Lake Inlet	4.51E-02	4.51E-02	3.50E-02	4.23E-02	4.95E-01	6.05E+01

Table B.9: Maximun Radiological Doses to Human Receptors during Project Phases

Human Receptor	COPC	Maximum Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Camp Worker Adult (Whitefish Lake)		**Average Baseline**												
	Uranium-238	1.28E-04	3.51E-13	6.33E-06	4.80E-11	1.15E-07	1.27E-03	5.78E-08	6.16E-07	0.00E+00	4.42E-06	1.96E-04	2.98E-04	**1.91E-03**
	Uranium-234	1.54E-04	8.58E-13	6.89E-06	8.37E-12	1.25E-07	6.41E-06	6.29E-08	2.23E-09	0.00E+00	4.81E-06	2.13E-04	3.25E-04	**7.11E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.45E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	1.69E-04	6.71E-04	1.86E-03	**3.54E-03**
	Radium-226	0.00E+00	0.00E+00	5.92E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	2.48E-04	1.30E-02	8.26E-03	**8.19E-02**
	Lead-210	0.00E+00	0.00E+00	1.37E-03	1.21E-09	2.72E-05	6.30E-03	4.62E-05	2.62E-06	0.00E+00	2.74E-03	6.80E-02	3.10E-02	**1.09E-01**
	Polonium-210	0.00E+00	0.00E+00	2.43E-03	7.30E-12	4.24E-05	1.26E-06	8.18E-05	1.12E-08	0.00E+00	1.21E-02	1.55E-01	1.28E-01	**2.99E-01**
		Project Total Dose - Project Phases												
	Uranium-238	1.96E-03	5.37E-12	6.33E-05	4.80E-10	3.10E-07	3.43E-03	3.86E-07	4.12E-06	0.00E+00	4.79E-05	4.34E-04	3.34E-04	**6.28E-03**
	Uranium-234	2.36E-03	1.31E-11	6.89E-05	8.37E-11	3.37E-07	1.73E-05	4.20E-07	1.49E-08	0.00E+00	5.21E-05	4.73E-04	3.64E-04	**3.34E-03**
	Thorium-230	0.00E+00	0.00E+00	1.14E-03	7.76E-10	2.27E-06	3.47E-05	1.16E-06	2.87E-08	0.00E+00	2.61E-04	6.71E-04	2.29E-03	**4.40E-03**
	Radium-226	0.00E+00	0.00E+00	6.53E-04	2.91E-07	2.29E-06	5.93E-02	3.55E-06	4.25E-04	0.00E+00	2.81E-04	1.30E-02	8.27E-03	**8.20E-02**
	Lead-210	0.00E+00	0.00E+00	1.86E-03	1.64E-09	2.72E-05	6.30E-03	5.77E-05	3.26E-06	0.00E+00	3.48E-03	6.80E-02	3.23E-02	**1.12E-01**
	Polonium-210	0.00E+00	0.00E+00	2.97E-03	8.92E-12	4.24E-05	1.26E-06	1.01E-04	1.39E-08	0.00E+00	1.42E-02	1.55E-01	1.41E-01	**3.13E-01**
		Project Incremental Dose - Project Phases												
	Uranium-238	1.83E-03	5.02E-12	5.69E-05	4.32E-10	1.95E-07	2.16E-03	3.28E-07	3.50E-06	0.00E+00	4.35E-05	2.38E-04	3.59E-05	**4.37E-03**
	Uranium-234	2.21E-03	1.23E-11	6.20E-05	7.53E-11	2.12E-07	1.09E-05	3.58E-07	1.27E-08	0.00E+00	4.73E-05	2.60E-04	3.90E-05	**2.63E-03**
	Thorium-230	0.00E+00	0.00E+00	3.40E-04	2.30E-10	1.99E-10	3.06E-09	2.85E-07	7.05E-09	0.00E+00	9.20E-05	2.97E-08	4.31E-04	**8.63E-04**
	Radium-226	0.00E+00	0.00E+00	6.14E-05	2.74E-08	1.82E-12	4.10E-08	2.68E-07	3.21E-05	0.00E+00	3.31E-05	4.66E-09	1.08E-05	**1.38E-04**
	Lead-210	0.00E+00	0.00E+00	4.82E-04	4.24E-10	0.00E+00	0.00E+00	1.15E-05	6.48E-07	0.00E+00	7.32E-04	0.00E+00	1.30E-03	**2.52E-03**
	Polonium-210	0.00E+00	0.00E+00	5.39E-04	1.62E-12	0.00E+00	0.00E+00	1.94E-05	2.66E-09	0.00E+00	2.04E-03	0.00E+00	1.21E-02	**1.47E-02**
	Total by Pathway	**4.03E-03**	**1.73E-11**	**1.54E-03**	**2.86E-08**	**4.07E-07**	**2.17E-03**	**3.21E-05**	**3.63E-05**	**0.00E+00**	**2.98E-03**	**4.98E-04**	**1.39E-02**	**2.52E-02**
Rec F/H Adult (McGowan Lake)		**Average Baseline**												
	Uranium-238	1.28E-04	3.51E-13	6.33E-06	4.80E-11	1.15E-07	1.27E-03	5.78E-08	6.16E-07	0.00E+00	8.84E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.89E-06	8.37E-12	1.25E-07	6.41E-06	6.29E-08	2.23E-09	0.00E+00	9.63E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.45E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.92E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.37E-03	1.21E-09	2.72E-05	6.30E-03	4.62E-05	2.62E-06	0.00E+00	5.49E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.43E-03	7.30E-12	4.24E-05	1.26E-06	8.18E-05	1.12E-08	0.00E+00	2.43E-02	3.11E-01	2.18E-01	**5.56E-01**
		Project Total Dose - Project Phases												
	Uranium-238	4.12E-04	1.13E-12	2.55E-05	1.94E-10	1.44E-07	1.60E-03	1.83E-07	1.95E-06	0.00E+00	9.58E-05	8.69E-04	3.60E-04	**3.37E-03**
	Uranium-234	4.98E-04	2.77E-12	2.78E-05	3.37E-11	1.57E-07	8.07E-06	1.99E-07	7.08E-09	0.00E+00	1.04E-04	9.46E-04	3.92E-04	**1.98E-03**
	Thorium-230	0.00E+00	0.00E+00	9.35E-04	6.34E-10	2.27E-06	3.47E-05	1.00E-06	2.47E-08	0.00E+00	5.23E-04	1.34E-03	3.70E-03	**6.54E-03**
	Radium-226	0.00E+00	0.00E+00	6.24E-04	2.78E-07	2.29E-06	5.93E-02	3.39E-06	4.06E-04	0.00E+00	5.63E-04	2.61E-02	8.24E-03	**9.53E-02**
	Lead-210	0.00E+00	0.00E+00	1.67E-03	1.47E-09	2.72E-05	6.30E-03	4.89E-05	2.77E-06	0.00E+00	6.96E-03	1.36E-01	4.55E-02	**1.97E-01**
	Polonium-210	0.00E+00	0.00E+00	2.87E-03	8.62E-12	4.24E-05	1.26E-06	8.63E-05	1.18E-08	0.00E+00	2.84E-02	3.11E-01	2.42E-01	**5.85E-01**
		Project Incremental Dose - Project Phases												
	Uranium-238	2.84E-04	7.80E-13	1.92E-05	1.46E-10	2.97E-08	3.29E-04	1.25E-07	1.34E-06	0.00E+00	8.69E-05	4.77E-04	7.19E-05	**1.27E-03**
	Uranium-234	3.43E-04	1.91E-12	2.09E-05	2.54E-11	3.23E-08	1.66E-06	1.36E-07	4.85E-09	0.00E+00	9.47E-05	5.19E-04	7.82E-05	**1.06E-03**
	Thorium-230	0.00E+00	0.00E+00	1.31E-04	8.84E-11	3.00E-11	4.62E-10	1.24E-07	3.06E-09	0.00E+00	1.84E-04	5.94E-08	8.57E-04	**1.17E-03**
	Radium-226	0.00E+00	0.00E+00	3.21E-05	1.43E-08	2.27E-13	7.45E-09	1.09E-07	1.31E-05	0.00E+00	6.62E-05	9.31E-09	2.15E-05	**1.33E-04**
	Lead-210	0.00E+00	0.00E+00	2.92E-04	2.58E-10	0.00E+00	0.00E+00	2.63E-06	1.49E-07	0.00E+00	1.47E-03	0.00E+00	2.58E-03	**4.34E-03**
	Polonium-210	0.00E+00	0.00E+00	4.39E-04	1.32E-12	0.00E+00	0.00E+00	4.49E-06	6.16E-10	0.00E+00	4.07E-03	0.00E+00	2.45E-02	**2.90E-02**
	Total by Pathway	**6.28E-04**	**2.69E-12**	**9.34E-04**	**1.49E-08**	**6.20E-08**	**3.31E-04**	**7.61E-06**	**1.46E-05**	**0.00E+00**	**5.97E-03**	**9.96E-04**	**2.81E-02**	**3.70E-02**

Human Receptor	COPC	Maximum Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Rec F/H One-year-old (McGowan Lake)		**Average Baseline**												
	Uranium-238	1.28E-04	4.56E-13	4.40E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.01E-07	0.00E+00	5.21E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.76E-06	2.07E-12	5.05E-06	8.58E-06	2.54E-06	2.90E-09	0.00E+00	5.65E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.09E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.54E-08	1.20E-04	7.94E-02	1.71E-04	5.13E-04	0.00E+00	3.76E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.87E-03	2.46E-10	2.16E-03	8.43E-03	3.68E-03	3.40E-06	0.00E+00	6.33E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.65E-03	1.81E-12	4.75E-03	1.64E-06	9.15E-03	1.46E-08	0.00E+00	3.94E-02	1.25E+00	3.84E-01	**1.69E+00**
		Project Total Dose - Project Phases												
	Uranium-238	4.11E-04	1.47E-12	1.77E-05	4.78E-11	5.87E-06	2.14E-03	7.44E-06	2.54E-06	0.00E+00	5.65E-05	1.15E-03	4.86E-04	**4.28E-03**
	Uranium-234	4.81E-04	3.60E-12	1.92E-05	8.35E-12	6.36E-06	1.08E-05	8.07E-06	9.20E-09	0.00E+00	6.12E-05	1.24E-03	5.27E-04	**2.36E-03**
	Thorium-230	0.00E+00	0.00E+00	4.76E-04	1.57E-10	6.75E-05	3.95E-05	2.98E-05	3.21E-08	0.00E+00	2.26E-04	1.44E-03	1.63E-03	**3.90E-03**
	Radium-226	0.00E+00	0.00E+00	5.57E-04	6.89E-08	1.20E-04	7.94E-02	1.77E-04	5.30E-04	0.00E+00	4.27E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	2.27E-03	2.98E-10	2.16E-03	8.43E-03	3.89E-03	3.60E-06	0.00E+00	8.02E-03	3.89E-01	7.29E-02	**4.87E-01**
	Polonium-210	0.00E+00	0.00E+00	5.48E-03	2.14E-12	4.75E-03	1.64E-06	9.65E-03	1.54E-08	0.00E+00	4.60E-02	1.25E+00	4.16E-01	**1.73E+00**
		Project Incremental Dose - Project Phases												
	Uranium-238	2.84E-04	1.01E-12	1.33E-05	3.60E-11	1.21E-06	4.40E-04	5.10E-06	1.74E-06	0.00E+00	5.12E-05	5.90E-04	2.82E-05	**1.41E-03**
	Uranium-234	3.32E-04	2.48E-12	1.44E-05	6.28E-12	1.31E-06	2.22E-06	5.52E-06	6.30E-09	0.00E+00	5.55E-05	6.39E-04	3.06E-05	**1.08E-03**
	Thorium-230	0.00E+00	0.00E+00	6.64E-05	2.19E-11	9.02E-10	5.24E-10	3.68E-06	3.97E-09	0.00E+00	7.94E-05	6.37E-08	2.06E-04	**3.55E-04**
	Radium-226	0.00E+00	0.00E+00	2.87E-05	3.55E-09	1.46E-11	7.45E-09	5.70E-06	1.71E-05	0.00E+00	5.01E-05	2.24E-08	8.82E-06	**1.10E-04**
	Lead-210	0.00E+00	0.00E+00	3.97E-04	5.22E-11	0.00E+00	0.00E+00	2.09E-04	1.93E-07	0.00E+00	1.69E-03	0.00E+00	1.66E-03	**3.96E-03**
	Polonium-210	0.00E+00	0.00E+00	8.39E-04	3.27E-13	0.00E+00	0.00E+00	5.02E-04	8.00E-10	0.00E+00	6.60E-03	0.00E+00	3.21E-02	**4.00E-02**
	Total by Pathway	**6.15E-04**	**3.50E-12**	**1.36E-03**	**3.67E-09**	**2.51E-06**	**4.43E-04**	**7.31E-04**	**1.90E-05**	**0.00E+00**	**8.53E-03**	**1.23E-03**	**3.40E-02**	**4.69E-02**
Rec F/H Adult (Russell Lake)		**Average Baseline**												
	Uranium-238	1.28E-04	3.51E-13	6.33E-06	4.80E-11	1.15E-07	1.27E-03	5.78E-08	6.16E-07	0.00E+00	8.84E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.89E-06	8.37E-12	1.25E-07	6.41E-06	6.29E-08	2.23E-09	0.00E+00	9.63E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.45E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.92E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.37E-03	1.21E-09	2.72E-05	6.30E-03	4.62E-05	2.62E-06	0.00E+00	5.49E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.43E-03	7.30E-12	4.24E-05	1.26E-06	8.18E-05	1.12E-08	0.00E+00	2.43E-02	3.11E-01	2.18E-01	**5.56E-01**
		Project Total Dose - Project Phases												
	Uranium-238	2.04E-04	5.59E-13	2.01E-05	1.53E-10	1.23E-07	1.36E-03	1.49E-07	1.59E-06	0.00E+00	7.15E-05	5.19E-04	3.31E-04	**2.51E-03**
	Uranium-234	2.46E-04	1.37E-12	2.19E-05	2.66E-11	1.34E-07	6.86E-06	1.63E-07	5.77E-09	0.00E+00	7.79E-05	5.65E-04	3.60E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	9.02E-04	6.11E-10	2.27E-06	3.47E-05	9.70E-07	2.40E-08	0.00E+00	4.77E-04	1.34E-03	3.49E-03	**6.25E-03**
	Radium-226	0.00E+00	0.00E+00	6.19E-04	2.76E-07	2.29E-06	5.93E-02	3.36E-06	4.03E-04	0.00E+00	5.47E-04	2.61E-02	8.24E-03	**9.52E-02**
	Lead-210	0.00E+00	0.00E+00	1.64E-03	1.45E-09	2.72E-05	6.30E-03	4.78E-05	2.71E-06	0.00E+00	6.66E-03	1.36E-01	4.49E-02	**1.96E-01**
	Polonium-210	0.00E+00	0.00E+00	2.86E-03	8.60E-12	4.24E-05	1.26E-06	8.45E-05	1.16E-08	0.00E+00	2.80E-02	3.11E-01	2.33E-01	**5.75E-01**
		Project Incremental Dose - Project Phases												
	Uranium-238	7.60E-05	2.08E-13	1.38E-05	1.05E-10	7.92E-09	8.79E-05	9.15E-08	9.76E-07	0.00E+00	6.27E-05	1.27E-04	4.23E-05	**4.11E-04**
	Uranium-234	9.17E-05	5.10E-13	1.50E-05	1.82E-11	8.63E-09	4.43E-07	9.97E-08	3.54E-09	0.00E+00	6.83E-05	1.39E-04	4.60E-05	**3.60E-04**
	Thorium-230	0.00E+00	0.00E+00	9.75E-05	6.61E-11	7.73E-12	1.20E-10	9.40E-08	2.32E-09	0.00E+00	1.39E-04	1.59E-08	6.45E-04	**8.81E-04**
	Radium-226	0.00E+00	0.00E+00	2.75E-05	1.23E-08	0.00E+00	0.00E+00	8.11E-08	9.72E-06	0.00E+00	4.99E-05	1.86E-09	1.66E-05	**1.04E-04**
	Lead-210	0.00E+00	0.00E+00	2.71E-04	2.39E-10	0.00E+00	0.00E+00	1.60E-06	9.03E-08	0.00E+00	1.17E-03	0.00E+00	2.03E-03	**3.47E-03**
	Polonium-210	0.00E+00	0.00E+00	4.30E-04	1.29E-12	0.00E+00	0.00E+00	2.72E-06	3.74E-10	0.00E+00	3.66E-03	0.00E+00	1.48E-02	**1.89E-02**
	Total by Pathway	**1.68E-04**	**7.18E-13**	**8.55E-04**	**1.27E-08**	**1.66E-08**	**8.83E-05**	**4.69E-06**	**1.08E-05**	**0.00E+00**	**5.15E-03**	**2.66E-04**	**1.76E-02**	**2.42E-02**

Human Receptor	COPC	Maximum Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Rec F/H One-year-old (Russell Lake)		Average Baseline												
	Uranium-238	1.28E-04	4.56E-13	4.40E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.01E-07	0.00E+00	5.21E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.76E-06	2.07E-12	5.05E-06	8.58E-06	2.54E-06	2.90E-09	0.00E+00	5.65E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.09E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.54E-08	1.20E-04	7.94E-02	1.71E-04	5.13E-04	0.00E+00	3.76E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.87E-03	2.46E-10	2.16E-03	8.43E-03	3.68E-03	3.40E-06	0.00E+00	6.33E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.65E-03	1.81E-12	4.75E-03	1.64E-06	9.15E-03	1.46E-08	0.00E+00	3.94E-02	1.25E+00	3.84E-01	**1.69E+00**
		Project Total Dose - Project Phases												
	Uranium-238	2.03E-04	7.27E-13	1.40E-05	3.77E-11	4.99E-06	1.82E-03	6.07E-06	2.07E-06	0.00E+00	4.22E-05	7.16E-04	4.74E-04	**3.28E-03**
	Uranium-234	2.38E-04	1.78E-12	1.51E-05	6.58E-12	5.40E-06	9.18E-06	6.58E-06	7.50E-09	0.00E+00	4.57E-05	7.75E-04	5.14E-04	**1.61E-03**
	Thorium-230	0.00E+00	0.00E+00	4.59E-04	1.51E-10	6.75E-05	3.95E-05	2.89E-05	3.12E-08	0.00E+00	2.06E-04	1.44E-03	1.58E-03	**3.82E-03**
	Radium-226	0.00E+00	0.00E+00	5.53E-04	6.84E-08	1.20E-04	7.94E-02	1.76E-04	5.25E-04	0.00E+00	4.14E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	2.24E-03	2.94E-10	2.16E-03	8.43E-03	3.81E-03	3.52E-06	0.00E+00	7.68E-03	3.89E-01	7.25E-02	**4.86E-01**
	Polonium-210	0.00E+00	0.00E+00	5.47E-03	2.13E-12	4.75E-03	1.64E-06	9.46E-03	1.51E-08	0.00E+00	4.53E-02	1.25E+00	4.04E-01	**1.72E+00**
		Project Incremental Dose - Project Phases												
	Uranium-238	7.57E-05	2.71E-13	9.58E-06	2.58E-11	3.22E-07	1.18E-04	3.72E-06	1.27E-06	0.00E+00	3.69E-05	1.57E-04	1.65E-05	**4.19E-04**
	Uranium-234	8.86E-05	6.63E-13	1.04E-05	4.51E-12	3.49E-07	5.93E-07	4.03E-06	4.60E-09	0.00E+00	4.00E-05	1.71E-04	1.79E-05	**3.32E-04**
	Thorium-230	0.00E+00	0.00E+00	4.96E-05	1.64E-11	2.40E-10	1.42E-10	2.80E-06	3.02E-09	0.00E+00	5.98E-05	1.70E-08	1.55E-04	**2.67E-04**
	Radium-226	0.00E+00	0.00E+00	2.46E-05	3.04E-09	0.00E+00	0.00E+00	4.24E-06	1.27E-05	0.00E+00	3.78E-05	3.73E-09	6.80E-06	**8.61E-05**
	Lead-210	0.00E+00	0.00E+00	3.68E-04	4.84E-11	0.00E+00	0.00E+00	1.27E-04	1.17E-07	0.00E+00	1.35E-03	0.00E+00	1.30E-03	**3.15E-03**
	Polonium-210	0.00E+00	0.00E+00	8.22E-04	3.20E-13	0.00E+00	0.00E+00	3.05E-04	4.86E-10	0.00E+00	5.94E-03	0.00E+00	1.94E-02	**2.64E-02**
	Total by Pathway	**1.64E-04**	**9.34E-13**	**1.28E-03**	**3.14E-09**	**6.71E-07**	**1.18E-04**	**4.46E-04**	**1.41E-05**	**0.00E+00**	**7.46E-03**	**3.28E-04**	**2.09E-02**	3.07E-02
Seasonal Resident Adult (Russell Lake)		Average Baseline												
	Uranium-238	1.28E-04	3.51E-13	6.33E-06	4.80E-11	1.15E-07	1.27E-03	5.78E-08	6.16E-07	0.00E+00	8.84E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.89E-06	8.37E-12	1.25E-07	6.41E-06	6.29E-08	2.23E-09	0.00E+00	9.63E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.45E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.92E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.37E-03	1.21E-09	2.72E-05	6.30E-03	4.62E-05	2.62E-06	0.00E+00	5.49E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.43E-03	7.30E-12	4.24E-05	1.26E-06	8.18E-05	1.12E-08	0.00E+00	2.43E-02	3.11E-01	2.18E-01	**5.56E-01**
		Project Total Dose - Project Phases												
	Uranium-238	2.04E-04	5.59E-13	2.01E-05	1.53E-10	1.23E-07	1.36E-03	1.49E-07	1.59E-06	0.00E+00	2.74E-05	4.30E-04	3.07E-04	**2.35E-03**
	Uranium-234	2.46E-04	1.37E-12	2.19E-05	2.66E-11	1.34E-07	6.86E-06	1.63E-07	5.77E-09	0.00E+00	2.99E-05	4.68E-04	3.35E-04	**1.11E-03**
	Thorium-230	0.00E+00	0.00E+00	9.02E-04	6.11E-10	2.27E-06	3.47E-05	9.70E-07	2.40E-08	0.00E+00	3.79E-04	1.34E-03	3.03E-03	**5.69E-03**
	Radium-226	0.00E+00	0.00E+00	6.19E-04	2.76E-07	2.29E-06	5.93E-02	3.36E-06	4.03E-04	0.00E+00	5.19E-04	2.61E-02	8.23E-03	**9.52E-02**
	Lead-210	0.00E+00	0.00E+00	1.64E-03	1.45E-09	2.72E-05	6.30E-03	4.78E-05	2.71E-06	0.00E+00	6.50E-03	1.36E-01	4.45E-02	**1.95E-01**
	Polonium-210	0.00E+00	0.00E+00	2.86E-03	8.60E-12	4.24E-05	1.26E-06	8.45E-05	1.16E-08	0.00E+00	2.83E-02	3.11E-01	2.23E-01	**5.65E-01**
		Project Incremental Dose - Project Phases												
	Uranium-238	7.60E-05	2.08E-13	1.38E-05	1.05E-10	7.92E-09	8.79E-05	9.15E-08	9.76E-07	0.00E+00	1.86E-05	3.83E-05	1.91E-05	**2.55E-04**
	Uranium-234	9.17E-05	5.10E-13	1.50E-05	1.82E-11	8.63E-09	4.43E-07	9.97E-08	3.54E-09	0.00E+00	2.03E-05	4.18E-05	2.08E-05	**1.90E-04**
	Thorium-230	0.00E+00	0.00E+00	9.75E-05	6.61E-11	7.73E-12	1.20E-10	9.40E-08	2.32E-09	0.00E+00	4.05E-05	4.77E-09	1.85E-04	**3.23E-04**
	Radium-226	0.00E+00	0.00E+00	2.75E-05	1.23E-08	0.00E+00	0.00E+00	8.11E-08	9.72E-06	0.00E+00	2.17E-05	0.00E+00	7.15E-06	**6.62E-05**
	Lead-210	0.00E+00	0.00E+00	2.71E-04	2.39E-10	0.00E+00	0.00E+00	1.60E-06	9.03E-08	0.00E+00	1.01E-03	0.00E+00	1.67E-03	**2.96E-03**
	Polonium-210	0.00E+00	0.00E+00	4.30E-04	1.29E-12	0.00E+00	0.00E+00	2.72E-06	3.74E-10	0.00E+00	4.02E-03	0.00E+00	4.82E-03	**9.28E-03**
	Total by Pathway	**1.68E-04**	**7.18E-13**	**8.55E-04**	**1.27E-08**	**1.66E-08**	**8.83E-05**	**4.69E-06**	**1.08E-05**	**0.00E+00**	**5.13E-03**	**8.01E-05**	**6.73E-03**	1.31E-02

Human Receptor	COPC	Maximum Dose by Pathway during Project Phases (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Seasonal Resident One-year-old (Russell Lake)	**Average Baseline**													
	Uranium-238	1.28E-04	4.56E-13	4.40E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.01E-07	0.00E+00	5.21E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.76E-06	2.07E-12	5.05E-06	8.58E-06	2.54E-06	2.90E-09	0.00E+00	5.65E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.09E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.54E-08	1.20E-04	7.94E-02	1.71E-04	5.13E-04	0.00E+00	3.76E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.87E-03	2.46E-10	2.16E-03	8.43E-03	3.68E-03	3.40E-06	0.00E+00	6.33E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.65E-03	1.81E-12	4.75E-03	1.64E-06	9.15E-03	1.46E-08	0.00E+00	3.94E-02	1.25E+00	3.84E-01	**1.69E+00**
	Project Total Dose - Project Phases													
	Uranium-238	2.03E-04	7.27E-13	1.40E-05	3.77E-11	4.99E-06	1.82E-03	6.07E-06	2.07E-06	0.00E+00	1.62E-05	6.05E-04	4.65E-04	**3.14E-03**
	Uranium-234	2.38E-04	1.78E-12	1.51E-05	6.58E-12	5.40E-06	9.18E-06	6.58E-06	7.50E-09	0.00E+00	1.75E-05	6.56E-04	5.04E-04	**1.45E-03**
	Thorium-230	0.00E+00	0.00E+00	4.59E-04	1.51E-10	6.75E-05	3.95E-05	2.89E-05	3.12E-08	0.00E+00	1.64E-04	1.44E-03	1.47E-03	**3.66E-03**
	Radium-226	0.00E+00	0.00E+00	5.53E-04	6.84E-08	1.20E-04	7.94E-02	1.76E-04	5.25E-04	0.00E+00	3.93E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	2.24E-03	2.94E-10	2.16E-03	8.43E-03	3.81E-03	3.52E-06	0.00E+00	7.50E-03	3.89E-01	7.23E-02	**4.86E-01**
	Polonium-210	0.00E+00	0.00E+00	5.47E-03	2.13E-12	4.75E-03	1.64E-06	9.46E-03	1.51E-08	0.00E+00	4.59E-02	1.25E+00	3.90E-01	**1.71E+00**
	Project Incremental Dose - Project Phases													
	Uranium-238	7.57E-05	2.71E-13	9.58E-06	2.58E-11	3.22E-07	1.18E-04	3.72E-06	1.27E-06	0.00E+00	1.10E-05	4.71E-05	7.17E-06	**2.73E-04**
	Uranium-234	8.86E-05	6.63E-13	1.04E-05	4.51E-12	3.49E-07	5.93E-07	4.03E-06	4.60E-09	0.00E+00	1.19E-05	5.11E-05	7.77E-06	**1.75E-04**
	Thorium-230	0.00E+00	0.00E+00	4.96E-05	1.64E-11	2.40E-10	1.42E-10	2.80E-06	3.02E-09	0.00E+00	1.75E-05	5.12E-09	4.30E-05	**1.13E-04**
	Radium-226	0.00E+00	0.00E+00	2.46E-05	3.04E-09	0.00E+00	0.00E+00	4.24E-06	1.27E-05	0.00E+00	1.65E-05	3.73E-09	2.97E-06	**6.10E-05**
	Lead-210	0.00E+00	0.00E+00	3.68E-04	4.84E-11	0.00E+00	0.00E+00	1.27E-04	1.17E-07	0.00E+00	1.17E-03	0.00E+00	1.07E-03	**2.73E-03**
	Polonium-210	0.00E+00	0.00E+00	8.22E-04	3.20E-13	0.00E+00	0.00E+00	3.05E-04	4.86E-10	0.00E+00	6.52E-03	0.00E+00	5.86E-03	**1.35E-02**
	Total by Pathway	**1.64E-04**	**9.34E-13**	**1.28E-03**	**3.14E-09**	**6.71E-07**	**1.18E-04**	**4.46E-04**	**1.41E-05**	**0.00E+00**	**7.74E-03**	**9.82E-05**	**6.99E-03**	**1.69E-02**
Fisher/ Trapper Adult (Russell Lake)	**Average Baseline**													
	Uranium-238	1.28E-04	3.51E-13	6.33E-06	4.80E-11	1.15E-07	1.27E-03	5.78E-08	6.16E-07	0.00E+00	6.09E-05	0.00E+00	1.98E-04	**1.67E-03**
	Uranium-234	1.54E-04	8.58E-13	6.89E-06	8.37E-12	1.25E-07	6.41E-06	6.29E-08	2.23E-09	0.00E+00	6.63E-05	0.00E+00	2.15E-04	**4.50E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.45E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	2.33E-03	0.00E+00	7.78E-04	**3.95E-03**
	Radium-226	0.00E+00	0.00E+00	5.92E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	3.42E-03	0.00E+00	9.66E-03	**7.34E-02**
	Lead-210	0.00E+00	0.00E+00	1.37E-03	1.21E-09	2.72E-05	6.30E-03	4.62E-05	2.62E-06	0.00E+00	3.78E-02	0.00E+00	2.26E-01	**2.71E-01**
	Polonium-210	0.00E+00	0.00E+00	2.43E-03	7.30E-12	4.24E-05	1.26E-06	8.18E-05	1.12E-08	0.00E+00	1.67E-01	0.00E+00	1.89E+00	**2.06E+00**
	Project Total Dose - Project Phases													
	Uranium-238	2.55E-04	6.98E-13	2.95E-05	2.24E-10	1.28E-07	1.42E-03	2.10E-07	2.24E-06	0.00E+00	4.92E-04	0.00E+00	1.28E-03	**3.47E-03**
	Uranium-234	3.07E-04	1.71E-12	3.21E-05	3.89E-11	1.39E-07	7.15E-06	2.29E-07	8.13E-09	0.00E+00	5.36E-04	0.00E+00	1.39E-03	**2.27E-03**
	Thorium-230	0.00E+00	0.00E+00	9.70E-04	6.57E-10	2.27E-06	3.47E-05	1.03E-06	2.55E-08	0.00E+00	3.29E-03	0.00E+00	8.44E-04	**5.14E-03**
	Radium-226	0.00E+00	0.00E+00	6.28E-04	2.80E-07	2.29E-06	5.93E-02	3.41E-06	4.09E-04	0.00E+00	3.76E-03	0.00E+00	9.76E-03	**7.39E-02**
	Lead-210	0.00E+00	0.00E+00	1.65E-03	1.46E-09	2.72E-05	6.30E-03	4.89E-05	2.77E-06	0.00E+00	4.59E-02	0.00E+00	2.28E-01	**2.82E-01**
	Polonium-210	0.00E+00	0.00E+00	2.85E-03	8.55E-12	4.24E-05	1.26E-06	8.63E-05	1.18E-08	0.00E+00	1.92E-01	0.00E+00	1.91E+00	**2.10E+00**
	Project Incremental Dose - Project Phases													
	Uranium-238	1.27E-04	3.47E-13	2.31E-05	1.76E-10	1.32E-08	1.46E-04	1.53E-07	1.63E-06	0.00E+00	4.32E-04	0.00E+00	1.08E-03	**1.81E-03**
	Uranium-234	1.53E-04	8.50E-13	2.52E-05	3.06E-11	1.44E-08	7.38E-07	1.66E-07	5.90E-09	0.00E+00	4.70E-04	0.00E+00	1.17E-03	**1.82E-03**
	Thorium-230	0.00E+00	0.00E+00	1.65E-04	1.12E-10	1.32E-11	2.04E-10	1.57E-07	3.88E-09	0.00E+00	9.53E-04	0.00E+00	6.56E-05	**1.18E-03**
	Radium-226	0.00E+00	0.00E+00	3.65E-05	1.63E-08	0.00E+00	0.00E+00	1.35E-07	1.62E-05	0.00E+00	3.43E-04	0.00E+00	1.04E-04	**5.00E-04**
	Lead-210	0.00E+00	0.00E+00	2.81E-04	2.47E-10	0.00E+00	0.00E+00	2.63E-06	1.49E-07	0.00E+00	8.06E-03	0.00E+00	2.25E-03	**1.06E-02**
	Polonium-210	0.00E+00	0.00E+00	4.15E-04	1.25E-12	0.00E+00	0.00E+00	4.48E-06	6.15E-10	0.00E+00	2.52E-02	0.00E+00	1.56E-02	**4.12E-02**
	Total by Pathway	**2.79E-04**	**1.20E-12**	**9.45E-04**	**1.68E-08**	**2.76E-08**	**1.47E-04**	**7.72E-06**	**1.80E-05**	**0.00E+00**	**3.55E-02**	**0.00E+00**	**2.02E-02**	**5.71E-02**

Table B.10: Maximun Radiological Doses to Human Receptors during Future Centuries

Human receptor	COPC	Maximum Dose by Pathway during Future Centuries (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Permanent Resident Adult (Whitefish Lake)		Baseline Dose												
	Uranium-238	1.28E-04	3.51E-13	6.34E-06	4.81E-11	1.15E-07	1.27E-03	5.79E-08	6.17E-07	0.00E+00	8.86E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.91E-06	8.39E-12	1.25E-07	6.41E-06	6.30E-08	2.24E-09	0.00E+00	9.65E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.46E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.93E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.38E-03	1.22E-09	2.72E-05	6.30E-03	4.64E-05	2.63E-06	0.00E+00	5.52E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.44E-03	7.34E-12	4.24E-05	1.26E-06	8.21E-05	1.13E-08	0.00E+00	2.44E-02	3.11E-01	2.18E-01	**5.56E-01**
		Project Total Dose - Future Centuries												
	Uranium-238	1.28E-04	3.51E-13	7.76E-06	5.89E-11	1.37E-07	1.52E-03	7.08E-08	7.55E-07	0.00E+00	1.08E-05	5.30E-04	2.90E-04	**2.48E-03**
	Uranium-234	1.54E-04	8.58E-13	8.45E-06	1.03E-11	1.49E-07	7.65E-06	7.71E-08	2.74E-09	0.00E+00	1.18E-05	5.77E-04	3.16E-04	**1.07E-03**
	Thorium-230	0.00E+00	0.00E+00	8.26E-04	5.60E-10	2.27E-06	3.48E-05	9.00E-07	2.22E-08	0.00E+00	3.48E-04	1.34E-03	2.87E-03	**5.43E-03**
	Radium-226	0.00E+00	0.00E+00	6.79E-04	3.03E-07	2.29E-06	5.93E-02	3.76E-06	4.51E-04	0.00E+00	5.70E-04	2.61E-02	8.24E-03	**9.54E-02**
	Lead-210	0.00E+00	0.00E+00	1.58E-03	1.40E-09	2.72E-05	6.30E-03	5.33E-05	3.01E-06	0.00E+00	6.33E-03	1.36E-01	4.36E-02	**1.94E-01**
	Polonium-210	0.00E+00	0.00E+00	2.80E-03	8.42E-12	4.24E-05	1.26E-06	9.42E-05	1.29E-08	0.00E+00	2.80E-02	3.11E-01	2.39E-01	**5.81E-01**
		Project Incremental Dose - Future Centuries												
	Uranium-238	0.00E+00	0.00E+00	1.42E-06	1.07E-11	2.20E-08	2.44E-04	1.29E-08	1.38E-07	0.00E+00	1.98E-06	1.38E-04	1.48E-06	**3.87E-04**
	Uranium-234	0.00E+00	0.00E+00	1.54E-06	1.87E-12	2.40E-08	1.23E-06	1.41E-08	4.99E-10	0.00E+00	2.15E-06	1.50E-04	1.62E-06	**1.57E-04**
	Thorium-230	0.00E+00	0.00E+00	2.12E-05	1.44E-11	7.69E-10	1.18E-08	2.31E-08	5.71E-10	0.00E+00	8.93E-06	8.84E-07	3.11E-05	**6.22E-05**
	Radium-226	0.00E+00	0.00E+00	8.68E-05	3.87E-08	9.39E-11	2.43E-06	4.80E-07	5.75E-05	0.00E+00	7.28E-05	2.07E-06	2.40E-05	**2.46E-04**
	Lead-210	0.00E+00	0.00E+00	2.03E-04	1.79E-10	0.00E+00	0.00E+00	6.83E-06	3.86E-07	0.00E+00	8.12E-04	0.00E+00	7.09E-04	**1.73E-03**
	Polonium-210	0.00E+00	0.00E+00	3.59E-04	1.08E-12	0.00E+00	0.00E+00	1.21E-05	1.66E-09	0.00E+00	3.59E-03	0.00E+00	2.02E-02	**2.42E-02**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**6.73E-04**	**3.89E-08**	**4.68E-08**	**2.48E-04**	**1.94E-05**	**5.81E-05**	**0.00E+00**	**4.49E-03**	**2.91E-04**	**2.10E-02**	**2.67E-02**
Permanent Resident One-year-old (Whitefish Lake)		Baseline Dose												
	Uranium-238	1.28E-04	4.56E-13	4.41E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.02E-07	0.00E+00	5.22E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.78E-06	2.08E-12	5.05E-06	8.58E-06	2.55E-06	2.91E-09	0.00E+00	5.66E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.10E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.55E-08	1.20E-04	7.94E-02	1.72E-04	5.13E-04	0.00E+00	3.77E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.88E-03	2.47E-10	2.16E-03	8.43E-03	3.69E-03	3.42E-06	0.00E+00	6.36E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.67E-03	1.82E-12	4.75E-03	1.64E-06	9.19E-03	1.46E-08	0.00E+00	3.96E-02	1.25E+00	3.85E-01	**1.69E+00**
		Project Total Dose - Future Centuries												
	Uranium-238	1.28E-04	4.56E-13	5.39E-06	1.46E-11	5.56E-06	2.03E-03	2.88E-06	9.81E-07	0.00E+00	6.39E-06	7.60E-04	4.59E-04	**3.40E-03**
	Uranium-234	1.49E-04	1.12E-12	5.84E-06	2.54E-12	6.02E-06	1.02E-05	3.12E-06	3.56E-09	0.00E+00	6.92E-06	8.23E-04	4.97E-04	**1.50E-03**
	Thorium-230	0.00E+00	0.00E+00	4.20E-04	1.39E-10	6.75E-05	3.95E-05	2.68E-05	2.89E-08	0.00E+00	1.50E-04	1.44E-03	1.43E-03	**3.57E-03**
	Radium-226	0.00E+00	0.00E+00	6.07E-04	7.51E-08	1.20E-04	7.94E-02	1.97E-04	5.88E-04	0.00E+00	4.32E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	2.15E-03	2.83E-10	2.16E-03	8.43E-03	4.24E-03	3.92E-06	0.00E+00	7.30E-03	3.89E-01	7.17E-02	**4.85E-01**
	Polonium-210	0.00E+00	0.00E+00	5.36E-03	2.09E-12	4.75E-03	1.64E-06	1.05E-02	1.68E-08	0.00E+00	4.54E-02	1.25E+00	4.12E-01	**1.73E+00**
		Project Incremental Dose - Future Centuries												
	Uranium-238	0.00E+00	0.00E+00	9.84E-07	2.66E-12	8.95E-07	3.27E-04	5.25E-07	1.79E-07	0.00E+00	1.17E-06	2.02E-04	6.43E-07	**5.33E-04**
	Uranium-234	0.00E+00	0.00E+00	1.07E-06	4.64E-13	9.70E-07	1.65E-06	5.69E-07	6.49E-10	0.00E+00	1.26E-06	2.19E-04	6.97E-07	**2.25E-04**
	Thorium-230	0.00E+00	0.00E+00	1.08E-05	3.56E-12	2.29E-08	1.34E-08	6.88E-07	7.42E-10	0.00E+00	3.85E-06	9.46E-07	7.46E-06	**2.38E-05**
	Radium-226	0.00E+00	0.00E+00	7.75E-05	9.59E-09	4.90E-09	3.26E-06	2.51E-05	7.51E-05	0.00E+00	5.52E-05	3.90E-06	9.87E-06	**2.50E-04**
	Lead-210	0.00E+00	0.00E+00	2.76E-04	3.63E-11	0.00E+00	0.00E+00	5.43E-04	5.02E-07	0.00E+00	9.36E-04	0.00E+00	4.63E-04	**2.22E-03**
	Polonium-210	0.00E+00	0.00E+00	6.87E-04	2.68E-13	0.00E+00	0.00E+00	1.35E-03	2.15E-09	0.00E+00	5.82E-03	0.00E+00	2.65E-02	**3.43E-02**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**1.05E-03**	**9.63E-09**	**1.89E-06**	**3.32E-04**	**1.92E-03**	**7.58E-05**	**0.00E+00**	**6.82E-03**	**4.26E-04**	**2.69E-02**	**3.76E-02**

Human receptor	COPC	Maximum Dose by Pathway during Future Centuries (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Rec F/H Adult (McGowan Lake)	**Baseline Dose**													
	Uranium-238	1.28E-04	3.51E-13	6.34E-06	4.81E-11	1.15E-07	1.27E-03	5.79E-08	6.17E-07	0.00E+00	8.86E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.91E-06	8.39E-12	1.25E-07	6.41E-06	6.30E-08	2.24E-09	0.00E+00	9.65E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.46E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.93E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.38E-03	1.22E-09	2.72E-05	6.30E-03	4.64E-05	2.63E-06	0.00E+00	5.52E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.44E-03	7.34E-12	4.24E-05	1.26E-06	8.21E-05	1.13E-08	0.00E+00	2.44E-02	3.11E-01	2.18E-01	**5.56E-01**
	Project Total Dose - Future Centuries													
	Uranium-238	1.28E-04	3.51E-13	6.63E-06	5.03E-11	1.16E-07	1.29E-03	6.04E-08	6.45E-07	0.00E+00	1.02E-05	4.10E-04	2.89E-04	**2.14E-03**
	Uranium-234	1.54E-04	8.58E-13	7.21E-06	8.76E-12	1.27E-07	6.51E-06	6.58E-08	2.34E-09	0.00E+00	1.11E-05	4.46E-04	3.15E-04	**9.40E-04**
	Thorium-230	0.00E+00	0.00E+00	8.10E-04	5.49E-10	2.27E-06	3.47E-05	8.82E-07	2.18E-08	0.00E+00	3.46E-04	1.34E-03	2.87E-03	**5.41E-03**
	Radium-226	0.00E+00	0.00E+00	6.11E-04	2.73E-07	2.29E-06	5.93E-02	3.38E-06	4.06E-04	0.00E+00	5.49E-04	2.61E-02	8.24E-03	**9.52E-02**
	Lead-210	0.00E+00	0.00E+00	1.40E-03	1.24E-09	2.72E-05	6.30E-03	4.72E-05	2.67E-06	0.00E+00	5.83E-03	1.36E-01	4.35E-02	**1.93E-01**
	Polonium-210	0.00E+00	0.00E+00	2.48E-03	7.46E-12	4.24E-05	1.26E-06	8.35E-05	1.15E-08	0.00E+00	2.58E-02	3.11E-01	2.26E-01	**5.65E-01**
	Project Incremental Dose - Future Centuries													
	Uranium-238	0.00E+00	0.00E+00	2.82E-07	2.14E-12	1.67E-09	1.86E-05	2.57E-09	2.75E-08	0.00E+00	1.31E-06	1.80E-05	6.51E-07	**3.89E-05**
	Uranium-234	0.00E+00	0.00E+00	3.07E-07	3.73E-13	1.82E-09	9.36E-08	2.80E-09	9.95E-11	0.00E+00	1.43E-06	1.96E-05	7.09E-07	**2.22E-05**
	Thorium-230	0.00E+00	0.00E+00	4.78E-06	3.24E-12	5.84E-11	8.91E-10	5.20E-09	1.29E-10	0.00E+00	6.70E-06	1.15E-07	3.09E-05	**4.25E-05**
	Radium-226	0.00E+00	0.00E+00	1.82E-05	8.15E-09	7.05E-12	1.83E-07	1.01E-07	1.21E-05	0.00E+00	5.11E-05	2.68E-07	1.76E-05	**9.96E-05**
	Lead-210	0.00E+00	0.00E+00	2.31E-05	2.03E-11	0.00E+00	0.00E+00	7.76E-07	4.39E-08	0.00E+00	3.07E-04	0.00E+00	5.62E-04	**8.93E-04**
	Polonium-210	0.00E+00	0.00E+00	4.08E-05	1.23E-13	0.00E+00	0.00E+00	1.37E-06	1.88E-10	0.00E+00	1.36E-03	0.00E+00	7.67E-03	**9.07E-03**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**8.75E-05**	**8.17E-09**	**3.56E-09**	**1.88E-05**	**2.26E-06**	**1.22E-05**	**0.00E+00**	**1.73E-03**	**3.80E-05**	**8.28E-03**	**1.02E-02**
Rec F/H One-year-old (McGowan Lake)	**Baseline Dose**													
	Uranium-238	1.28E-04	4.56E-13	4.41E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.02E-07	0.00E+00	5.22E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.78E-06	2.08E-12	5.05E-06	8.58E-06	2.55E-06	2.91E-09	0.00E+00	5.66E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.10E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.55E-08	1.20E-04	7.94E-02	1.72E-04	5.13E-04	0.00E+00	3.77E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.88E-03	2.47E-10	2.16E-03	8.43E-03	3.69E-03	3.42E-06	0.00E+00	6.36E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.67E-03	1.82E-12	4.75E-03	1.64E-06	9.19E-03	1.46E-08	0.00E+00	3.96E-02	1.25E+00	3.85E-01	**1.69E+00**
	Project Total Dose - Future Centuries													
	Uranium-238	1.28E-04	4.56E-13	4.60E-06	1.24E-11	4.73E-06	1.73E-03	2.46E-06	8.38E-07	0.00E+00	6.00E-06	5.85E-04	4.58E-04	**2.92E-03**
	Uranium-234	1.49E-04	1.12E-12	4.99E-06	2.17E-12	5.13E-06	8.71E-06	2.66E-06	3.04E-09	0.00E+00	6.50E-06	6.33E-04	4.96E-04	**1.31E-03**
	Thorium-230	0.00E+00	0.00E+00	4.12E-04	1.36E-10	6.75E-05	3.95E-05	2.62E-05	2.83E-08	0.00E+00	1.49E-04	1.44E-03	1.43E-03	**3.56E-03**
	Radium-226	0.00E+00	0.00E+00	5.46E-04	6.75E-08	1.20E-04	7.94E-02	1.77E-04	5.29E-04	0.00E+00	4.16E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.91E-03	2.51E-10	2.16E-03	8.43E-03	3.76E-03	3.47E-06	0.00E+00	6.72E-03	3.89E-01	7.16E-02	**4.84E-01**
	Polonium-210	0.00E+00	0.00E+00	4.75E-03	1.85E-12	4.75E-03	1.64E-06	9.34E-03	1.49E-08	0.00E+00	4.18E-02	1.25E+00	3.95E-01	**1.71E+00**
	Project Incremental Dose - Future Centuries													
	Uranium-238	0.00E+00	0.00E+00	1.96E-07	5.30E-13	6.81E-08	2.48E-05	1.05E-07	3.57E-08	0.00E+00	7.75E-07	2.63E-05	2.95E-07	**5.27E-05**
	Uranium-234	0.00E+00	0.00E+00	2.13E-07	9.24E-14	7.38E-08	1.25E-07	1.13E-07	1.29E-10	0.00E+00	8.39E-07	2.85E-05	3.19E-07	**3.02E-05**
	Thorium-230	0.00E+00	0.00E+00	2.43E-06	8.02E-13	1.75E-09	1.02E-09	1.55E-07	1.67E-10	0.00E+00	2.89E-06	1.23E-07	7.40E-06	**1.30E-05**
	Radium-226	0.00E+00	0.00E+00	1.63E-05	2.02E-09	3.78E-10	2.46E-07	5.28E-06	1.58E-05	0.00E+00	3.87E-05	5.07E-07	7.27E-06	**8.41E-05**
	Lead-210	0.00E+00	0.00E+00	3.14E-05	4.13E-12	0.00E+00	0.00E+00	6.17E-05	5.71E-08	0.00E+00	3.55E-04	0.00E+00	3.63E-04	**8.10E-04**
	Polonium-210	0.00E+00	0.00E+00	7.80E-05	3.04E-14	0.00E+00	0.00E+00	1.54E-04	2.45E-10	0.00E+00	2.20E-03	0.00E+00	1.00E-02	**1.25E-02**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**1.29E-04**	**2.02E-09**	**1.44E-07**	**2.52E-05**	**2.21E-04**	**1.59E-05**	**0.00E+00**	**2.60E-03**	**5.55E-05**	**1.04E-02**	**1.35E-02**

Human receptor	COPC	Maximum Dose by Pathway during Future Centuries (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Rec F/H Adult (Russell Lake)	**Baseline Dose**													
	Uranium-238	1.28E-04	3.51E-13	6.34E-06	4.81E-11	1.15E-07	1.27E-03	5.79E-08	6.17E-07	0.00E+00	8.86E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.91E-06	8.39E-12	1.25E-07	6.41E-06	6.30E-08	2.24E-09	0.00E+00	9.65E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.46E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.93E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.38E-03	1.22E-09	2.72E-05	6.30E-03	4.64E-05	2.63E-06	0.00E+00	5.52E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.44E-03	7.34E-12	4.24E-05	1.26E-06	8.21E-05	1.13E-08	0.00E+00	2.44E-02	3.11E-01	2.18E-01	**5.56E-01**
	Project Total Dose - Future Centuries													
	Uranium-238	1.28E-04	3.51E-13	6.55E-06	4.97E-11	1.15E-07	1.28E-03	5.97E-08	6.37E-07	0.00E+00	9.83E-06	3.96E-04	2.89E-04	**2.11E-03**
	Uranium-234	1.54E-04	8.58E-13	7.13E-06	8.66E-12	1.25E-07	6.44E-06	6.51E-08	2.31E-09	0.00E+00	1.07E-05	4.32E-04	3.14E-04	**9.25E-04**
	Thorium-230	0.00E+00	0.00E+00	8.09E-04	5.48E-10	2.27E-06	3.47E-05	8.80E-07	2.18E-08	0.00E+00	3.44E-04	1.34E-03	2.87E-03	**5.40E-03**
	Radium-226	0.00E+00	0.00E+00	6.06E-04	2.71E-07	2.29E-06	5.93E-02	3.36E-06	4.03E-04	0.00E+00	5.36E-04	2.61E-02	8.23E-03	**9.52E-02**
	Lead-210	0.00E+00	0.00E+00	1.39E-03	1.23E-09	2.72E-05	6.30E-03	4.69E-05	2.65E-06	0.00E+00	5.71E-03	1.36E-01	4.33E-02	**1.93E-01**
	Polonium-210	0.00E+00	0.00E+00	2.47E-03	7.41E-12	4.24E-05	1.26E-06	8.30E-05	1.14E-08	0.00E+00	2.52E-02	3.11E-01	2.23E-01	**5.62E-01**
	Project Incremental Dose - Future Centuries													
	Uranium-238	0.00E+00	0.00E+00	2.07E-07	1.57E-12	4.47E-10	4.95E-06	1.89E-09	2.02E-08	0.00E+00	9.65E-07	4.80E-06	4.36E-07	**1.14E-05**
	Uranium-234	0.00E+00	0.00E+00	2.26E-07	2.74E-13	4.86E-10	2.50E-08	2.06E-09	7.31E-11	0.00E+00	1.05E-06	5.23E-06	4.74E-07	**7.01E-06**
	Thorium-230	0.00E+00	0.00E+00	3.64E-06	2.47E-12	1.55E-11	2.40E-10	3.97E-09	9.81E-11	0.00E+00	5.11E-06	3.07E-08	2.35E-05	**3.23E-05**
	Radium-226	0.00E+00	0.00E+00	1.36E-05	6.08E-09	1.82E-12	4.84E-08	7.54E-08	9.04E-06	0.00E+00	3.81E-05	7.26E-08	1.35E-05	**7.45E-05**
	Lead-210	0.00E+00	0.00E+00	1.40E-05	1.23E-11	0.00E+00	0.00E+00	4.69E-07	2.65E-08	0.00E+00	1.86E-04	0.00E+00	3.42E-04	**5.42E-04**
	Polonium-210	0.00E+00	0.00E+00	2.33E-05	7.01E-14	0.00E+00	0.00E+00	8.27E-07	1.14E-10	0.00E+00	7.80E-04	0.00E+00	4.63E-03	**5.44E-03**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**5.50E-05**	**6.10E-09**	**9.50E-10**	**5.03E-06**	**1.38E-06**	**9.09E-06**	**0.00E+00**	**1.01E-03**	**1.01E-05**	**5.01E-03**	**6.10E-03**
Rec F/H One-year-old (Russell Lake)	**Baseline Dose**													
	Uranium-238	1.28E-04	4.56E-13	4.41E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.02E-07	0.00E+00	5.22E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.78E-06	2.08E-12	5.05E-06	8.58E-06	2.55E-06	2.91E-09	0.00E+00	5.66E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.10E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.55E-08	1.20E-04	7.94E-02	1.72E-04	5.13E-04	0.00E+00	3.77E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.88E-03	2.47E-10	2.16E-03	8.43E-03	3.69E-03	3.42E-06	0.00E+00	6.36E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.67E-03	1.82E-12	4.75E-03	1.64E-06	9.19E-03	1.46E-08	0.00E+00	3.96E-02	1.25E+00	3.85E-01	**1.69E+00**
	Project Total Dose - Future Centuries													
	Uranium-238	1.28E-04	4.56E-13	4.55E-06	1.23E-11	4.68E-06	1.71E-03	2.43E-06	8.28E-07	0.00E+00	5.79E-06	5.65E-04	4.58E-04	**2.88E-03**
	Uranium-234	1.49E-04	1.12E-12	4.93E-06	2.14E-12	5.07E-06	8.62E-06	2.63E-06	3.00E-09	0.00E+00	6.28E-06	6.12E-04	4.96E-04	**1.29E-03**
	Thorium-230	0.00E+00	0.00E+00	4.11E-04	1.36E-10	6.75E-05	3.95E-05	2.62E-05	2.83E-08	0.00E+00	1.48E-04	1.44E-03	1.43E-03	**3.56E-03**
	Radium-226	0.00E+00	0.00E+00	5.42E-04	6.70E-08	1.20E-04	7.94E-02	1.76E-04	5.25E-04	0.00E+00	4.06E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.90E-03	2.49E-10	2.16E-03	8.43E-03	3.73E-03	3.45E-06	0.00E+00	6.58E-03	3.89E-01	7.14E-02	**4.84E-01**
	Polonium-210	0.00E+00	0.00E+00	4.71E-03	1.84E-12	4.75E-03	1.64E-06	9.28E-03	1.48E-08	0.00E+00	4.08E-02	1.25E+00	3.91E-01	**1.70E+00**
	Project Incremental Dose - Future Centuries													
	Uranium-238	0.00E+00	0.00E+00	1.44E-07	3.89E-13	1.82E-08	6.63E-06	7.69E-08	2.62E-08	0.00E+00	5.69E-07	7.02E-06	2.01E-07	**1.47E-05**
	Uranium-234	0.00E+00	0.00E+00	1.56E-07	6.79E-14	1.97E-08	3.34E-08	8.33E-08	9.50E-11	0.00E+00	6.16E-07	7.61E-06	2.17E-07	**8.74E-06**
	Thorium-230	0.00E+00	0.00E+00	1.85E-06	6.11E-13	4.66E-10	2.73E-10	1.18E-07	1.27E-10	0.00E+00	2.21E-06	3.28E-08	5.65E-06	**9.86E-06**
	Radium-226	0.00E+00	0.00E+00	1.22E-05	1.51E-09	9.46E-11	6.71E-08	3.94E-06	1.18E-05	0.00E+00	2.89E-05	1.38E-07	5.56E-06	**6.26E-05**
	Lead-210	0.00E+00	0.00E+00	1.90E-05	2.49E-12	0.00E+00	0.00E+00	3.73E-05	3.45E-08	0.00E+00	2.14E-04	0.00E+00	2.21E-04	**4.92E-04**
	Polonium-210	0.00E+00	0.00E+00	4.46E-05	1.74E-14	0.00E+00	0.00E+00	9.25E-05	1.48E-10	0.00E+00	1.26E-03	0.00E+00	6.06E-03	**7.46E-03**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**7.79E-05**	**1.51E-09**	**3.84E-08**	**6.73E-06**	**1.34E-04**	**1.19E-05**	**0.00E+00**	**1.51E-03**	**1.48E-05**	**6.29E-03**	**8.04E-03**

Human receptor	COPC	Maximum Dose by Pathway during Future Centuries (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
Seasonal Resident Adult (Russell Lake)		**Baseline Dose**												
	Uranium-238	1.28E-04	3.51E-13	6.34E-06	4.81E-11	1.15E-07	1.27E-03	5.79E-08	6.17E-07	0.00E+00	8.86E-06	3.92E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	6.91E-06	8.39E-12	1.25E-07	6.41E-06	6.30E-08	2.24E-09	0.00E+00	9.65E-06	4.26E-04	3.14E-04	**9.18E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.46E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	3.39E-04	1.34E-03	2.84E-03	**5.37E-03**
	Radium-226	0.00E+00	0.00E+00	5.93E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	4.97E-04	2.61E-02	8.22E-03	**9.51E-02**
	Lead-210	0.00E+00	0.00E+00	1.38E-03	1.22E-09	2.72E-05	6.30E-03	4.64E-05	2.63E-06	0.00E+00	5.52E-03	1.36E-01	4.29E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.44E-03	7.34E-12	4.24E-05	1.26E-06	8.21E-05	1.13E-08	0.00E+00	2.44E-02	3.11E-01	2.18E-01	**5.56E-01**
		Project Total Dose - Future Centuries												
	Uranium-238	1.28E-04	3.51E-13	6.55E-06	4.97E-11	1.15E-07	1.28E-03	5.97E-08	6.37E-07	0.00E+00	9.15E-06	3.93E-04	2.88E-04	**2.10E-03**
	Uranium-234	1.54E-04	8.58E-13	7.13E-06	8.66E-12	1.25E-07	6.44E-06	6.51E-08	2.31E-09	0.00E+00	9.97E-06	4.28E-04	3.14E-04	**9.20E-04**
	Thorium-230	0.00E+00	0.00E+00	8.09E-04	5.48E-10	2.27E-06	3.47E-05	8.80E-07	2.18E-08	0.00E+00	3.40E-04	1.34E-03	2.85E-03	**5.38E-03**
	Radium-226	0.00E+00	0.00E+00	6.06E-04	2.71E-07	2.29E-06	5.93E-02	3.36E-06	4.03E-04	0.00E+00	5.09E-04	2.61E-02	8.22E-03	**9.52E-02**
	Lead-210	0.00E+00	0.00E+00	1.39E-03	1.23E-09	2.72E-05	6.30E-03	4.69E-05	2.65E-06	0.00E+00	5.58E-03	1.36E-01	4.30E-02	**1.92E-01**
	Polonium-210	0.00E+00	0.00E+00	2.47E-03	7.41E-12	4.24E-05	1.26E-06	8.30E-05	1.14E-08	0.00E+00	2.46E-02	3.11E-01	2.20E-01	**5.58E-01**
		Project Incremental Dose - Future Centuries												
	Uranium-238	0.00E+00	0.00E+00	2.07E-07	1.57E-12	4.47E-10	4.95E-06	1.89E-09	2.02E-08	0.00E+00	2.90E-07	1.44E-06	1.35E-07	**7.05E-06**
	Uranium-234	0.00E+00	0.00E+00	2.26E-07	2.74E-13	4.86E-10	2.50E-08	2.06E-09	7.31E-11	0.00E+00	3.15E-07	1.57E-06	1.47E-07	**2.28E-06**
	Thorium-230	0.00E+00	0.00E+00	3.64E-06	2.47E-12	1.55E-11	2.40E-10	3.97E-09	9.81E-11	0.00E+00	1.53E-06	9.31E-09	6.94E-06	**1.21E-05**
	Radium-226	0.00E+00	0.00E+00	1.36E-05	6.08E-09	1.82E-12	4.84E-08	7.54E-08	9.04E-06	0.00E+00	1.14E-05	2.05E-08	4.51E-06	**3.88E-05**
	Lead-210	0.00E+00	0.00E+00	1.40E-05	1.23E-11	0.00E+00	0.00E+00	4.69E-07	2.65E-08	0.00E+00	5.58E-05	0.00E+00	1.03E-04	**1.73E-04**
	Polonium-210	0.00E+00	0.00E+00	2.33E-05	7.01E-14	0.00E+00	0.00E+00	8.27E-07	1.14E-10	0.00E+00	2.34E-04	0.00E+00	1.42E-03	**1.68E-03**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**5.50E-05**	**6.10E-09**	**9.50E-10**	**5.03E-06**	**1.38E-06**	**9.09E-06**	**0.00E+00**	**3.03E-04**	**3.04E-06**	**1.54E-03**	**1.91E-03**
Seasonal Resident One-year-old (Russell Lake)		**Baseline Dose**												
	Uranium-238	1.28E-04	4.56E-13	4.41E-06	1.19E-11	4.67E-06	1.70E-03	2.35E-06	8.02E-07	0.00E+00	5.22E-06	5.58E-04	4.58E-04	**2.86E-03**
	Uranium-234	1.49E-04	1.12E-12	4.78E-06	2.08E-12	5.05E-06	8.58E-06	2.55E-06	2.91E-09	0.00E+00	5.66E-06	6.05E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.10E-04	1.35E-10	6.75E-05	3.95E-05	2.61E-05	2.82E-08	0.00E+00	1.46E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.29E-04	6.55E-08	1.20E-04	7.94E-02	1.72E-04	5.13E-04	0.00E+00	3.77E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.88E-03	2.47E-10	2.16E-03	8.43E-03	3.69E-03	3.42E-06	0.00E+00	6.36E-03	3.89E-01	7.12E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.67E-03	1.82E-12	4.75E-03	1.64E-06	9.19E-03	1.46E-08	0.00E+00	3.96E-02	1.25E+00	3.85E-01	**1.69E+00**
		Project Total Dose - Future Centuries												
	Uranium-238	1.28E-04	4.56E-13	4.55E-06	1.23E-11	4.68E-06	1.71E-03	2.43E-06	8.28E-07	0.00E+00	5.39E-06	5.60E-04	4.58E-04	**2.87E-03**
	Uranium-234	1.49E-04	1.12E-12	4.93E-06	2.14E-12	5.07E-06	8.62E-06	2.63E-06	3.00E-09	0.00E+00	5.84E-06	6.07E-04	4.96E-04	**1.28E-03**
	Thorium-230	0.00E+00	0.00E+00	4.11E-04	1.36E-10	6.75E-05	3.95E-05	2.62E-05	2.83E-08	0.00E+00	1.47E-04	1.44E-03	1.42E-03	**3.55E-03**
	Radium-226	0.00E+00	0.00E+00	5.42E-04	6.70E-08	1.20E-04	7.94E-02	1.76E-04	5.25E-04	0.00E+00	3.86E-04	4.91E-02	1.60E-02	**1.46E-01**
	Lead-210	0.00E+00	0.00E+00	1.90E-03	2.49E-10	2.16E-03	8.43E-03	3.73E-03	3.45E-06	0.00E+00	6.43E-03	3.89E-01	7.13E-02	**4.83E-01**
	Polonium-210	0.00E+00	0.00E+00	4.71E-03	1.84E-12	4.75E-03	1.64E-06	9.28E-03	1.48E-08	0.00E+00	4.00E-02	1.25E+00	3.87E-01	**1.70E+00**
		Project Incremental Dose - Future Centuries												
	Uranium-238	0.00E+00	0.00E+00	1.44E-07	3.89E-13	1.82E-08	6.63E-06	7.69E-08	2.62E-08	0.00E+00	1.71E-07	2.11E-06	5.89E-08	**9.23E-06**
	Uranium-234	0.00E+00	0.00E+00	1.56E-07	6.79E-14	1.97E-08	3.34E-08	8.33E-08	9.50E-11	0.00E+00	1.85E-07	2.28E-06	6.39E-08	**2.82E-06**
	Thorium-230	0.00E+00	0.00E+00	1.85E-06	6.11E-13	4.66E-10	2.73E-10	1.18E-07	1.27E-10	0.00E+00	6.62E-07	9.90E-09	1.62E-06	**4.26E-06**
	Radium-226	0.00E+00	0.00E+00	1.22E-05	1.51E-09	9.46E-11	6.71E-08	3.94E-06	1.18E-05	0.00E+00	8.67E-06	4.10E-08	1.91E-06	**3.86E-05**
	Lead-210	0.00E+00	0.00E+00	1.90E-05	2.49E-12	0.00E+00	0.00E+00	3.73E-05	3.45E-08	0.00E+00	6.43E-05	0.00E+00	6.53E-05	**1.86E-04**
	Polonium-210	0.00E+00	0.00E+00	4.46E-05	1.74E-14	0.00E+00	0.00E+00	9.25E-05	1.48E-10	0.00E+00	3.79E-04	0.00E+00	1.75E-03	**2.26E-03**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**7.79E-05**	**1.51E-09**	**3.84E-08**	**6.73E-06**	**1.34E-04**	**1.19E-05**	**0.00E+00**	**4.53E-04**	**4.44E-06**	**1.82E-03**	**2.50E-03**
		Baseline Dose												
	Uranium-238	1.28E-04	3.51E-13	6.34E-06	4.81E-11	1.15E-07	1.27E-03	5.79E-08	6.17E-07	0.00E+00	6.10E-05	0.00E+00	1.98E-04	**1.67E-03**
	Uranium-234	1.54E-04	8.58E-13	6.91E-06	8.39E-12	1.25E-07	6.41E-06	6.30E-08	2.24E-09	0.00E+00	6.64E-05	0.00E+00	2.15E-04	**4.50E-04**
	Thorium-230	0.00E+00	0.00E+00	8.05E-04	5.46E-10	2.27E-06	3.47E-05	8.76E-07	2.17E-08	0.00E+00	2.33E-03	0.00E+00	7.78E-04	**3.95E-03**
	Radium-226	0.00E+00	0.00E+00	5.93E-04	2.64E-07	2.29E-06	5.93E-02	3.28E-06	3.93E-04	0.00E+00	3.42E-03	0.00E+00	9.66E-03	**7.34E-02**
	Lead-210	0.00E+00	0.00E+00	1.38E-03	1.22E-09	2.72E-05	6.30E-03	4.64E-05	2.63E-06	0.00E+00	3.80E-02	0.00E+00	2.26E-01	**2.72E-01**
	Polonium-210	0.00E+00	0.00E+00	2.44E-03	7.34E-12	4.24E-05	1.26E-06	8.21E-05	1.13E-08	0.00E+00	1.68E-01	0.00E+00	1.89E+00	**2.06E+00**

Human receptor	COPC	Maximum Dose by Pathway during Future Centuries (mSv/yr)												
		Air (internal)	Air (external)	Water (internal)	Water (external)	Soil (internal)	Soil (external)	Sediment (internal)	Sediment (external)	Aquatic Plants	Aquatic Animals	Terrestrial Plants	Terrestrial Animals	Total by Radionuclide
		Project Total Dose - Future Centuries												
Fisher/ Trapper Adult (Russell Lake)	**Uranium-238**	1.28E-04	3.51E-13	6.69E-06	5.08E-11	1.15E-07	1.28E-03	6.10E-08	6.51E-07	0.00E+00	6.77E-05	0.00E+00	1.99E-04	**1.68E-03**
	Uranium-234	1.54E-04	8.58E-13	7.28E-06	8.84E-12	1.26E-07	6.46E-06	6.64E-08	2.36E-09	0.00E+00	7.37E-05	0.00E+00	2.16E-04	**4.58E-04**
	Thorium-230	0.00E+00	0.00E+00	8.11E-04	5.50E-10	2.27E-06	3.47E-05	8.83E-07	2.18E-08	0.00E+00	2.37E-03	0.00E+00	7.81E-04	**4.00E-03**
	Radium-226	0.00E+00	0.00E+00	6.15E-04	2.75E-07	2.29E-06	5.93E-02	3.41E-06	4.09E-04	0.00E+00	3.69E-03	0.00E+00	9.74E-03	**7.38E-02**
	Lead-210	0.00E+00	0.00E+00	1.40E-03	1.24E-09	2.72E-05	6.30E-03	4.72E-05	2.67E-06	0.00E+00	3.93E-02	0.00E+00	2.26E-01	**2.73E-01**
	Polonium-210	0.00E+00	0.00E+00	2.48E-03	7.46E-12	4.24E-05	1.26E-06	8.35E-05	1.15E-08	0.00E+00	1.73E-01	0.00E+00	1.90E+00	**2.07E+00**
		Project Incremental Dose - Future Centuries												
	Uranium-238	0.00E+00	0.00E+00	3.45E-07	2.62E-12	7.44E-10	8.26E-06	3.15E-09	3.36E-08	0.00E+00	6.65E-06	0.00E+00	8.10E-07	**1.61E-05**
	Uranium-234	0.00E+00	0.00E+00	3.76E-07	4.57E-13	8.11E-10	4.16E-08	3.43E-09	1.22E-10	0.00E+00	7.24E-06	0.00E+00	8.82E-07	**8.54E-06**
	Thorium-230	0.00E+00	0.00E+00	6.07E-06	4.11E-12	2.57E-11	4.00E-10	6.61E-09	1.63E-10	0.00E+00	3.52E-05	0.00E+00	2.40E-06	**4.37E-05**
	Radium-226	0.00E+00	0.00E+00	2.27E-05	1.01E-08	3.18E-12	8.20E-08	1.26E-07	1.51E-05	0.00E+00	2.63E-04	0.00E+00	8.59E-05	**3.86E-04**
	Lead-210	0.00E+00	0.00E+00	2.33E-05	2.05E-11	0.00E+00	0.00E+00	7.82E-07	4.42E-08	0.00E+00	1.28E-03	0.00E+00	3.90E-04	**1.69E-03**
	Polonium-210	0.00E+00	0.00E+00	3.89E-05	1.17E-13	0.00E+00	0.00E+00	1.38E-06	1.89E-10	0.00E+00	5.37E-03	0.00E+00	4.57E-03	**9.98E-03**
	Total by Pathway	**0.00E+00**	**0.00E+00**	**9.16E-05**	**1.02E-08**	**1.58E-09**	**8.38E-06**	**2.30E-06**	**1.51E-05**	**0.00E+00**	**6.96E-03**	**0.00E+00**	**5.05E-03**	**1.21E-02**

Table B. 11: Sample Calculation - Mallard (McGowan Lake) Dose and Risk Calculations for Selenium

Parameter	Symbol	Calculation	Selenium		
			Value	Unit	Source
Environmental Media Concentration					
Water Concentration	C_w	-	2.59E-04	mg/L	Table 3-3
Sediment Concentration (dry weight)	$C_{sed(dw)}$	-	3.71E+00	mg/kg dw	Table 3-3
Outdoor Air Concentration	C_{air}	-	1.55E-07	mg/m^3	Table 3-13
Aquatic Plant Concentration					
Bioaccumulation Factor (BAF)	$BAF_{aquatic\ plant}$	-	1.77E+02	L/kg fw	Table 3-9 (IMPACT Model Report)
Aquatic Plant Tissue Concentration	$C_{aquatic\ plant}$	$C_{aquatic\ plant} = C_w * BAF_{aquatic\ plant}$	4.59E-02	mg/kg fw	Calculated
Benthic Invertebrate Concentration					
Water-to-Sediment Partitioning Coefficient	k_d	-	2.00E+04	L/kg	Table 3-6 (IMPACT Model Report)
Dry Bulk Density	ρ	-	1.10E-01	kg/L	Table 2-1 (IMPACT Model Report)
Water Content (Volume Basis)	θ	-	9.60E-01	unitless	Table 2-1 (IMPACT Model Report)
Fraction in Porewater Phase	$C_{pw\ (fraction)}$	$C_{pw\ (fraction)} = 1 - (k_d * \rho / \theta) / (1 + k_d * \rho / \theta)$	4.36E-04	unitless	Calculated
Concentration Ratio – Porewater to Sediment	$Ratio_{pw-sed}$	$Ratio_{pw-sed} = C_{pw\ (fraction)} * \rho / \theta$	5.00E-05	kg/L	Calculated
Sediment Porewater Concentration	$C_{pw\ (sed)}$	$C_{pw\ (sed)} = C_{sed(dw)} * Ratio_{pw-sed}$	1.86E-04	mg/L	Calculated
Bioaccumulation Factor (BAF)	$BAF_{benthic\ inv}$	-	1.07E+03	L/kg fw	Table 3-9 (IMPACT Model Report)
Sediment Occupancy Factor	OF_{sed}	-	1.00E+02	%	Table 2-5 (IMPACT Model Report)
Benthic Invertebrate Tissue Concentration	$C_{benthic\ inv}$	$C_{benthic\ inv} = (1 - (OF_{sed}/100) * C_{sed(dw)} + (OF_{sed}/100) * C_{pw\ (sed)}) * BAF_{benthic\ inv}$	1.99E-01	Bq/kg fw	Calculated
Mallard Exposure Factors					
Water Intake	IR_w	-	6.40E-02	L/d	Table 5-7
Sediment Intake	IR_s	-	2.00E-03	kg dw/d	Table 5-7
Air Intake	IR_{air}	-	2.00E-02	m^3/d	Table 5-7
Aquatic Plant Intake	$IR_{aquatic\ plant}$	-	6.00E-02	kg fw/d	Table 5-7
Benthic Invertebrate Intake	$IR_{benthic\ inv}$	-	1.80E-01	kg fw/d	Table 5-7
Body Weight	BW	-	1.13	kg fw	Table 5-7
Toxicological Benchmark	TRV	-	1.29E+00	mg/kg d	Table 5-13
Mallard Dose and HQ					
Total Dose	D_{total}	$D_{total} = (C_w*IR_w + C_{s(dw)}*IR_s + C_{air}*IR_{air} + C_{aquatic\ plant}*IR_{aquatic\ plant} + C_{benthic\ inv}*IR_{benthic\ inv})/BW$	4.07E-02	mg/kg d	Calculated (Table 5-9)
Hazard Quotient	HQ	$HQ = D_{total}/TRV$	3.15E-02	unitless	Calculated (Table 5-24)

Table B.12: Sample Calculation - Adult Recreational Fisher/Hunter (McGowan Lake) Dose and Risk Calculations for Selenium

Parameter	Symbol	Calculation	Selenium		
			Value	Unit	Source
Water Ingestion Dose					
Water Concentration (LA-1)	$C_{w\ (LA\text{-}1)}$	-	2.59E-04	mg/L	Table 3-3
Water Concentration (Reference)	$C_{w\ (Ref)}$	-	3.35E-05	mg/L	Table 3-3
Linkage Fraction of Water (LA-1)	$LF_{w\ (LA\text{-}1)}$	-	3.00E-01	Unitless	Assumed
Linkage Fraction of Water (Reference)	$LF_{w\ (Ref)}$	-	7.00E-01	Unitless	Assumed
Water Intake	IR_w	-	1.04E+00	L/d	Table 2-7 (IMPACT Model Report)
Human Adult Body Mass	BW	-	7.07E+01	kg	Health Canada, 2021
Ingestion Dose (Water)	D_w	$D_w = ((C_{w\ (LA\text{-}1)} * LF_{w\ (LA\text{-}1)} + C_{w\ (Ref)} * LF_{w\ (Ref)}) * IR_w) / BW$	1.49E-06	mg/kg/d fw	Calculated
Soil Ingestion Dose					
Soil Concentration (LA-1)	$C_{s\ (LA\text{-}1)}$	-	1.07E-01	mg/kg dw	Table 3-13
Soil Concentration (Reference)	$C_{s\ (Ref)}$	-	1.07E-01	mg/kg dw	Table 3-13
Linkage Fraction of Soil (LA-1)	$LF_{s\ (LA\text{-}1)}$	-	3.00E-01	Unitless	Assumed
Linkage Fraction of Soil (Reference)	$LF_{s\ (Ref)}$	-	7.00E-01	Unitless	Assumed
Soil Intake	IR_s	-	4.00E-06	kg dw/d	Table 2-7 (IMPACT Model Report)
Days Exposed to Soil per Year	Exp_{days}	-	1.35E+02	d/y	Assumed
Human Adult Body Mass	BW	-	7.07E+01	kg	Health Canada, 2021
Ingestion Dose (Soil)	D_s	$D_s = (((C_{s\ (LA\text{-}1)} * LF_{s\ (LA\text{-}1)} + C_{s\ (Ref)} * LF_{s\ (Ref)}) * IR_s) / BW) * (Exp_{days} / 365)$	2.24E-09	mg/kg/d fw	Calculated
Terrestrial Plant Ingestion Dose					
Labrador Tea Concentration (LA-1)	$C_{LT\ (LA\text{-}1)}$	-	6.16E-02	mg/kg fw	Table B.5
Blueberry Concentration (LA-1)	$C_{BB\ (LA\text{-}1)}$	-	5.71E-02	mg/kg fw	Table B.5
Labrador Tea Concentration (Reference)	$C_{LT\ (Ref)}$	-	6.14E-02	mg/kg fw	Table B.5
Blueberry Concentration (Reference)	$C_{BB\ (Ref)}$	-	5.71E-02	mg/kg fw	Table B.5
Food Intake (Terrestrial Plants)	IR_{TP}	-	1.98E+01	kg/y fw	Assumed, site-specific
Linkage Fraction of Labrador Tea (Reference)	$LF_{LT\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Blueberry (Reference)	$LF_{BB\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Labrador Tea (LA-1)	$LF_{LT\ (LA\text{-}1)}$	-	9.20E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Blueberry (LA-1)	$LF_{BB\ (LA\text{-}1)}$	-	9.91E-01	Unitless	Table 2-10 (IMPACT Model Report)
Human Adult Body Mass	BW	-	7.07E+01	kg	Health Canada, 2021
Food Processing Factor	FPF	-	1.00E+00	Unitless	Assumed
Ingestion Dose (Terrestrial Plants)	D_{TP}	$D_{TP} = ((C_{LT\ (LA\text{-}1)} * LF_{LT\ (LA\text{-}1)} + C_{BB\ (LA\text{-}1)} * LF_{BB\ (LA\text{-}1)} + C_{LT\ (Ref)} * LF_{LT\ (Ref)} + C_{BB\ (Ref)} * LF_{BB\ (Ref)}) * IR_{TP} * FPF) / (BW * 365)$	4.39E-05	mg/kg/d fw	Calculated
Aquatic Animal Ingestion Dose					
Northern Pike Concentration (LA-1)	$C_{NP\ (LA\text{-}1)}$	-	1.02E+00	mg/kg fw	Table B.5
White Sucker Concentration (LA-1)	$C_{WS\ (LA\text{-}1)}$	-	1.06E+00	mg/kg fw	Table B.5
Northern Pike Concentration (Reference)	$C_{NP\ (Ref)}$	-	1.89E-01	mg/kg fw	Table B.5
White Sucker Concentration (Reference)	$C_{WS\ (Ref)}$	-	1.46E-01	mg/kg fw	Table B.5
Food Intake (Aquatic Animals)	IR_{AA}	-	2.67E+01	kg/y fw	Assumed, site-specific

Parameter	Symbol	Calculation	Selenium		
			Value	Unit	Source
Linkage Fraction of Northern Pike (Reference)	$LF_{NP\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of White Sucker (Reference)	$LF_{WS\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Northern Pike (LA-1)	$LF_{NP\ (LA\text{-}1)}$	-	5.00E-01	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of White Sucker (LA-1)	$LF_{WS\ (LA\text{-}1)}$	-	5.00E-01	Unitless	Table 2-10 (IMPACT Model Report)
Human Adult Body Mass	BW	-	7.07E+01	kg	Health Canada, 2021
Food Processing Factor	FPF	-	1.00E+00	Unitless	Assumed
Ingestion Dose (Aquatic Animals)	D_{AA}	$D_{AA} = ((C_{NP\ (LA\text{-}1)} * LF_{NP\ (LA\text{-}1)} + C_{WS\ (LA\text{-}1)} * LF_{WS\ (LA\text{-}1)} + C_{NP\ (Ref)} * LF_{NP\ (Ref)} + C_{WS\ (Ref)} * LF_{WS\ (Ref)}) * IR_{AA} * FPF) / (BW * 365)$	1.08E-03	mg/kg/d fw	Calculated
Terrestrial Animal Ingestion Dose					
Woodland Caribou Concentration (LA-5)	$C_{WC\ (LA\text{-}5)}$	-	1.50E-01	mg/kg fw	Table B.5
Moose Concentration (LA-1)	$C_{M\ (LA\text{-}1)}$	-	1.75E-01	mg/kg fw	Table B.5
Moose Organs Concentration (LA-1)	$C_{MO\ (LA\text{-}1)}$	-	1.75E-01	mg/kg fw	Table B.5
Muskrat Concentration (LA-1)	$C_{Mus\ (LA\text{-}1)}$	-	2.54E-01	mg/kg fw	Table B.5
Mallard Concentration (LA-1)	$C_{Mal\ (LA\text{-}1)}$	-	6.80E-01	mg/kg fw	Table B.5
Goose Concentration (LA-1)	$C_{G\ (LA\text{-}1)}$	-	1.95E-02	mg/kg fw	Table B.5
Store Food Concentration (LA-1)	$C_{SF\ (LA\text{-}1)}$	-	6.30E-02	mg/kg fw	Table 2-11 (IMPACT Model Report)
Woodland Caribou Concentration (Reference)	$C_{WC\ (Ref)}$	-	1.06E-01	mg/kg fw	Table B.5
Moose Concentration (Reference)	$C_{M\ (Ref)}$	-	1.17E-01	mg/kg fw	Table B.5
Moose Organs Concentration (Reference)	$C_{MO\ (Ref)}$	-	1.17E-01	mg/kg fw	Table B.5
Muskrat Concentration (Reference)	$C_{Mus\ (Ref)}$	-	3.74E-02	mg/kg fw	Table B.5
Mallard Concentration (Reference)	$C_{Mal\ (Ref)}$	-	1.13E-01	mg/kg fw	Table B.5
Goose Concentration (Reference)	$C_{G\ (Ref)}$	-	1.93E-02	mg/kg fw	Table B.5
Store Food Concentration (Reference)	$C_{SF\ (Ref)}$	-	6.30E-02	mg/kg fw	Table 2-11 (IMPACT Model Report)
Food Intake (Terrestrial Animals)	IR_{TA}	-	6.60E+02	kg/y fw	Assumed, site-specific
Linkage Fraction of Woodland Caribou (LA-5)	$LF_{WC\ (LA\text{-}5)}$		4.00E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Moose (LA-1)	$LF_{M\ (LA\text{-}1)}$	-	1.78E-02	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Moose Organs (LA-1)	$LF_{MO\ (LA\text{-}1)}$	-	6.80E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Muskrat (LA-1)	$LF_{Mus\ (LA\text{-}1)}$	-	3.70E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Mallard (LA-1)	$LF_{Mal\ (LA\text{-}1)}$	-	4.60E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Goose (LA-1)	$LF_{G\ (LA\text{-}1)}$	-	2.80E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Store Food (LA-1)	$LF_{SF\ (LA\text{-}1)}$	-	9.60E-01	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Woodland Caribou	$LF_{WC\ (Ref)}$		0.00E+00	Unitless	Assumed
Linkage Fraction of Moose (Reference)	$LF_{M\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Moose Organs (Reference)	$LF_{MO\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Muskrat (Reference)	$LF_{Mus\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Mallard (Reference)	$LF_{Mal\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Goose (Reference)	$LF_{G\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Linkage Fraction of Store Food (Reference)	$LF_{SF\ (Ref)}$	-	0.00E+00	Unitless	Assumed
Human Adult Body Mass	BW	-	7.07E+01	kg	Health Canada, 2021
Food Processing Factor	FPF	-	1.00E+00	Unitless	Assumed

Parameter	Symbol	Calculation	Selenium		
			Value	Unit	Source
Ingestion Dose (Terrestrial Animals)	D_{TA}	D_{AA} = (($C_{WC\ (LA-5)}$ * $LF_{WC\ (LA-5)}$ + $C_{M\ (LA-1)}$ * $LF_{M\ (LA-1)}$ + $C_{MO\ (LA-1)}$ * $LF_{MO\ (LA-1)}$ + $C_{Mus\ (LA-1)}$ * $LF_{Mus\ (LA-1)}$ + $C_{Mal\ (LA-1)}$ * $LF_{Mal\ (LA-1)}$ + $C_{G\ (LA-1)}$ * $LF_{G\ (LA-1)}$ + $C_{SF\ (LA-1)}$ * $LF_{SF\ (LA-1)}$ + $C_{WC\ (Ref)}$ * $LF_{WC\ (Ref)}$ + $C_{M\ (Ref)}$ * $LF_{M\ (Ref)}$ + $C_{MO\ (Ref)}$ * $LF_{MO\ (Ref)}$ + $C_{Mus\ (Ref)}$ * $LF_{Mus\ (Ref)}$ + $C_{Mal\ (Ref)}$ * $LF_{Mal\ (Ref)}$ + $C_{G\ (Ref)}$ * $LF_{G\ (Ref)}$ + $C_{SF\ (Ref)}$ * $LF_{SF\ (Ref)}$)* IR_{TA} * FPF) / (BW * 365)	1.78E-03	mg/kg/d fw	Calculated
Adult Recreational Fisher/Hunter Total Dose and HQ					
Total Ingestion Dose	D_{total}	$D_{total} = D_w + D_s + D_{TP} + D_{AA} + D_{TA}$	2.90E-03	mg/kg/d fw	Calculated (Table 4-5)
Toxicological Benchmark	TRV	-	5.70E-03	mg/kg d	Table 4-14
Hazard Quotient	HQ	$HQ = D_{total} / TRV$	5.08E-01	Unitless	Calculated (Table 4-15)

Table B.13: Sample Calculation - Mallard (McGowan Lake) Radiological Dose for Polonium-210

Parameter	Symbol	Calculation	Polonium-210		
			Value	Unit	Source
Environmental Media Concentrations					
Water Concentration	C_w	-	6.23E-03	Bq/L	Table 3-3
Sediment Concentration (dry weight)	$C_{s(dw)}$	-	4.47E+02	Bq/kg dw	Table 3-3
Outdoor Air Concentration	C_{air}	-	0.00E+00	Bq/m^3	Table 3-13
Sediment Dry Bulk Density	ρ_s	-	1.10E-01	kg dw/ L	Table 2-1 (IMPACT Model Report)
Mixing Depth	d	-	3.00E-02	m	Table 2-1 (IMPACT Model Report)
Sediment Surface Concentration (dry weight)	$C_{s(dw)}'$	$C_{s(dw)}' = C_{s(dw)} * \rho_s * d * 1000\ L/m^3$	1.48E+03	Bq dw/ m^2	Calculated
Aquatic Plant Concentration					
Bioaccumulation Factor - Aquatic Plant	$BAF_{aquatic\ plant}$	-	2.93E+02	L/kg fw	Table 3-9 (IMPACT Model Report)
Aquatic Plant Concentration (fresh weight)	$C_{aquatic\ plant}$	$C_{aquatic\ plant} = C_w * BAF_{aquatic\ plant}$	1.82E+00	Bq/kg fw	Calculated
Benthic Invertebrate Concentration					
Water-to-Sediment Partitioning Coefficient	k_d	-	1.20E+05	L/kg	Table 3-6 (IMPACT Model Report)
Dry Bulk Density	ρ	-	1.10E-01	kg/L	Table 2-1 (IMPACT Model Report)
Water Content (Volume Basis)	θ	-	9.60E-01	unitless	Table 2-1 (IMPACT Model Report)
Fraction in Porewater Phase	$C_{pw\ (fraction)}$	$C_{pw\ (fraction)} = 1 - (k_d * \rho / \theta) / (1 + k_d * \rho / \theta)$	7.27E-05	unitless	Calculated
Concentration Ratio – Porewater to Sediment	$Ratio_{pw\text{-}sed}$	$Ratio_{pw\text{-}sed} = C_{pw\ (fraction)} * \rho / \theta$	8.33E-06	kg/L	Calculated
Sediment Porewater Concentration	$C_{pw\ (sed)}$	$C_{pw\ (sed)} = C_{sed(dw)} * Ratio_{pw\text{-}sed}$	3.73E-03	Bq/L	Calculated
Bioaccumulation Factor (BAF)	$BAF_{benthic\ inv}$	-	1.58E+04	L/kg fw	Table 3-9 (IMPACT Model Report)
Sediment Occupancy Factor	OF_{sed}	-	1.00E+02	%	Table 2-5 (IMPACT Model Report)
Benthic Invertebrate Tissue Concentration	$C_{benthic\ inv}$	$C_{benthic\ inv} = (1 - (OF_{sed}/100) * C_{sed(dw)} + (OF_{sed}/100) * C_{pw\ (sed)}) * BAF_{benthic\ inv}$	5.88E+01	Bq/kg fw	Calculated
Mallard Exposure Factors					
Water Intake	IR_w	-	6.40E-02	L/d	Table 5-7
Sediment Intake	IR_s	-	2.00E-03	kg dw/d	Table 5-7
Air Intake	IR_{air}	-	2.00E-02	m^3/d	Table 5-7
Aquatic Plant Intake	$IR_{aquatic\ plant}$	-	6.00E-02	kg fw/d	Table 5-7
Benthic Invertebrate Intake	$IR_{benthic\ inv}$	-	1.80E-01	kg fw/d	Table 5-7
Fraction of Time Spent on Site	f_0	-	1.00E+00	unitless	Assumed
Mallard Internal Dose (Radiological)					
Ingestion Transfer Factor	TF_{ing}	-	3.68E+00	d/kg fw	Table 3-16 (IMPACT Model Report)
Mallard Tissue Concentration	C_t	$C_t = f_0 * TF_{ing} * (C_w * IR_w + C_{s(dw)} * IR_s + C_{aquatic\ plant} * IR_{aquatic\ plant} + C_{benthic\ inv} * IR_{benthic\ inv})$	4.27E+01	Bq/kg fw	Calculated
Dose Conversion Factor (Internal) - Duck	DC_{int}	-	3.04E-02	(µGy/hr)/(Bq/kg fw)	Table 3-18 (IMPACT Model Report)
Internal Dose	D_{int}	$D_{int} = C_t * DC_{int}$	1.30E+00	µGy/hr	Calculated
Internal Dose (converted units)	D_{int}'	$D_{int}' = D_{int} * 24\ h/d / 1000\ \mu Gy/mGy$	3.12E-02	mGy/d	Calculated
Mallard External Dose (Radiological)					
Occupancy Factor, Sediment - Riparian Birds	OF_s	-	0.00E+00	unitless	Table 2-5 (IMPACT Model Report)

Parameter	Symbol	Calculation	Polonium-210		
			Value	Unit	Source
Occupancy Factor, Sediment Surface - Riparian Birds	OF_{ss}	-	5.00E-01	unitless	Table 2-5 (IMPACT Model Report)
Dose Conversion Factor (External) - Duck	$DC_{ext\ (on\ soil)}$	-	2.63E-11	$(\mu Gy/hr)/(Bq/m^2)$	Table 3-19 (IMPACT Model Report)
External Dose	D_{ext}	$D_{ext} = f_0 * (C_{s(dw)}' * OF_{ss} * DC_{ext\ (on\ soil)})$	5.87E-09	µGy/hr	Calculated
External Dose (converted units)	D_{ext}'	$D_{ext}' = D_{ext}$ * 24 h/d / 1000 µGy/mGy	1.41E-10	mGy/d	Calculated
Mallard Total Dose (Radiological)					
Total Dose	D_{total}	$D_{total} = D_{int} + D_{ext}$	1.30E+00	µGy/hr	Calculated
Total Dose (converted units)	D_{total}'	$D_{total}' = D_{int}' + D_{ext}'$	3.12E-02	mGy/d	Calculated (Table 5-10)

Table B.14: Sample Calculation - Adult Recreational Fisher/Hunter (McGowan Lake) Radiological Dose for Polonium-210

Parameter	Symbol	Calculation	Polonium-210		
			Value	Unit	Source
Environmental Media Concentrations					
Water Concentration (LA-1)	C_w	-	6.23E-03	Bq/L	Table 3-3
Water Concentration reference (Max)	$C_{w\ (Ref\text{-}M)}$	-	6.33E-03	Bq/L	Table 3-3
Water Concentration reference (Ave)	$C_{w\ (Ref\text{-}A)}$		5.34E-03	Bq/L	
Soil Concentration (dry weight)	$C_{s(dw)}$	-	6.55E+01	Bq/kg dw	Table 3-13
Soil Concentration reference (dry weight)	$C_{s(dw)\ (Ref)}$	-	6.55E+01	Bq/kg dw	Table 3-13
Soil Concentration incremental (dry weight)	$C_{s(dw)}'$	$C_{s(dw)}' = C_{s(dw)} - C_{s(dw)\ (Ref)}$	0.00E+00	Bq/kg dw	Calculated
Outdoor Air Concentration	C_{air}	-	0.00E+00	Bq/m^3	Table 3-13
Soil Dry Bulk Density (Sand)	ρ_s	-	1.50E+00	kg(dw)/ L	CSA N288.1-20 (cl. 6.3.2.2)
Mixing Depth	d	-	2.00E-01	m	CSA N288.1-20 (cl. 6.3.1.1)
Soil Surface Concentration	C_{ss}	$C_{ss} = C_{s(dw)}' * \rho_s * d * 1000\ L/m^3$	0.00E+00	Bq(dw)/m^2	Calculated
Linkage Fraction of Environmental Media (LA-1)	$LF_{EM\ (LA\text{-}1)}$	-	3.00E-01	Unitless	Assumed
Linkage Fraction ofEnvironmental Media (Reference)	$LF_{EM\ (Ref)}$	-	7.00E-01	Unitless	Assumed
Air Immersion Dose					
Air Immersion Dose	D_{air}	$D_{air} = C_{air} * f_o * (f_u + (1 - f_u) * S_b) * DCF_a$	0.00E+00	Sv/a	Calculated
Unit conversion	D_{air}'	$D_{air}' = D_{air} * 1000$ mSv / Sv	0.00E+00	mSv/a	Calculated (Table 4-9)
Air Inhalation Dose					
Inhalation Rate	IR_{air}	-	5.95E+03	m^3/a	Table 2-7 (IMPACT Model Report)
Dose Conversion Factor (Inhalation)	DCF_{inh}	-	3.30E-06	Sv/Bq	Table 3-20 (IMPACT Model Report)
Air Inhalation Dose	D_{inh}	$D_{inh} = C_{air} * IR_{air} * DCF_{inh}$	0.00E+00	Sv/a	Calculated
Unit conversion	D_{inh}'	$D_{inh}' = D_{inh} * 1000$ mSv / Sv	0.00E+00	mSv/a	Calculated (Table 4-9)
Water Ingestion Dose					
Ingestion Rate	IR_w	-	3.80E+02	L/a	Table 2-7 (IMPACT Model Report)
Dose Conversion Factor (Food)	DCF_f	-	1.20E-06	Sv/Bq	Table 3-20 (IMPACT Model Report)
Water Ingestion Dose (Total)	$D_{w\text{-}T}$	$D_w = (C_w * LF_{EM(LA\text{-}1)} + C_{w(Ref\text{-}M)} * LF_{EM(Ref)}) * IR_w * DCF_f$	2.87E-06	Sv/a	Calculated
Water Ingestion Dose (Reference)	$D_{w\text{-}R}$	$D_{w\text{-}R} = C_{w\ (Ref\text{-}A)} * IR_w * DCF_f$	2.43E-06	Sv/a	Calculated
Water Ingestion Dose (Incremental)	D_w	$D_w = D_{w\text{-}T} - D_{w\text{-}R}$	4.39E-07	Sv/a	Calculated
Unit Conversion	D_w'	$D_w' = D_w * 1000$ mSv / Sv	4.39E-04	mSv/a	Calculated (Table 4-9)
Water Immersion Dose					
Bathtub Correction Factor	D_c	-	7.00E-01	Unitless	CSA N288.1-20 (cl. 6.16.12)
Occupancy Factor - Swimming Surface Water	OF^s_w	-	1.04E-02	Unitless	CSA N288.1-20 (cl. 6.16.1.3)
Occupancy Factor - Pool Water	OF^p_w	-	3.13E-02	Unitless	CSA N288.1-20 (cl. 7.6.1.2)
Occupancy Factor - Bath Water	OF^b_w	-	1.40E-02	Unitless	CSA N288.1-20 (cl. 6.16.1.3)
Dose Conversion Factor (Water)	DCF_w	-	2.66E-11	Sv/Bq	Table 3-20 (IMPACT Model Report)
Water Immersion Dose (Total)	$D_{imm\text{-}T}$	$D_{imm\text{-}T} = (Cw * LF_{EM(LA\text{-}1)} + C_{w(Ref\text{-}M)} * LF_{EM(Ref)}) * (OF^s_w + D_c *$	8.62E-15	Sv/a	Calculated
Water Immersion Dose (Reference)	$D_{imm\text{-}R}$	$D_{imm\text{-}R} = C_{w\ (Ref\text{-}A)} * (OF^s_w + D_c * OF^b_w + OF^p_w) * DCF_w$	7.30E-15	Sv/a	Calculated
Water Immersion Dose (Incremental)		$D_{imm} = D_{imm\text{-}T} - D_{imm\text{-}R}$	1.32E-15	Sv/a	Calculated
Unit Conversion	D_{imm}'	$D_{imm}' = D_{imm} * 1000$ mSv / Sv	1.32E-12	mSv/a	Calculated (Table 4-9)
External Soil Dose					
Soil reduction factor	f_r	-	6.80E-01	Unitless	CSA N288.1-20 (cl. 6.4.6.3)
Groundshine Shielding Factor	S_g	-	2.00E-01	Unitless	CSA N288.1-20 (cl. 6.14.3)

Parameter	Symbol	Calculation	Polonium-210		
			Value	Unit	Source
Dose Conversion Factor (Soil)	DCF_g	-	2.61E-13	$(Sv/a)/(Bq/m^2)$	Table 3-20 (IMPACT Model Report)
Soil External Dose (Incremental)	D_g	$D_g = C_{ss} * f_o * f_r * (f_u + (1 - f_u) * S_g) * DCF_g$	0.00E+00	Sv/a	Calculated
Unit conversion	D_g'	$D_g' = D_g * 1000$ mSv / Sv	0.00E+00	mSv/a	Calculated (Table 4-9)
Internal Soil Dose					
Soil Intake Rate	IR_s	-	4.00E-06	kg(dw)/d	CSA N288.1-20 (Table 20)
Soil Exposure Frequency	t_d	-	1.35E+02	d/y	Assumed
Dose Conversion Factor (Food)	DCF_f	-	1.20E-06	Sv/Bq	Table 3-20 (IMPACT Model Report)
Internal Soil Dose (Incremental)	D_s	$D_s = C_{s(dw)}' * IR_s * t_d * DCF_f$	0.00E+00	Sv/a	Calculated
Unit conversion	D_s'	$D_s' = D_s * 1000$ mSv / Sv	0.00E+00	mSv/a	Calculated (Table 4-9)
Terrestrial Plant Ingestion Dose					
Labrador Tea Concentration (LA-1)	$C_{LT\ (LA-1)}$	-	5.06E+00	Bq/kg fw	Table B.7
Blueberry Concentration (LA-1)	$C_{BB\ (LA-1)}$	-	1.31E+01	Bq/kg fw	Table B.7
Labrador Tea Concentration (Reference)	$C_{LT\ (Ref)}$	-	5.06E+00	Bq/kg fw	Table B.7
Blueberry Concentration (Reference)	$C_{BB\ (Ref)}$	-	1.31E+01	Bq/kg fw	Table B.7
Labrador Tea Concentration (Incremental)	$C_{LT\ (LA-1)}'$	$C_{LT\ (LA-1)}' = C_{LT\ ((LA-1)} - C_{LT\ (Ref)}$	0.00E+00	Bq/kg fw	Calculated
Blueberry Concentration (Incremental)	$C_{BB\ (LA-1)}'$	$C_{BB\ (LA-1)}' = C_{BB\ ((LA-1)} - C_{BB\ (Ref)}$	0.00E+00	Bq/kg fw	Calculated
Food Intake (Terrestrial Plants)	IR_{TP}	-	1.98E+01	kg/a fw	Assumed, site-specific
Linkage Fraction of Labrador Tea (LA-1)	$LF_{LT\ (LA-1)}$	-	9.20E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Blueberry (LA-1)	$LF_{BB\ (LA-1)}$	-	9.91E-01	Unitless	Table 2-10 (IMPACT Model Report)
Dose Conversion Factor (Food)	DCF_f	-	1.20E-06	Sv/Bq	Table 3-20 (IMPACT Model Report)
Incremental Ingestion Dose (Terrestrial Plants)	D_{TP}	$D_{TP} = (C_{LT\ (LA-1)}' * LF_{LT\ (LA-1)} + C_{BB\ (LA-1)}' * LF_{BB\ (LA-1)}) * IR_{TP} * DCF_f$	0.00E+00	Sv/a	Calculated
Unit conversion	D_{TP}'	$D_{TP}' = D_{TP} * 1000$ mSv / Sv	0.00E+00	mSv/a	Calculated (Table 4-9)
Aquatic Animal Ingestion Dose					
Northern Pike Concentration (LA-1)	$C_{NP\ (LA-1)}$	-	9.34E-01	Bq/kg fw	Table B.7
White Sucker Concentration (LA-1)	$C_{WS\ (LA-1)}$	-	8.40E-01	Bq/kg fw	Table B.7
Northern Pike Concentration (Reference_Average)	$C_{NP\ (Ref)}$	-	8.00E-01	Bq/kg fw	
White Sucker Concentration (Reference_Average)	$C_{WS\ (Ref)}$	-	7.19E-01	Bq/kg fw	
Northern Pike Concentration (Incremental)	$C_{NP\ (LA-1)}'$	$C_{NP\ (LA-1)}' = C_{NP\ (LA-1)} - C_{NP\ (Ref)}$	1.34E-01	Bq/kg fw	Calculated
White Sucker Concentration (Incremental)	$C_{WS\ (LA-1)}'$	$C_{WS\ (LA-1)}' = C_{WS\ (LA-1)} - C_{WS\ (Ref)}$	1.21E-01	Bq/kg fw	Calculated
Food Intake (Aquatic Animals)	IR_{AA}	-	2.67E+01	kg/a fw	Assumed, site-specific
Linkage Fraction of Northern Pike (LA-1)	$LF_{NP\ (LA-1)}$	-	5.00E-01	Unitless	Assumed
Linkage Fraction of White Sucker (LA-1)	$LF_{WS\ (LA-1)}$	-	5.00E-01	Unitless	Assumed
Dose Conversion Factor (Food)	DCF_f	-	1.20E-06	Sv/Bq	Table 3-20 (IMPACT Model Report)
Incremental Ingestion Dose (Aquatic Animals)	D_{AA}	$D_{AA} = ((C_{NP\ (LA-1)}' * LF_{NP\ (LA-1)} + C_{WS\ LA-1)}' * LF_{WS\ (LA-1))} * IR_{AA} *$	4.07E-06	mg/kg/d fw	Calculated
Unit conversion	D_{AA}'	$D_{AA}' = D_{AA} * 1000$ mSv / Sv	4.07E-03	mSv/a	Calculated (Table 4-9)
Terrestrial Animal Ingestion Dose					
Woodland Caribou Concentration (LA-5)	$C_{WC\ (LA-5)}$		8.58E+00	Bq/kg fw	Table B.7
Moose Concentration (LA-1)	$C_{M\ (LA-1)}$	-	1.30E+00	Bq/kg fw	Table B.7
Moose Organs Concentration (LA-1)	$C_{MO\ (LA-1)}$	-	1.30E-02	Bq/kg fw	Table B.7
Muskrat Concentration (LA-1)	$C_{Mus\ (LA-1)}$	-	9.72E-01	Bq/kg fw	Table B.7
Mallard Concentration (LA-1)	$C_{Mal\ (LA-1)}$	-	4.26E+01	Bq/kg fw	Table B.7
Goose Concentration (LA-1)	$C_{G\ (LA-1)}$	-	1.06E+00	Bq/kg fw	Table B.7
Store Food Concentration (LA-1)	$C_{SF\ (LA-1)}$	-	4.80E-02	Bq/kg fw	Table 2-11 (IMPACT Model Report)

Parameter	Symbol	Calculation	Polonium-210		
			Value	Unit	Source
Woodland Caribou Concentration (Reference_Average)	$C_{WC\ (Ref)}$		8.54E+00	Bq/kg fw	
Moose Concentration (Reference_Average)	$C_{M\ (Ref)}$	-	1.27E+00	Bq/kg fw	
Moose Organs Concentration (Reference_Average)	$C_{MO\ (Ref)}$	-	1.27E-02	Bq/kg fw	
Muskrat Concentration (Reference_Average)	$C_{Mus\ (Ref)}$	-	8.27E-01	Bq/kg fw	
Mallard Concentration(Reference_Average)	$C_{Mal\ (Ref)}$	-	3.62E+01	Bq/kg fw	
Goose Concentration (Reference_Average)	$C_{G\ (Ref)}$	-	1.07E+00	Bq/kg fw	
Store Food Concentration (Reference)	$C_{SF\ (Ref)}$	-	4.80E-02	Bq/kg fw	Table 2-11 (IMPACT Model Report)
Woodland Caribou Concentration (Incremental)	$C_{WC\ (LA-1)}'$	$C_{WC\ (LA-5)}' = C_{WC\ (LA-5)} - C_{WC\ (Ref)}$	3.67E-02	Bq/kg fw	Calculated
Moose Concentration (Incremental)	$C_{M\ (LA-1)}'$	$C_{M\ (LA-1)}' = C_{M\ (LA-1)} - C_{M\ (Ref)}$	3.09E-02	Bq/kg fw	Calculated
Moose Organs Concentration (Incremental)	$C_{MO\ (LA-1)}'$	$C_{MO\ (LA-1)}' = C_{MO\ (LA-1)} - C_{MO\ (Ref)}$	3.09E-04	Bq/kg fw	Calculated
Muskrat Concentration (Incremental)	$C_{Mus\ (LA-1)}'$	$C_{Mus\ (LA-1)}' = C_{Mus\ (LA-1)} - C_{Mus\ (Ref)}$	1.45E-01	Bq/kg fw	Calculated
Mallard Concentration (Incremental)	$C_{Mal\ (LA-1)}'$	$C_{Mal\ (LA-1)}' = C_{Mal\ (LA-1)} - C_{Mal\ (Ref)}$	6.47E+00	Bq/kg fw	Calculated
Goose Concentration (Incremental)	$C_{G\ (LA-1)}'$	$C_{G\ (LA-1)}' = C_{G\ (LA-1)} - C_{G\ (Ref)}$	-5.04E-03	Bq/kg fw	Calculated
Store Food Concentration (Incremental)	$C_{SF\ (LA-1)}'$	$C_{SF\ (LA-1)}' = C_{SF\ (LA-1)} - C_{SF\ (Ref)}$	0.00E+00	Bq/kg fw	Calculated
Linkage Fraction of Woodland Caribou (LA-5)	$LF_{WC\ (LA-5)}$		4.00E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Moose (LA-1)	$LF_{M\ (LA-1)}$	-	1.78E-02	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Moose Organs (LA-1)	$LF_{MO\ (LA-1)}$	-	6.80E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Muskrat (LA-1)	$LF_{Mus\ (LA-1)}$	-	3.70E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Mallard (LA-1)	$LF_{Mal\ (LA-1)}$	-	4.60E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Goose (LA-1)	$LF_{G\ (LA-1)}$	-	2.80E-03	Unitless	Table 2-10 (IMPACT Model Report)
Linkage Fraction of Store Food (LA-1)	$LF_{SF\ (LA-1)}$	-	9.60E-01	Unitless	Table 2-10 (IMPACT Model Report)
Food Intake (Terrestrial Animals)	IR_{TA}	-	6.60E+02	kg/a fw	Assumed, site-specific
Dose Conversion Factor (Food)	DCF_f	-	1.20E-06	Sv/Bq	Table 3-20 (IMPACT Model Report)
Incremental Ingestion Dose (Terrestrial Animals)	D_{TA}	$D_{TA} = ((C_{WC\ (LA-5)}' * LF_{WC\ (LA-5)} + C_{M\ (LA-1)}' * LF_{M\ (LA-1)} + C_{MO\ (LA-1)}' * LF_{MO\ (LA-1)} + C_{Mus\ (LA-1)}' * LF_{Mus\ (LA-1)} + C_{Mal\ (LA-1)}' * LF_{Mal\ (LA-1)} + C_{G\ (LA-1)}' * LF_{G\ (LA-1)} + C_{SF\ (LA-1)}' * LF_{SF\ (LA-1)}) * IR_{TA} * DCF_f$	2.45E-05	Sv/a	Calculated
Unit conversion	D_{TA}'	$D_{TA}' = D_{TA}$ * 1000 mSv / Sv	2.45E-02	mSv/a	Calculated (Table 4-9)
Adult Recreational Fisher/Hunter Total Incremental Dose					
Total Incremental Dose	D_{total}	$D_{total} = D_{air}' + D_{inh}' + D_w' + D_{imm}' + D_g' + D_s' + D_{TP}' + D_{AA}' + D_{TA}'$	2.90E-02	mSv/a	Calculated (Table 4-9)

Appendix C Ecological Receptor Profiles

Appendix C Ecological Receptor Profiles

One of the key considerations, which defines the scope of a risk assessment is the selection of ecological receptors. In selecting ecological receptors, it is important to identify plants and animals that are likely to be most exposed to the effects of the project. As it is not possible to evaluate all ecological species at a site, representative species were selected based on the selection process provided in Table 7.1 of CSA N288.6 (2012).

This appendix describes the aquatic and terrestrial ecological receptors (groups or species) selected for the assessment. The general characteristics of each receptor including any status under COSEWIC, SARA or provincial ranking, its distribution and presence in the Regional Study Area (RSA), its home range and diet, as well as how it is incorporated into the ecological and/or human health models and the protection level that it is afforded in the risk assessment.

1.0 Aquatic and Riparian Biota

1.1 Aquatic Vegetation

1.1.1 Macrophytes

Macrophytes are aquatic plants growing in or near water and can be either emergent, submergent or floating. Emergent macrophytes are rooted in shallow water whereas submergent macrophytes are typically rooted in sediment and the entire plant is submerged. Macrophytes are primary producers that provide food, cover and shelter for wildlife, such as spawning and nursery habitats for fish and nesting habitats for waterfowl, improve water quality and clarity, and help to stabilize shorelines and bottom sediments.

Patches of emergent and submergent macrophyte occurred in several areas in Kratchkowsky Lake (LA-7), Whitefish Lake (LA-5 & LA-6), McGowan Lake (LA-1) and Russell Lake (Ecometrix, 2020). Dense patches of long-stemmed submergent vegetation were observed near the inlet delta edge on the west side of the Whitefish Lake. Some sparse submergent vegetation stems were observed in the mid-basin, however the stem heights were only approximately 10 to 20 cm. Emergent vegetation was limited to the nearshore and shoreline areas. Larger emergent and submergent macrophyte beds were also generally limited to embayments of Kratchkowsky Lake.

In the ecological model, macrophytes are exposed to aquatic release through surface water, and they provide food for woodland caribou, moose, muskrat, lesser scaup and mallard. Because of their importance as a potential link between constituents in sediments and surface water to other aquatic and terrestrial receptors, macrophytes were conservatively assumed to be present in every surface water body within the RSA.

In the ERA, macrophytes are assessed as a group at a community level.

1.1.2 Phytoplankton

Phytoplankton are small primary producers that use sunlight to produce oxygen and nutrients for other organisms. Phytoplankton are an important food source for organisms in an aquatic environment.

Phytoplankton samples were collected in 2016 at six locations within the study area (Ecometrix, 2020). The phytoplankton community within the study area consisted of 55 taxa from 7 classes. At least 6 classes were identified at each location. Diatoms (*Bacilliarophyceae*) were numerically dominant, based on measured biovolume, at most locations. The cryptophytes (*Cryptophyceae*), cyanophytes (*Cyanophyceae*), and dinoflagellates (*Dinophyceae*) were also numerically important, comprising > 10% of total phytoplankton biovolume, at some locations.

In the model, phytoplankton are exposed to aquatic release through surface water. Phytoplankton communities represent a potential link between constituents in surface water and other aquatic and terrestrial receptors.

In the ERA, phytoplankton are assessed as a group at a community level.

1.2 Aquatic Invertebrates

1.2.1 Benthic Invertebrates

Benthic invertebrates or "benthos" live on or within the sediments of surface water bodies. Benthic invertebrates play an integral role in the freshwater ecosystem through nutrient cycling and they function as an important food source for wildlife such as the diving and dabbling (e.g. Mallard) ducks, and fish (e.g. White Sucker). Epifaunal benthic invertebrates live in water bodies on or attached to submerged substrates such as the bottom sediment or hard surfaces and feed at the substrate surface. Epifaunal benthic invertebrates primarily include amphipods, bivalves, shrimps, crabs, snails, and some aquatic insects. Infaunal benthic invertebrates live and burrow in the sediments and feed within sediments. Infaunal benthic invertebrates primarily include bivalves, worms, and some aquatic insects.

Benthic invertebrate samples were collected in 2016 at ten lake locations and a total of 78 benthic invertebrate taxa from 38 major taxonomic groups (Families) were identified within the study area (Ecometrix, 2020). Chironomids were prevalent across the study area and were the most numerically dominant taxon at most locations. Other taxonomic groups that represented more than 10% of the total benthic invertebrate density at a sampling location were detritus worms (*Naididae*), pill clams (*Pisidiidae*), water fleas from the families Holopedidae and Macrothricidae, and phantom midges (*Chaoboridae*). From a feeding group perspective, predatory taxa and those that feed on fine particulate organic matter (collector-gatherers) were generally the most abundant groups in lakes within the study area.

In the model, benthic invertebrates are exposed to aquatic release through surface water and sediment. Benthic invertebrates provide links from water to fish and sediment to fish pathways and a link between aquatic and terrestrial ecosystems. Many benthic invertebrate species feed on decaying organic matter and thereby form an important link between the decomposer and primary consumer levels.

In the ERA, benthic invertebrates are assessed as a group at a community level.

1.2.2 Zooplankton

Zooplankton are small aquatic animals that are intermediaries in the aquatic food chain. Zooplankton are primary or secondary consumers that are also prey of other larger zooplankton predators or fish. Zooplankton are exposed to aquatic release through surface water.

Zooplankton samples were collected in 2016 at six locations within the study area (Ecometrix, 2020). The zooplankton community within the study area consisted of 32 taxa from 10 classes. At least 7 classes were identified at each location. Branchiopods (*Branchiopoda*) were numerically dominant, based on measured biovolume, at all locations. The copepods (*Copepoda*) and rotifers (*Monogononta*) were also numerically important at some locations.

In the model, zooplankton are exposed to aquatic release through surface water. Zooplankton communities represent a potential link between constituents in surface water and phytoplankton, and other aquatic and terrestrial receptors.

In the ERA, zooplankton are assessed as a group at a community level.

1.3 Fish

1.3.1 Northern Pike

Northern pike (*Esox lucius*) is a pelagic top predator fish, of the family Esicidae, that is widely distributed in freshwater environments across Canada. It is of ecological and economic importance.

Eleven fish species were collected within study area lakes including representative forage and sport fish species (Ecometrix, 2020). Northern Pike and its spawning habitats were present in nearly all study area lakes, as well as most stream stations. Adult and juvenile Northern Pike were most abundant in Kratchkowsky Lake and Whitefish Lake. Northern pike tissue samples were retained for chemical analysis. It is assumed that the northern pike spends 100% of its time in the project area waterbody where it is assessed.

Northern pike is exposed to aquatic release through surface water and consumption of prey (aquatic vertebrates and/or aquatic invertebrates). In the model, northern pike is exposed to aquatic release through surface water. Northern pike represent a potential link between constituents in surface water, other aquatic and terrestrial receptors, and human receptor groups. In the ecological model, northern pike is consumed by black bear, mink, bald eagle and common loon. In the human health model, they are a component of the human Traditional Foods diet and are used as a surrogate for other common predatory fish, such as walleye, which are also items in the human Traditional Foods diet.

In the ERA, northern pike is assessed as a representative pelagic predator fish species at a population level.

1.3.2 White Sucker

White sucker (*Catostomus commersonii*) was selected to represent a bottom-feeding forage fish species. White suckers spawn in inlet or outlet streams, usually with a gravel bottom, often in the same areas as, but later than, Longnose Sucker (McPhail and Lindsey, 1970). White suckers were found in nearly all study area lakes (Ecometrix, 2020). White suckers spawning habitats were observed within the inlet tributary from nearly all study area lakes. Adult and juvenile white sucker were most abundant in Kratchkowsky Lake, Whitefish Lake, McGowan Lake and Russell Lake. White sucker tissue samples were retained for chemical analysis. It is assumed that the white sucker spends 50% of its time in the project area waterbody and 50% of its time in the sediment of lakes where it is assessed.

White sucker is exposed to aquatic release through surface water and sediment. In the model, white sucker represents a potential link between constituents in surface water, sediment, and human receptor groups. In the human health model, they are a component of the human Traditional Foods diet and are used as a surrogate for other common forage fish, such as lake whitefish and longnose Sucker, which are also items in the human Traditional Foods diet.

In the ERA, white sucker is assessed as a representative forage fish species at a population level.

1.4 Riparian Mammals

1.4.1 American Mink

American mink (*Neovison vison*) is a semi-aquatic, carnivorous mammal belonging to the weasel family (Mustelidae), measuring approximately 30 to 40 cm not including the tail and weighing on average 1 kg. Minks are widely distributed throughout North America, except in the far north, arid areas in southwestern United States, and Mexico. Mink trails were observed in the RSA and are trapped for fur and traditional lifestyles (Omnia, 2020).

Preferred habitats for minks generally consist of aquatic habitats such as rivers, lakes, streams, marshes, and swamps, with wooded cover. Mink typically use bank burrows of other animals such as muskrats, cavities in tree roots, rock or brush piles, log jams, and beaver lodges for denning instead of constructing their own (US EPA, 1993). Minks have been known to travel up to 200 m away from a water body and males have the largest home ranges of up to 10 km^2 (US EPA, 1993). For the ecological model, it is assumed that the mink spends 100% of its time at the location where it is assessed.

Minks are nocturnal opportunistic hunters, consuming a variety of prey around shorelines or emergent vegetation, preferring small mammals such as voles, muskrats and shrews. Other secondary prey items include aquatic birds, fish, amphibians, and crustaceans (US EPA, 1993). For the ecological model it is assumed that the mink’s diet consists of small mammals, represented by muskrat (45%); fish, represented by northern pike (30%); benthic invertebrates (15%) and aquatic birds; represented by mallard (10%).

In the ERA, minks are assessed as a representative riparian carnivore species at a population level.

1.4.2 Muskrat

The muskrat (*Ondatra zibethicus*) is a large rodent (Muridae), measuring approximately 50 cm from tip of the nose to tail, and weighing on average 1 kg. Muskrats exist all over North America, from the Arctic Ocean in the north to the Gulf of Mexico in the south, from the Pacific Ocean in the west to the Atlantic Ocean in the east. Their mean home range size in the summer is between 0.048 to 0.17 hectares (U.S. EPA, 1993). Muskrats are present in the RSA and are trapped for fur and meat for traditional lifestyles (Omnia, 2020).

Muskrats prefer freshwater marshes, marshy areas of lakes, and slow-moving streams. The preferred water depth in these areas is 1 to 2 m, deep enough not to freeze fully during the winter but shallow enough to allow aquatic vegetation to grow. Muskrats nest in compact mounds of partially dried and decayed plant material such as cattails and bulrushes. In winter, muskrats generally occupy lodges that they build through burrowing underneath their mounds, and spends most of its time eating and sleeping. They are capable of extended dives, allowing them to dig channels and burrows underwater, cut submerged stems and roots with their teeth, and travel long distances beneath the ice (EC & CWF 1986). Breeding generally occurs in March, April, or May. Birth of the litter usually occurs within 1 month of mating and usually contains 5 to 10 young. Breeding can occur multiple times throughout the season (EC & CWF, 1986). For the ecological model, it is assumed that the muskrat spends 100% of its time at the location where it is assessed.

Muskrats mainly feed on aquatic plants such as cattails, bulrushes, horsetails, or pondweeds; although they prefer cattails. When aquatic plants are unavailable, muskrats are also known to feed on fish, frogs, and clams. In the model, muskrats are exposed to aquatic release through water, food and sediment. For the ecological model, it is assumed that the muskrat's diet consists of aquatic plants (80%) and benthic invertebrates (20%).

In the ERA, muskrats are assessed as a representative riparian herbivore species at a population level.

1.5 Riparian Birds

1.5.1 Common Loon

The loon (*Gavia immer*) is a piscivorous migratory waterfowl of the family Gaviidae, that breeds in Canada during the summer (FCSAP, 2012). Male loons average 5.3 kg in weight and females about 4.7 kg in weight (FCSAP, 2012). Loons are common to northern Saskatchewan and are known to breed in the RSA (Omnia, 2020).

Loons commonly inhabit open water areas of lakes and rivers during the summer (FCSAP, 2012). Loons do not walk well on land, so they spend their time on water. They prefer to nest offshore, on islands, islets, or floating mounds of vegetation in shallow water. Loon pairs may reuse the same nesting site year after year. They have one brood per year with 1 or 2 chicks being produced. Eggs hatch after an incubation period of 26-29 days (Cornell Lab (no date)). For the ecological model, it is conservatively assumed that the loon spends 100% of its time at the location where it is assessed.

Loons surface dive to the water column to catch fish. Loons are opportunistic feeders but appear to prefer perch to salmons (FCSAP, 2012). Aquatic invertebrates and crayfish are significant secondary components of their diet especially if the water is not clear. For the ecological model, loons are assumed to eat 90% fish (northern pike) and 10% aquatic invertebrates. In the model, loons are exposed to aquatic release through water and food.

In the ERA, loons are assessed as a representative avian piscivorous species at a population level.

1.5.2 Lesser Scaup

The lesser scaup (*Aythya affinis*) is one of the most abundant North American ducks. They breed principally throughout western Canada and Alaska, although their breeding range extends into the western United States as far south as Colorado and Ohio (U.S. EPA, 1993). The lesser scaup averages 42 cm from bill tip to tail tip with average 0.8 kg in weight. Males are larger and more colorful than the brown females.

Lesser scaup are found on large lakes and bays during the fall and winter and are common on smaller bodies of water (e.g., ponds) during the spring. They breed in the prairie potholes region, most often on permanent or semipermanent wetlands of 0.85 to 2.0 ha with trees and shrubs bordering at least half of the shorelines. Primary brood habitat is characterized by permanent wetlands dominated by emergent vegetation. Lesser scaup are known to breed in the RSA (Omnia, 2020). For the ecological model, it is assumed that the scaup spends 100% of its time at the location where it is assessed.

Most populations of lesser scaup consume primarily aquatic invertebrates, both from the water column and from the surfaces of aquatic vegetation and other substrates. Common prey includes snails, clams, scuds (amphipods), midges, chironomids, and leeches. Scaup are omnivorous, however, and the percentage of plant materials (almost exclusively seeds) in the diet varies seasonally as the availability of different foods changes. For the ecological model, lesser scaup are assumed to eat 90% aquatic invertebrates and 10% aquatic plants. In the model, lesser scaup are exposed to aquatic release through water and food.

In the ERA, lesser scaup are assessed as a representative avian omnivorous species at a population level.

1.5.3 Mallard

The mallard (*Anas platyrhynchos*) is an omnivorous migratory duck (Anatidae) that has a summer breeding range in Canada (U.S. EPA, 1993; FCSAP, 2012). Male mallards average 1.1 kg in weight and females about 1.2 kg in weight (FCSAP, 2012). Mallards are common to northern Saskatchewan and are known to breed in the RSA (Omnia, 2020). Mallards are an important component of the traditional foods diet for First Nations living in the Boreal Shield ecozone of Saskatchewan (Chan *et al*. 2018 and 2019).

The general habitat of the mallard is wetlands. The mean home range of a mallard in spring is between 111 and 620 hectares (U.S. EPA, 1993). Mallard typically nest on the ground in thick vegetation away from a waterbody. Mating pairs may produce more than one clutch per season, with the first clutch generally being finished by in late Spring, in the northern United States (US EPA, 1993). Females remain with their brood until fledging (US EPA, 1993). Although mallards are not present in the vicinity of the Project for over half the year due to migration, they have a small home range while nesting and rearing of their young. For the ecological model, it is conservatively assumed that the mallard spends 100% of its time at the location where it is assessed.

The mallard forages by dabbling and filtering though sediment (U.S. EPA, 1993). The bulk of the mallard`s diet is plant material, mostly aquatic plants and seeds, with the remaining portions of the diet consisting of aquatic invertebrates, especially during the breeding season (FCSAP, 2012). For the ecological model it is assumed that the mallard's diet while in the RSA consists of benthic invertebrates (75%) and aquatic plants (25%).

In the model, mallards are exposed to aquatic release through water, food and sediment. In the ecological model, mallards are prey for mink and bald eagle. In the human health model, mallards are a component of the First Nation's traditional foods diet and are used as a surrogate for other water birds with a similar diet.

In the ERA, mallards are assessed as a representative riparian avian species at a population level.

2.0 Terrestrial Biota

2.1 Terrestrial Invertebrates

Terrestrial invertebrates are considered to be primary consumers. They are represented by earthworms, which live in soil and are therefore exposed to constituents in soil layers through direct contact. Earthworms live in soil and depending on the species they either move vertically or horizontally indifferent soil layers. Earthworms acquire their nutrition through the organic matter in soil as well as the decomposing remains of other animals. They can devour one third of their own body weight per day.

For the ecological model, terrestrial invertebrates represented by the earthworm are assumed to spend 100% of their time at the location where they are assessed.

In the model, terrestrial invertebrates are exposed to atmospheric release through deposition to soil. Terrestrial invertebrate communities represent a potential link between constituents in air and other terrestrial receptors. In the ecological model, terrestrial invertebrates are part of the diet for the American robin (*Turdus migratorius*) and olive-sided flycatcher (*Contopus cooperi*).

In the ERA, terrestrial invertebrates are assessed as a group at a community level.

2.2 Terrestrial Vegetation

Terrestrial vegetation types are dietary components for terrestrial animals and humans. They are represented by browse (various shrubs and grasses), lichen (various species), blueberries (*Vaccinium myrtilloides*), and Labrador tea (*Rhododendron groenlandicum)*.

Individual plant species are included as food for other ecological receptors and for human receptors in the ecological and human health models. Three individual species are assessed in the model as representative species for lichen, fruits and berries (blueberry), and leafy plants and browse (Labrador tea). Plants are immobile and therefore are assumed to spend 100% of their time at the location where they are assessed.

In the ERA, terrestrial vegetation is assessed as a group at a community level.

2.2.1 Blueberry

Blueberry (*Vaccinium myrtilloides*) is a low spreading deciduous shrub that is common to Canada and northern United States. It often grows in the form of small thickets in open areas of coniferous forests in loose acidic soil, and in burn areas. Blueberries produce clusters of small sweet fruits. Blueberries are generally present in the RSA and is the most prevalent ground cover species in the uplands (Omnia, 2020). Blueberries are an important Traditional Foods component for First Nations living in the Boreal Shield and Boreal Plains ecozones of Saskatchewan (Chan *et al.* 2018 and 2019).

In the model, plants like blueberry are exposed to atmospheric release through deposition to soil and uptake from soil. In the ecological model, blueberries are part of the diet for a number of mammals and birds including snowshoe hare; southern red-backed vole and black bear. In the human health model, blueberries are a component of the Traditional Foods diet, and is used as a surrogate for other fruits and berries in the human Traditional Foods diet, such as rosehips, cranberries, mooseberry and squashberry (Chan *et al*. 2018 and 2019).

2.2.2 Labrador Tea

Labrador tea (*Rhododendron groenlandicum*) is a common name for three closely related plant species in the genus Rhododendron, including *Rhododendron groenlandicum* which is the most common ground cover plant in low sites in the RSA (Omnia, 2020). Labrador tea is an important Traditional Foods component for First Nations living in the Boreal Shield ecozone of Saskatchewan (Chan *et al*. 2018 and 2019), and is infused as a tea.

In the model, plants like Labrador tea are exposed to atmospheric release through deposition to soil. In the human health model Labrador tea is a component of the Traditional Foods diet, and is used as a surrogate for other plants in the human Traditional Foods diet, such as mint and rat root (Chan *et al*. 2018 and 2019).

2.2.3 Lichen

Lichens are not plants, but rather they are composite organisms and symbiotic partnerships between fungus and algae. Some species are arboreal and grow on branches of higher plants, while others are terrestrial and grow on rocks and soil. The fungus provides structure and protection to the algae, while the algae which has chlorophyll, photosynthesizes and provides nutrition to the fungus. Lichens are found around the world in many different habitats.

Stands of jack pine with a ground cover of lichen occupy the dry sandy sites, and open jack pine (*Pinus banksiana*) forests with a thin cover of lichen are common and dominate the uplands in the RSA (Omnia, 2020).

In the model, lichen is exposed to atmospheric release depositing from air. In the ecological model lichens are food for woodland caribou.

2.3 Terrestrial Mammals

2.3.1 Black Bear

Black bear (*Ursus americanus*) is a large terrestrial omnivore. The body weight of black bears varies seasonally and is at its greatest in the fall before winter hibernation. Adult males weigh about 135 kg and females are much smaller than males, averaging 70 kg, resulting in an average weight of 102.5 kg (Hinterland's Who's Who, 2007a). Although its natural range is across North America, black bears have been extirpated from much of their territory in the continental United States. Currently, black bears are commonly found across most of Canada and Alaska (EC & CWF, 2007). Black bears are widespread within the RSA (Omnia, 2020)

Black bears are found in a variety of habitats but appear to prefer heavily wooded areas and dense bushland. Black bears mate in June or early July, and the cubs, generally one or two, are born the following January or February while the mother is still in her winter den (EC & CWF, 2007). The availability of food in the foraging range leading up to denning is important to reproductive success because the bear's fetuses do not "implant" into the uterus until late fall when she enters her winter den (EC & CWF, 2007). Home ranges from for female black bears in the Saskatchewan Boreal Shield range from 40 km^2 to 130 km^2, as determined from GPS tracking data (McLoughlin et al., 2019). In the ecological model an average female home range of 80 km^2 is used. For the ecological model, the black bear is assumed to interact with more than one exposure location in the RSA for feeding and water intake, due to the large home range.

Black bears are omnivores and eat seasonally available food. Most of their diet is composed of plant material, including many berries (blueberries, buffalo berries, strawberries, elderberries, Saskatoon berries), fruits (black cherries, and apples) and nuts (acorns, hazelnuts, and beechnuts) (EC & CWF, 2007; FCSAP, 2012). Black bears also consume animals, especially invertebrates (ants, bee larvae), fish, small mammals and birds, and carrion (EC & CWF, 2007; FCSAP, 2012). In the ecological model, black bears are assumed to eat 70% berries (blueberries) and 30% fish (northern pike).

In the model, black bears are exposed to aquatic and atmospheric releases through water and food.

In the ERA, black bears are assessed as a representative terrestrial mammalian omnivorous species at a population level.

2.3.2 Canada Lynx

The Canada lynx (*Lynx canadensis*) is a medium-sized cat with long legs and large, well-furred paws. Lynx generally measures 75 to 90 cm long and weigh 6 to 14 kg, and males are 13-25 percent larger than females (U.S. FWS, 2017). For the ecological model a body weight of 14 kg was selected. The lynx generally inhabits forested wilderness areas. It favours old growth boreal forests with a dense undercover of thickets and windfalls. The size of the home range varies with numbers of lynxes and snowshoe hares in the area, available cover, and season. In summer, home ranges are larger than in winter (Hinterland's Who's Who, 2007b).

More than 75 percent of the lynx's diet in winter is snowshoe hares. In summer the lynx's diet is more varied. But even in summer hares remain the main prey, supplemented by grouse, voles, mice, squirrels, and foxes. In the ecological model, Canada lynx are assumed to eat 80% snowshoe hares, 15% small mammals represented by southern red-backed vole and 5% terrestrial birds represented by Canada goose.

In the model, Canada lynx are exposed to aquatic and atmospheric release through water and food.

In the ERA, Canada lynx is assessed as a representative upland mammalian carnivore species at a population level.

2.3.3 Moose

Moose (*Alces alces*) is a large ungulate of the family Cervidae, with an average weight for males and females of 453 kg and 350 kg, respectively (FCSAP, 2012). For the ecological model a body weight of 400 kg was selected. Moose are found in Canadian forests from the Alaska boundary to the eastern tip of Newfoundland and Labrador (EC & CWF, 1997). Moose are present in the RSA too (Omnia, 2020). Moose meat and organs are important components of the traditional foods diet for First Nations living in the Boreal Shield ecozone of Saskatchewan (Chan *et al*. 2018 and 2019).

Moose are essentially solitary animals that have one or several distinct seasonal home ranges to which they are strongly attached. Movements between seasonal home ranges may be extensive but home ranges are generally small and moose usually return to the same home ranges year after year (Franzmann, 1981; Wilson and Ruff, 1999). A seasonal home range of 10 km^2 was selected for the ecological model.

Breeding season, or rut, begins in mid-September. Cows usually bear one or two calves in the Spring, and the calves stay with the cow until she calves again the following spring. The number of calves born to a cow reflects the availability of nutrition during the rut. During the winter months, moose live almost solely on twigs and shrubs such as balsam fir, poplar, red osier dogwood, birch, willow, and red and striped maples (EC & CWF, 1997). In summer the moose's diet includes leaves, some upland plants, and water plants in great quantity where available (EC & CWF, 1997). The diet used in the ecological model reflects a spring/summer diet at the end of gestation and when calves are nursing. It assumes 80% browse and 20% macrophytes.

In the model, moose are exposed to aquatic and atmospheric releases through water and food. The moose is part of the Traditional Foods diet in the human health model, and is used as a surrogate for other ungulate species such as white-tailed deer (*Odocoileus virginianus*) and woodland caribou.

In the ERA, moose are assessed as a representative ungulate species at a population level.

2.3.4 Snowshoe Hare

The snowshoe hare (*Lepus americanus*) is a North American hare of the family Leporidae. Adult snowshoe hares typically weigh between 0.9 kg to 1.9 kg (FCSAP, 2012) and females are often slightly larger than males (EC & CWF 2005). For the ecological model a bodyweight of 1.8 kg was selected for snowshoe hare. Snowshoe hares are one of the most common woodland mammals of every province and territory of Canada, and are present in the RSA (Omnia, 2020).

Snowshoe hares prefer forested areas with a heavy understory such as conifer-dominated habitats and deciduous riparian forests. The size of their home range can reach up to 10 ha (EC & CWF, 2005), but their foraging range is relatively small (1.6 ha) especially for females during the spring and summer reproductive season (FCSAP, 2012). In the ecological model snowshoe hare are assumed to reside 100% of the time at the location where they are assessed.

During the summer, the snowshoe hare's diet consists of grasses, sedges, and forbs while during the winter they eat stems and branches of woody plants (FCSAP, 2012). They are also known to consume fruits and berries and some animal protein. In the ecological model, snowshoe hares are assumed to eat 90% browse and 10% berries represented by blueberries.

In the model, snowshoe hares are exposed to aquatic and atmospheric release through water and food. In the ecological model, snowshoe hare is part of the diet for the Canada lynx. Hare are represented by muskrat in the human traditional foods diet in the human health model.

In the ERA, snowshoe hare is assessed as a representative upland mammalian herbivore species at a population level.

2.3.5 Southern Red-Backed Vole

Southern red-backed vole (*Myodes gapperi*), is a woodland vole of the family Cricetidae, found in Canada and the northern United States, that weighs up to 0.042 kg. Red-backed voles are present in the RSA and were among the most abundant small mammals trapped during baseline studies (Omnia, 2020). A total of 197 individual small mammals of three species were captured during baseline studies. Red-backed voles (*Clethrionomys gapperi*) were most abundant with 140 captures, followed by meadow voles (*Microtis pennsylvanicus*), and dusky shrews (*Sorex monticolus*). Red-backed vole tissue samples were retained for chemical analysis. For the model, the body weight and total feed intake for the meadow vole were used because it is a similar species that is well characterized and commonly used in risk assessments (FCSAP, 2012).

Baseline studies indicate that red-backed voles are present in all ecosites and vegetation cover types in the RSA. Coarse woody debris and shrub cover are two major components of red-backed vole habitat (Omnia, 2020). They often reside in burrows created by other small mammals, and use runways they created through the vegetation understory or snow. They remain active year-round and generally feed during the night. Females may have two to four litters a year. In the ecological model, voles are assumed to reside 100% of the time at the location where they are assessed.

Southern red-backed voles are omnivorous. They generally feed on green plants, underground fungi, seeds, nuts, roots, and berries, but also eat small terrestrial invertebrates such as insects, snails. They are known to store food for later use. In the ecological model, voles are assumed to eat 60% berries (blueberries) and 40% browse.

In the model, voles are exposed to aquatic and atmospheric releases through water and food. In the ecological model voles are part of the diet for Canada lynx.

In the ERA, voles are assessed as a representative mammalian herbivore at a population level.

2.3.6 Woodland Caribou

Woodland caribou (*Rangifer tarandus caribou*) is a medium sized member of the deer family (Cervidae), weighing between 100 and 250 kg (COSEWIC, 2002). A body weight of 180 kg, representing the upper range mean for adult male and female woodland caribou (COSEWIC, 2002) was selected for the ecological model. The boreal population of woodland caribou is designated as Threatened by COSEWIC and SARA and is provincially-ranked S3, meaning that the species is vulnerable/rare to uncommon in Saskatchewan. Woodland caribou were observed in winter tracking, pellet and incidentally in the RSA during baseline studies (Omnia, 2020).

Woodland caribou have a relatively large home range that varies from 67 km^2 to 267 km^2 (McLoughlin, 2016). Caribou seek mature jack pine- and black spruce-dominated forest, black spruce bog, and open muskeg habitats common to the Boreal Shield during most of the year, and inaccessible rough terrain such as muskeg or islands on lakes for calving (McLoughlin 2016). For the ecological model, a home rage of 80 km^2 was considered appropriate based on the average female range during the most sensitive life stage of the caribou (calving and post calving). For the ecological model, the caribou is assumed to interact with more than one exposure location in the RSA for feeding and water intake, due to the large home range.

The food source for the woodland caribou in the winter is terrestrial or arboreal lichens; terrestrial and aquatic vegetation are also food sources in the remainder of the year. For the ecological model a diet comprised of 50% browse, 20% lichen and 30% macrophytes is assumed for the woodland caribou.

In the model, woodland caribou are exposed to aquatic and atmospheric release through water and food. The woodland caribou is part of the Traditional Foods diet in the human health model.

In the ERA, woodland caribou are assessed as a species of concern at an individual level and as a representative mammalian herbivore species at a population level.

2.4 Terrestrial Birds

2.4.1 American Robin

American Robin (*Turdus migratorius*) is a common, medium-sized songbird that averages 25 cm from tail-to-tip. There is little variation between the sexes in terms of size (U.S. EPA, 1993). They have a distinctive rust-orange coloured breast and a dark gray-brown back, with a yellow beak. For the ecological model a body weight of 0.1 kg was selected.

The American robin can live in a variety of habitats, including woodlands, swamps, suburbs, and parkland. They require access to freshwater, protected nesting sites, and productive foraging areas for their habitats. Breeding habitat includes moist forests, swamps, open woodlands, orchards, parks and lawns. They will form their nests out of mud and vegetation near the edges of a forest or other opening in vegetation, on horizontal branches, within shrubs, or on man-made structures with horizontal surfaces. The American robin is migratory, breeding in northern latitudes and wintering in the south (U.S. EPA, 1993). The American robin is present in the RSA (Omnia, 2020).

The diet of the American robin is made up of earthworms, insects, and fruit. The American robin forages on the ground in open areas, along habitat edges or streams by probing and gleaning; they also forage above ground in shrubs or in lower tree branches. The robin forages for ground-dwelling invertebrates on the ground, and in shrubs and lower tree branches for fruit and foliage-dwelling insects. During the breeding season the American robin eats primarily invertebrates with some fruit; the rest of the year the robin’s diet is primarily made up of fruit (U.S. EPA, 1993). In the ecological model, American robins are assumed to eat 60% fruit represented by blueberries and 40% earthworms.

In the model, American robins are exposed to aquatic and atmospheric releases through water and food.

In the ERA, American robins are assessed as a representative avian herbivore species at a population level.

2.4.2 Bald Eagle

The bald eagle (*Haliaeetus leucocephalus*) is a large bird of prey with pale eyes; yellow bills; white heads, necks and tails; and dark brown bodies. Young eagles are a mixture of brown and white, with a black bill in young birds. Bald eagles have long rounded wings, a large hooked bill, and sharp talons. Bald eagles are sexually dimorphic; females are significantly larger than males, but otherwise they look alike (US EPA, 1993). For the ecological model a body weight of 5.8 kg was selected.

Bald eagles are found throughout North America; they nest in a variety of habitats and forest types. Their habitats are usually restricted to coastal areas, lakes, or rivers; they prefer mature trees with large, open crowns and stout limbs for perching or roosting. Bald eagles are migratory under certain conditions; they will migrate from areas where the water bodies become completely frozen over in winter, but will remain as far north as open water and a reliable food supply allow (US EPA, 1993). The nests are nearly always near a major lake or river where most of their hunting is done; they prefer to build their nests in large trees with sturdy branches, but they will also nest in rocky outcrops. Bald eagles are present in the RSA (Omnia, 2020). The bald eagle has a home range of approximately 314 km^2. For the ecological model, the bald eagle is assumed to interact with more than one exposure location in the RSA for feeding and water intake, due to the large home range.

The bald eagle feeds primarily on fish, aquatic birds, and mammals, which it may take alive or find dead. Much of its live prey, especially the waterfowl, consists of sickly individuals or those wounded by hunters. For the ecological model a diet comprised of 80% fish represented by northern pike and 20% riparian birds represented by mallard is assumed for the bald eagle.

In the model, bald eagles are exposed to aquatic and atmospheric release through water and food.

In the ERA, bald eagles are assessed as a representative avian carnivore species at a population level.

2.4.3 Canada Goose

Canada goose (*Branta canadensis*) is a large terrestrial herbivore of the family Anatidae. Canada geese breed in open forested areas near lake shores and coastal marshes from the arctic tundra through temperate climates (US EPA, 1993). Canada goose was the most commonly detected bird species in the RSA during baseline studies (Omnia, 2020). Geese, including Canada geese and brant geese (*Branta bernicla*), are part of the Traditional Foods diet for the Boreal Shield ecozone of Saskatchewan (Chan *et al*. 2018 and 2019). The US EPA (1993) considers brant geese to be similar to Canada geese.

Body weights for Canada geese vary seasonally and are at their maximum in spring prior to migrating to their northern breeding grounds. Their body weights decline during reproduction and rearing of young (US EPA, 1993). For the ecological model, a body weight of 3.7 kg is used for the Canada goose.

The foraging areas for Canada geese vary seasonally. After hatching, goose families tend to move away from their nesting site to other areas, generally on land in riparian areas and near water, with adequate cover and forage to rear their broods (US EPA, 1993). Canada geese are almost exclusively vegetarian. They are primarily grazers but consume some grit to aid digestion (US EPA, 1993). In the ecological model, Canada geese are assumed to eat 100% browse, and they are assumed to spend 100% of their time at the location where they are assessed. In the model, Canada geese are exposed to aquatic and atmospheric releases through water and food. Canada goose is part of the diet for the Canada lynx.

In the ERA, Canada geese are assessed as a representative avian herbivore species at a population level.

2.4.4 Olive-sided Flycatcher

The olive-sided flycatcher (*Contopus cooperi*) is a small to medium sized passerine bird in the family Tyrannidae, the Tyrant flycatcher family. It is a migratory species that travels from South to North America to breed during the summer. Olive-sided flycatcher is a widespread migratory species, with 53% of its breeding range across most of forested Canada, and the remainder in the western and northeastern United States. It is a very agile flyer and mainly consumes flying insects on flight. The olive-sided flycatcher is designated as Special Concern by COSEWIC and as Threatened by SARA and is provincially-ranked S4, meaning that the species is apparently secure in Saskatchewan. Olive-sided flycatcher is most often associated with edges of coniferous or mixed forests with tall trees or snags for perching, alongside open areas, or in burned forest with standing trees and snags. Olive-sided flycatchers were observed in the RSA during baseline studies (Omnia, 2020).

Olive-sided flycatcher is an aerial insectivore, generally making short foraging flights from a high perch to intercept flying insects. The egg and nestling stages in Canada can last from late May/mid-June to early/mid-August, depending on latitude. Olive-sided flycatchers arrive on their Canadian breeding grounds between April and June, but predominantly around mid-May. They are socially monogamous, with large territories of 10-20 ha. Nests are typically built in coniferous trees. Average clutch size is three eggs, and a single brood is raised. Nest success ranges from 30 to 65%, differing by region and habitat type. Renesting is common if the first clutch fails. Olive-sided flycatchers have been known to live for at least 7 years. Fall migration begins in late July, with most birds departing for the wintering grounds between mid-August and early September.

For the ecological model a diet comprised of 90% earthworms and 10% benthic invertebrates is assumed for the olive-sided flycatcher. In the model, the olive-sided flycatcher is exposed to aquatic and atmospheric release through water and food.

In the ERA, olive-sided flycatchers are assessed as a species of concern at an individual level and as a representative avian herbivore species at a population level.

3.0 References

Chan L, Receveur O, Batal M, Sadik T, Schwartz H, Ing A, Fediuk K, Tikhonov C. 2018. First Nations Food, Nutrition and Environment Study (FNFNES): Results from Saskatchewan (2015). Ottawa: University of Ottawa.

Chan L, Receveur O, Batal M, Sadik T, Schwartz H, Ing A, Fediuk K, Tikhonov C. 2019. Erratum to the First Nations Food, Nutrition and Environment Study (FNFNES): Results from Saskatchewan 2015. Ottawa: University of Ottawa, 2018. July.

Cornell Lab. (no date) All about Birds. Common Loon. Retrieved September 2021 from: **https://www.allaboutbirds.org/guide/Common_Loon/lifehistory#**

COSEWIC 2002. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 98 pp.

Drilling, N., R. Titman and F. McKinney. 2002. Mallard (*Anas platyrhynchos*). In the Birds of North America, No. 658 (A. Poole and F. Gill, eds). The Birds of North America Online, Ithaca, New York.

Ecometrix (Ecometrix Incorporated), 2020. Wheeler River Project: Baseline Hydrology Summary Report. Report prepared for Denison Mines Corporation. March 2020.

Environment Canada and Canada Wildlife Federation (EC & CWF). 1986 (last revised by M. Aleksuik). Muskrat. Retrieved in September 2021 from **https://www.hww.ca/en/wildlife/mammals/muskrat.html**

Environment Canada and Canada Wildlife Federation (EC & CWF). 1997. Moose. Retrieved in September 2021 from **https://www.hww.ca/en/wildlife/mammals/moose.html**

Environment Canada and Canada Wildlife Federation (EC & CWF). 2005 (last revised by K.E. Hodges). Snowshoe Hare. Retrieved in September 2021 from **https://www.hww.ca/en/wildlife/mammals/snowshoe-hare.html**

Environment Canada and Canada Wildlife Federation (EC & CWF). 2007 (last revised by C. Samson). Black Bear. Retrieved in September 2021 from **https://www.hww.ca/en/wildlife/mammals/black-bear.html**

Federal Contaminated Sites Action Plan (FCSAP). 2012. Ecological Risk Assessment Guidance, Module 3: Standardization of Wildlife Receptor Characteristics. Prepared for: Environment Canada (Government of Canada), Vancouver, B.C., Prepared by Azimuth Consulting Group, Vancouver, B.C. March 2012.

Franzmann AW. 1981. Alces alces. Mammalian Species. 154:1–7. May.

Hinterland's Who's Who. 2007a. Black Bear. **https://hww.ca/en/wildlife/mammals/black-bear.html**

Hinterland's Who's Who. 2007a. Canada Lynx. **https://www.hww.ca/en/wildlife/mammals/canada-lynx-1.html**

McLoughlin PD, Stewart K, Superbie C, Perry T, Tomchuk P, Greuel R, Singh K, Truchon-Savard A, Henkelman J, Johnstone JF (Department of Biology, University of Saskatchewan). 2016. Population dynamics and critical habitat of woodland caribou in the Saskatchewan Boreal Shield. Interim Project Report, 2013-2016.

McPhail, J.D. and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Board Can. 173. Ottawa, ON. 381 pp.

Newfoundland and Labrador Fisheries and Land Resources (NL FLR). 2019. American Mink. Retrieved from, **https://www.flr.gov.nl.ca/wildlife/snp/programs/education/animal_facts/mammals/mink.html**

Omnia (Omnia Ecological Services), 2020. Denison Mines Corporation Wheeler River Project - Terrestrial Environment Wildlife and Vegetation Baseline Inventory.

United States Environmental Protection Agency (U.S. EPA). 1993. Wildlife Exposure Factors Handbook. Document No. EPA/600/R-93/187. December.

U.S. FWS (Fish and Wildlife Service), 2017. Species Status Assessment for the Canada Lynx (Lynxcanadensis), Contiguous United States Distinct Population Segment. Version 1.0 - Final, October 2017.

Wilson D, and Ruff S. 1999. The Smithsonian Book of North American Mammals. Smithsonian Institution Press, Washington.

20 CSA Group Standard, N288.6 – Environmental Risk Assessments at Nuclear Facilities and Uranium Mines and Mills, 2022 edition

21 CSA Group Standard, N288.5 – Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills, 2022 edition, published January 2022

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

22 CSA Group Standard, N288.8 – Establishing and Implementing Action Levels for Releases to the Environment From Nuclear Facilities, 2017 edition, reaffirmed in 2022

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

23 CSA Group Standard, N288.4 – Environmental Monitoring Programs at Nuclear Facilities and Uranium Mines and Mills, 2019 edition, reaffirmed in 2024

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

24 CSA Group Standard, N288.7 – Groundwater Protection Programs at Class I Nuclear Facilities and Uranium Mines and Mills, 2015 edition, reaffirmed in 2020

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

25 Denison Mines Corp., Wheeler River Operation, Groundwater Protection and Monitoring Plan, Version #1, January 2024

The information in this reference document is subject to a request for confidentiality under rule 12 of the *Canadian Nuclear Safety Commission Rules of Procedure*. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca) for more information concerning confidentiality.

26 CSA Group, CAN/CSA ISO 14001, Environmental Management Systems – Requirements with Guidance for Use, 2015 edition

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

27 Denison Mines Corp. Wheeler River Operation, Fire Protection Program, Version #1, July 2023

Denison Mines Corp.
Wheeler River Operation

Fire Protection Program

Document # 16

Version 1

September 2023

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
Version 1	29-Sept-2023	For CNSC Review			

Revision History

Version	Date	Description of Revision
Version 1	29-Sept-2023	For CNSC Review

Table of Contents

Figures

1 Introduction

The *Fire Protection Program* (the Program) is one of the Program documents that comprise the Management System for the Wheeler River Operation (the Operation). The *Fire Protection Program* is preceded by the *Management System Program* within the document framework for the Operation as shown in Figure 1. Consistent with all other Program documents, the *Fire Protection Program* is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

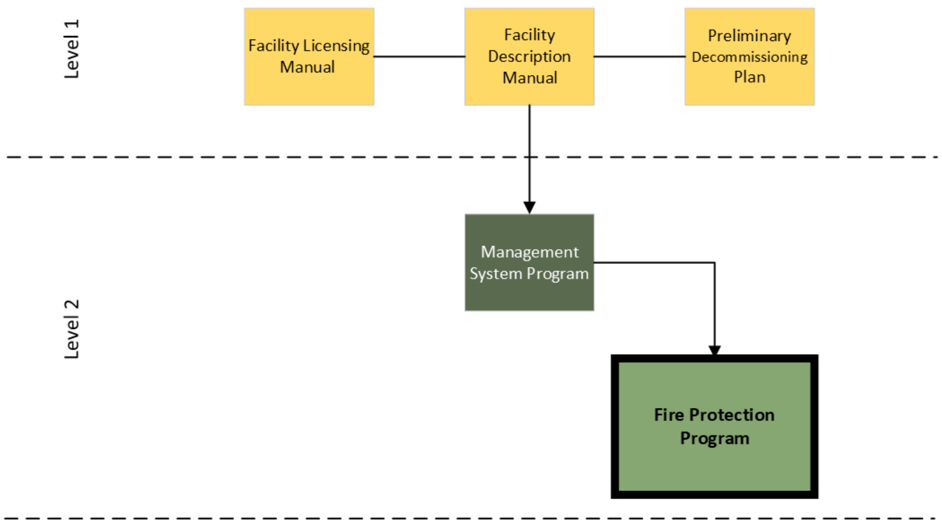


Figure 1: Program shown within Document Framework for the Wheeler River Operation

1.1 Purpose

The Operation has developed and implemented this Program which establishes the fire protection goals and associated safety performance criteria for the Operation. The Operation is designed, operated, inspected, tested, and maintained so that the fire protection goals, and safety performance criteria contained herein are achieved.

The Program summarizes protection requirements at the Operation and has been developed in consideration of applicable regulatory and statutory requirements, industry standards, and corporate and Operation requirements.

1.2 Scope

The Program applies to the activities required to manage fire protection activities at the Operation and details the methods and practices that are utilized for fire protection.

The Program applies to applicable buildings at the Operation and to the design and construction of new buildings and facilities; to the modification of existing facilities, and through their different operational stages, including shutdown and decommissioning.

The processes outlined in this Program apply to all Operation employees, contractors, and visitors.

The Program is implemented in an integrated manner with the Wheeler River *Emergency Preparedness and Response Program* which outlines measures to prevent, prepare for, respond to, and recover from surface emergencies (including fire) associated with the Operation (See Section 2.3). The response to wildfires that threaten the Operation is addressed under the Operation's *Emergency Response Plan* and is not included in this Program.

1.3 Program Overview and Principles

This Program is designed to align with Denison's overall goal of protecting and promoting the health, safety, well-being of people, and environment through all phases of the project.

The Program adheres to a defense-in-depth principle which is used to achieve a high degree of fire protection by providing redundancy, diversity, and balance in fire protection measures. The five elements of the defense-in-depth principle are outlined as follows:

<u>Level One: Prevent Fires</u>

Design measures are put in place to reduce or eliminate, where practicable, combustible materials, and ignition sources.

<u>Level Two: Detection & Response</u>

Detect and respond to events to prevent escalation of failures. Provide means to quickly detect and extinguish or control fires.

<u>Level Three: Minimize Consequences of Events</u>

Fire separations or other measures limit the spread of fire and its effects, thus minimizing the impact on the nuclear facility and its occupants.

<u>Level Four: Control & Mitigate (Fire)</u>

Control severe facility conditions and mitigate the consequences of severe accidents. Plans and procedures control event progression and mitigate the consequences of postulated fire scenarios and failure modes so that releases are minimized.

<u>Level Five: Control & Mitigate (Radiological)</u>

Mitigate radiological consequences of significant releases of radioactive substances. Plans provide for onsite and offsite emergency responses to mitigate the radiological consequences of an event.

1.4 Compliance and Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act (SC 1997, c.9)* and associated regulations, including the *General Nuclear Safety and Control Regulations (SOR/2000-202),* the *Uranium Mines and Mills Regulations (SOR2000-206).* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.10.2, *Fire Protection.*

Additionally, the Program meets CSA N393-13 *Fire protection for facilities that process, handle, or store nuclear substances*, requirements of the *Environmental Emergency Regulations, 2019,* and provincial requirements including the *Occupational Health and Safety Regulations,* the *Fire Safety Act SS, 2015,* and *The Mines Regulations, 2018 RRS.*

Where specific design or operational requirements are not addressed in this document, the National Building Code of Canada (NBCC) or National Fire Code of Canada (NFCC), good engineering practice will apply and, where appropriate, recognized standards (such as those of the National Fire Protection Association (NFPA) will be used.

1.5 Terminology

1.5.1 Definitions

Term	Definition
Code Compliance Review (CCR)	An assessment for compliance with the applicable sections of the codes of construction (i.e., the NBCC, NFCC, and CSA N393-13 Fire protection for facilities that process, handle, or store nuclear substances) and the codes and standards referenced therein.
Combustible Material	Material that, when in the form and under the conditions in which it is likely to be used, will ignite, support combustion, burn, or release flammable vapor when subject to fire or heat.
Defense-In-Depth	The provision of multiple levels of defense to prevent accidents and provide appropriate protection and mitigation in the event of an accident.
Design Basis Fire	A hypothetical fire used for fire protection design or analysis. The design basis fire is a fire that would result in the most severe consequences in the area under consideration, in the absence of fire suppression by automatic or manual systems.
Fire Hazard Analysis (FHA)	A set of analyses and assessments for evaluating fire hazards and appropriate fire protection systems and features used to mitigate a fire's effects.
Fire Prevention	Measures directed toward avoiding the inception of fire.
Fire Protection	Methods of providing for fire control or fire extinguishment.
Qualified Third Party	Qualified person(s) who have not been directly involved in or contributed to the work under consideration.
Systematic Approach to Training (SAT)	A structured approach used to manage training modules widely known as an instructional design model.
Transient Combustible	Combustible material located in a space on a temporary basis.
Worker	Any person working for Denison, including contractors.

1.5.2 Acronyms and Abbreviations

Acronym or Abbreviation	Term
CCR	Code Compliance Review
EPRP	Emergency Preparedness and Response
FHA	Fire Hazard Analysis
SAT	Systematic Approach to Training

2 Plan

2.1 Risk Management

Denison uses risk-based assessments to identify and prioritize the protection of workers, the public, and the environment. The risk management process includes identification of hazards, risk assessment of those hazards, and managing work practices to control the risks.

Risk management includes identifying Operation-related hazards that could result in fire emergencies, assessing the significance of the associated risks, and managing the risks to acceptable levels through the application of controls.

2.1.1 Risk Register

Denison uses a risk register to proactively identify and address significant fire hazards, controls, prioritize resources, and continuously improve its fire protection practices. The risk register is a central repository for recording and tracking information related to the significant fire protection risks.

The risk register may include information such as: risk identification, risk assessment, risk analysis, risk evaluation, risk prioritization, risk mitigation, risk monitoring and review. Further details on the risk register are provided in the *Management System Program*.

2.1.2 Fire Protection Assessments

Fire protection assessments are a set of evaluations that independently confirm the adequacy of fire prevention, detection, control, and mitigation measures. Fire protection assessments used by the Operation include code compliance review and fire hazard assessment.

2.1.2.1 Fire Hazard Assessments

The objective of the fire hazard assessment is to demonstrate that the fire protection goals, and safety performance criteria of the Program are met. The fire hazard assessment covers all site locations processing, handling, and storing nuclear substances, and associated nonnuclear facilities and exposures external to these areas.

Fire hazard assessment preparations or updates are related to the complexity of the facility and the potential risk to persons and the environment to meet the fire protection goals and safety performance criteria of the Program.

The fire hazard assessment evaluates potential fire hazards, as well as the fire protection systems and features (including both physical attributes and Program elements) used to mitigate the effects of fire. The fire hazard assessment confirms that the facility (including the design, operation, and maintenance provisions) meets the fire protection goals and safety performance criteria of the Program.

The fire hazard assessment is maintained as necessary to reflect nuclear facility modifications, significant changes in fire hazards, operating experience, and operational changes, and will be updated or confirmed at least once every five years.

The fire hazard assessment provides documentation and assessment of the following:

- Operation layout and separation analysis;

- The impact of fire and explosion hazards, and analyzes required separation between various portions of the operation;
- The inventory and configuration of combustibles in each zone, including transient combustibles that could be present;
- Fire detection measures as well as automatic and manual suppression measures;
- Fire mitigation measures such as fire separations, spatial separations, and smoke control measures;
- Combustible, toxic, radioactive, and explosive gas control measures;
- Hazardous materials and their impact on fires and fire detection and suppression measures;
- Identification of equipment, components, and circuits needed during fire or to maintain processes required for safety;
- Evaluation of the electrical and cable systems fire protection or fire confinement control for these processes;
- Systems that are needed to maintain their integrity;
- Postulation of the design basis fires in each fire zone required to be assessed and assessment of resulting damage to facility structure, systems, and components;
- Documentation includes the basis of each step in the assessment from fire initiation to fire growth, as well as equipment damage, failures, and consequences of radioactive release;
- Available forms of manual fire protection that can be considered for the facility, including emergency response team and mutual aid resources;
- Compliance with the applicable requirements of the most current version of CSA n393-13 and referenced documents; and
- Assessment of effectiveness, appropriateness, and reliability of the fire protection measures in meeting the goals and safety performance criteria of the program.

The defense-in-depth principle outlined in the Program is used in the fire hazard assessment development to help determine the fire protection measures required to demonstrate the fire protection goals, and safety performance criteria of the Program are met.

When assessing fire hazards and consequences of fires, the following are considered acceptable assumptions:

- Fires need not be postulated coincident with independent, low-frequency events or accidents in the facility;
- Two or more simultaneous, independent fires in the facility need not be postulated;
- Credit may be given to equipment or components that result in fail-safe conditions after damage by fire or fire suppression action, provided that the fail-safe qualities of the equipment or component are individually assessed against the failure modes induced by the fire or fire suppression action;
- Manual action may be credited, provided that the necessary conditions for correct and timely actions have been identified and justified; and
- Additional assumptions used in the analysis are to be stated and justified.

2.1.2.2 Code Compliance Review

To demonstrate an adequate level of safety, the Operation undergoes a code compliance review as part of the fire hazard assessment process. Where there are no deviations, the code compliance review report declares the facility as being in compliance with CSA N393-13, the *National Building Code of Canada*, and the *National Fire Code of Canada*. The results of the code compliance review are documented and submitted to the Canadian Nuclear Safety Commission.

A code compliance review is a third-party assessment of Operation design and Operation against applicable codes and standards (e.g., the *National Building Code of Canada*) to confirm whether requirements are met.

This includes reviewing fire protection systems, structures, and components such as:

- Suppression systems (e.g., water supply reticulation and pumps);
- Detection systems;
- Manual fire suppression equipment (e.g., portable fire extinguishers, hose stations, and fire hydrants);
- Storage, supply, and use of flammable liquids and gases; and
- Fire protection features (e.g., fire separations, fire doors, and penetration seals).

Code compliance reviews are supplemental to the general audit requirements of the *Management System Program*.

2.2 Objectives and Targets

The Operation is responsible for establishing, implementing, and documenting Program objectives and annual targets. Objectives and targets of this Program will be measurable, documented, and tracked. Performance against the objectives and targets will be communicated at regular intervals (i.e., during Management Review), and opportunities for continual improvement will be identified.

The process for setting overall objectives and targets is outlined in the *Management System Program* and supporting procedure.

2.3 Resources

Denison is committed to providing the necessary resources to support effective development, implementation, maintenance, and continual improvement of the Program, including achievement of its objectives and targets.

2.3.1 Roles and Responsibilities

This subsection outlines the specific roles and responsibilities within the Program, including EPRP Management and EPRP Coordinator, and other workers with various levels of responsibility.

For effective implementation of this Program, workers are informed of their roles and responsibilities and are accountable for comprehending and performing them. Executive and Leadership level roles and responsibilities are specified in the *Management System Program*.

General Manager

- Overseeing the implementation, and adherence to this Program;
- Confirming accountability of fire protection practices needed to carry out the Program;
- Confirming appropriate resources are made available for the Program;
- Working with applicable departments to verify that Program roles and responsibilities are identified and outlined, and that those with specific responsibilities are qualified to fulfill their roles;

Safety Coordinator

- Managing and monitoring the effectiveness of the Program;
- Development and implementation of fire protection measures;
- Ensuring adequate training for fire protection processes;
- Participating in the management review process; and
- Maintaining fire protection documents and records.

Safety Supervisor

- Implementation of the FPP at the Operation;
- Ensuring fire protection equipment is maintained;
- Liaison with external third-party reviewers; and
- Conducting the component of the maintenance and inspections related to fire protection.

Mill Maintenance General Supervisor

- Responsible for the implementation of the remainder of the maintenance and inspections related to fire protection.

2.3.2 Facilities and Equipment

Facilities and equipment used to effectively prevent, prepare for, respond to, and mitigate emergency events and situations are provided and maintained. Facilities are designed, constructed, operated, and maintained with consideration for worker health, safety, well-being, and in compliance with legal requirements.

2.3.3 Legal and Other

Denison is committed to complying with all applicable legal and other requirements related to fire protection. Types of legal requirements applicable to the Operation include:

- Federal and provincial acts and regulations;
- Environmental assessment commitments and follow-up monitoring; and
- Licensing obligations and commitments.

The process for managing legal and other requirements is outlined in the *Management System Program*. Denison has established procedures to ensure compliance with these requirements and that compliance obligations are regularly reviewed. Any changes relevant to fire protection compliance obligations are monitored and evaluated to determine if updates to the Program and its supporting Plans, Procedures, and Work Instructions are required.

2.4 Training and Competence

A systematic approach to training (SAT) is used to educate, train, and qualify workers and contractors to perform assigned work. Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely.

Records of training activities and competencies will be maintained as outlined in the *Training Management Program*.

2.5 Documentation and Records Management

Denison will establish and maintain documented Plans, Procedures and Work Instructions to ensure effective implementation of the Program. Documentation will be controlled, reviewed, and updated as necessary in accordance with the requirements in the *Management System Program*.

Documents and records will be generated as a result of implementation of the Program and completion of licensed activities. Examples of some records generated specific to the Program may include:

- Fire protection plans, procedures, and work instructions;
- Inventories of hazardous substances, waste dangerous goods, and emergency response equipment; and
- Equipment maintenance and calibration records.

Documents and records are readily accessible to those who require them. Further information on documentation and records management is provided in the *Management System Program.*

2.6 Communication

Communication both with internal and external stakeholders is a critical element of the Program to promote a safe work culture that understands the importance of fire protection for the Operation. Relevant information to inform workers of fire risks and hazards and any changes to personnel, processes, facilities, or equipment will be shared.

Effectively communicating information about fire emergencies to internal and external parties is a crucial element of this Program and the supporting plans. During and following fire and other emergency events and situations, information is communicated to and among various internal and external parties affected by, involved in, and interested in fire emergencies. This includes the following:

- Employees and contractors;
- Emergency response teams;
- Regulatory agencies; and
- Indigenous groups, local communities, and the public (as required).

Internal and external communication processes specific to emergency events and situations are further outlined in the *Emergency Response Plan*, the *Transportation Emergency Response Plan*, and *Crisis Management Plan.*

Communication principles and processes are further outlined in the *Management System Program,* and communication with indigenous groups, local communities, and the public is managed as outlined in the *Public and Indigenous Information Program.*

2.7 Change Management

Change is managed at the Operation to protect workers, the environment, and property, and to ensure that regulatory requirements are met. Any new building, equipment, structure, or modification that may affect, directly or indirectly, the existing fire safety measures, including the manual firefighting capability, is subject to the change and design control procedures. The Operation's change management process is outlined in the *Management System Program.*

Examples of changes captured by the process could include, but is not limited to changes to the:

- *Fire Protection Program* and supporting plans, procedures, and work instructions;
- Structures, systems, and components;
- Regulatory requirements related to fire protection;
- Emerging risks to workers; and
- Organizational changes.

All proposed modifications to the facility are assessed to determine their potential impact on fire protection and the associated safety performance criteria. This assessment is completed through the site change control process in accordance with CSA N393-13.

2.8 Emergency Preparedness and Response

The emergency response team is trained to deal with a range of events that require both operational and emergency response in accordance with the fire response needs analysis and CSA N393-13. Events can be non-radioactive and may result from situations and conditions external to the site. The designed emergency response capability and infrastructure is sufficiently flexible to be used for a broad range of events and disasters. Roles and responsibilities are captured in the *Emergency Response Plan* and role-specific training and competency details are outlined in the *Emergency Response Plan*, the *Transportation Emergency Response Plan*, and the *Crisis Management Plan*.

Training and competency required for surface industrial firefighting are prescribed under the authority for recognizing training with the Provincial Emergency Management and Fire Safety Branch, Office of the Fire Commissioner. Emergency response team personnel are enrolled in the Office of the Fire Commissioner Provincial Recognition of Training for the industrial fire brigade program. Training that exceeds the minimum requirements set out in this standard may be conducted at the discretion of Operation management and the approval of the assigned Program Coordinator.

3 Do

3.1 Fire Safety Training Needs Analysis

A fire safety training needs analysis is performed to identify and document the staff training necessary for implementation of the Program. The needs analysis is based on a review of work activities, fire hazards, and required responses. Employees and contractors receive fire safety training in accordance with employee orientation and the fire safety training needs analysis. It includes, but is not limited to:

- *Fire Protection Program* goals;
- Basic fire prevention;
- Life safety;
- Use of portable fire extinguishers;
- Emergency procedures;
- Maintenance of egress routes;
- Fire equipment availability;
- Control of transient material, hot work, and ignition sources; and
- Reporting of fire.

Review of the fire safety training accords with CSA N393-13 *Fire protection for facilities that process, handle, or store nuclear substances.*

3.2 Fire Protection Management

3.2.1 Fire Safety Plan

The objective of the *Fire Safety Plan* is to define those elements which positively contribute to prevent fires, maintain fire safe conditions at the Operation, maintain the reliability of the fire protection systems, provide an effective emergency response to limit the effects of fires, to protect the health and safety of all persons at the Operation, to protect the environment, and to minimize the loss of property in the event of a fire. The *Fire Safety Plan* provides information on specific responsibilities, emergency instructions in the event of a fire, training provided to personnel during orientation, fire protection inspections, execution of fire drills, description of how fire hazards are controlled at the site, and descriptions of specific fire hazards at the site.

The *Fire Safety Plan* meets the requirements of the National Fire Code of Canada, site license requirements and supporting reference materials, and Saskatchewan Provincial *Occupational Health and Safety Regulations.*

The Fire Safety Plan involves three elements: Fire Prevention, Fire Protection and Emergency Response and is reviewed and updated annually during construction and every three years or as necessary to reflect current Operation conditions.

3.2.2 Third Party Review

The Operation engages a third-party reviewer to review proposed projects with potential impact to fire protection. This review verifies Operation compliance with the *National Building Code of Canada* and the *National Fire Code of Canada.*

The third-party reviewer evaluates the proposed change(s), assesses its potential fire hazards, and appropriate fire protection system and features used to mitigate the fire hazards. This includes:

- The evaluations of physical construction and layout of the buildings and equipment, including electrical cables within fire compartments;
- An inventory of combustibles, including maximum transient combustibles within each fire compartment;
- A description of fire protection equipment, including detection systems, and manual and automatic extinguishing systems in each fire compartment; and
- An analysis to assure a single fire event cannot impair required safe shutdown functions or result in uncontrolled release of chemicals including radioactive contamination to the environment.

If the fire hazard assessment concludes that the objectives listed in Section 2.2 cannot be achieved, modifications and actions are to be taken to reduce the fire risk to an acceptable level.

Once the proposed changes are accepted, it is important that the integrity of the fire protection measures put in place are not compromised:

- Subsequent site modification proposals that may impact existing fire protection systems undergo another assessment and another third-party review conducted as required; and
- Administrative controls are put in place to assure that combustibles do not accumulate to a level that invalidates the assessment.

Third party reviews are carried out by one or more independent reviewers having specific expertise with such reviews; and submitted, in writing, to the CNSC prior to the implementation of the modification.

3.3 Fire Safety Controls

Controls eliminate, prevent, or reduce the risk of harm to workers, the public, the environment, and property during fire emergencies. Controls are documented in a fire hazard assessment as described in section 2.1.2.1 according to the frequency defined by the associated process documentation and are evaluated for effectiveness.

Controls are used, operated, and maintained according to their design, limitations, and appropriate training. Following appropriate procedures and training is critical in maintaining the effectiveness of controls.

This Program adopts the defense in depth approach to fire protection as described in section 1.3. Examples of defense in depth fire risk controls and the associated Programs which govern the associated processes are provided below.

Defense in Depth Controls:

Level I – Preventing Fires

- Fire hazard assessment;
- Hot work permit and fire watch;
- Housekeeping;
- Proper segregation, storage, control of combustibles and control of hazardous substances and waste dangerous goods;

- Employee orientation;
- Annual facility condition inspections
- Preventing access to restricted areas;
- Impairment procedures; and
- Design modification review.

Level II – Fire Detection and Suppression

- Designing, installing, inspecting, and maintaining fire detection, alarm, and suppression systems;
- Pre-incident planning;
- Impairment procedures;
- Employee orientation
- Adequately trained and resourced emergency response team; and
- Emergency response processes and equipment.

Level III – Limiting the Effects of Fire

- Fire hazard assessment
- Designing and constructing adequate fire separations, barriers, and fire stops;
- Proper segregation, storage, and control of combustibles;
- Proper segregation, storage, and control of hazardous substances and waste dangerous goods; and
- Design modification review.

Level IV – Controlling and Mitigating Fire Events

- Designing and constructing adequate fire separations, barriers, and fire stops;
- Proper segregation, storage, and control of combustibles;
- Proper segregation, storage, and control of hazardous substances and waste dangerous goods;
- Adequately trained and resourced emergency response team;
- Pre-incident planning;
- Emergency response processes and equipment; and
- Designing, installing, inspecting, and maintaining fire detection, alarm, and suppression systems.

Level V – Mitigating Fire Consequences

- Proper storage and control of nuclear substances;
- Emergency responses processes and equipment; and
- Agreements with other off-site, regional emergency responders.

3.4 Contractor Management

Contractors performing work at the Operation are subject to the requirements of this Program. Contractors with specialized knowledge or training may be used to prepare for, or respond to, fire emergencies. The process for ensuring contractors adhere to requirements is outlined in the *Contractor Management Plan*.

4 Check

4.1 Monitoring and Measurement

Fire protection performance is monitored and measured against established objectives and targets (identified in section 2.2). Denison will monitor, measure, analyze, and evaluate its fire protection effectiveness based on a defined process outlined in the *Management System Program*.

Monitoring and measurement activities specific to fire protection at the Operation may include:

- Scheduled inspections, testing and maintenance of fire protection systems;
- Testing and inspection performed in accordance with National Fire Code of Canada and associated site procedures;
- Corrective actions are addressed through the Denison corrective action process for any identified non-conformances or through the site preventative maintenance system to address equipment reliability issues;
- Performing and documenting all follow-up actions and corrections;
- Work orders generated for daily, weekly, monthly, and long-term inspections;
- Sourcing of specific maintenance duties and appropriate contractors;
- Documenting results of tests and inspections within the site preventative maintenance system; and
- Filing and archiving completed work orders.

All monitoring and measurement activities must also meet defined quality assurance and quality control requirements outlined within relevant Plans as part of this Program.

The results of monitoring and measurement activities are communicated internally and externally (see section 4.4) and documented as part of the records management process outlined in the *Management System Program*.

4.2 Inspections and Audits

Denison will conduct internal audits of the Program to assure compliance with the requirements set out in the Program and to determine if the Program is effectively implemented and maintained.

In addition to routine compliance and conformance audits, a third-party review of compliance with the inspection requirements of the National Fire Code of Canada is conducted by one or more external agencies that have specific expertise with such reviews. Findings are to be documented and provided in a report to the Operation.

The internal audits will follow the process and procedures outlined in the *Management System Program.*

4.2.1 Fire Risk Needs Analysis

An analysis is performed in compliance with CSA N393-13 standard. The standard requires that a need analysis be completed to determine the manual response requirements based on the type, size, and location of potential fires as well as other impediments that would impact manual fire suppression operations.

The fire risk needs analysis determines:

- The most demanding fire risks on-site, specifying fuel, maximum credible fire size, extent in terms of area or geometry, impact of exposures, impact on life safety, and likely impact on the public in terms of nuclear safety;
- The requirements for extinguishment by all available means, including automatic or manual, using water, foam, dry chemical, and inert gas;
- The required equipment to deliver the appropriate extinguishing agent;
- Whether the on-site firefighting organization has adequate support for offsite assistance, if necessary, based on response time, mutual aid assistance plan, or other considerations;
- Personal protective equipment requirements;
- Training requirements; and
- The site's fire response capabilities and expectations.

Nonconformities, instances of regulatory noncompliance, or opportunities for improvement identified through audits and inspections are managed as outlined in the *Management System Program.*

4.3 Management Review

The *Fire Protection Program* will be reviewed by Denison management in accordance with the defined frequency to assure the Program is meeting its objectives or needs adjustment. Examples of the types of items related to fire protection that Denison management will review may include, but is not limited to:

- Suitability, adequacy, and performance of fire protection objectives and targets;
- Upcoming or new legislation related to fire protection;
- Recent or planned changes in facility operations;
- Results of monitoring in relation to meeting performance objectives and targets;
- Results of audits and inspections in relation meeting performance objectives and targets;
- Status of training objectives for industrial fire brigade;
- Identified opportunities for improvement based on incident reports and other sources;
- Communications from interested parties;
- Adequacy of resources; and
- Any needs for program adjustment.

Where necessary, Denison management will identify opportunities for improvement and establish action plans to implement change in accordance with the process outlined in the *Management System Program*.

4.4 Reporting

Denison will routinely report both internally and externally on the performance of the *Fire Protection Program*. External reporting can include reporting to regulators, the public, and Indigenous and local communities.

External reports to regulators will be produced in accordance with regulatory requirements.

External reports to the public or Indigenous communities on the performance of the Program will be tailored to the interests of these groups as identified through community engagement activities. Reporting, disclosure, and communication to the public and Indigenous and local communities is discussed in more detail in the *Public and Indigenous Information Program.*

5 Act

5.1 Corrective Action

Non-conformities or areas for improvement are identified following the process outlined in the *Management System Program* and the supporting procedures. These non-conformities can include related incidents, near-misses, and deviations from the *Fire Protection Program.* Non-conformities can also be identified during inspections and audits.

Responses to identification of non-conformities include investigation of cause, and corrective action if appropriate. Corrective actions are planned, implemented, verified, and reviewed for effectiveness based on the process identified in the *Management System Program*.

5.2 Continual Improvement

Opportunities for improvement of this Program will be identified and addressed to enhance fire protection for the Operation. The continual improvement process for this Program follows the overall continual improvement process outlined in the *Management System* and the supporting procedures. Continual improvement may also include updating Program objectives and targets based on changing circumstances or new information. Improvement may involve benchmarking performance against other similar projects and facilities. Any changes identified through the continual improvement process will be implemented in a systematic and controlled manner.

With respect to fire protection, opportunities for continual improvement may be identified through review by the monitoring and measurement of Program effectiveness, fire protection evaluations, or specific actions from an event, audit, or inspection.

6 References

6.1 Internal

Document Name
Management System Policy
Management System Program
Wildfire Prevention and Preparedness Plan
Emergency Preparedness and Response Program
Emergency Response Plan
Transportation Emergency Response Plan
Crisis Management Plan
Corporate Office Emergency Response Plan
Training Program
Indigenous and Public Engagement Program
Health and Safety Program
Security Program
Asset Management Program
Contractor Management Program

6.2 External

Federal

Nuclear Safety and Control Act

Uranium Mines and Mills Regulations

Radiation Protection Regulations

Nuclear Substances and Radioactive Devices Regulations

General Nuclear Safety and Control Regulations

Canadian Nuclear Safety Commission. *REGDOC 2.10.1 Nuclear Emergency Preparedness and Response*

Canadian Nuclear Safety Commission. *REGDOC 2.10.2 Fire Protection*

CSA *N393-13 Fire protection for facilities that process and handle or store nuclear substances.*

Provincial

The Saskatchewan Employment Act, 1993

The Occupational Health and Safety Regulations 1996

The Mines Regulations, 2018

Saskatchewan Mine Rescue Manual

The Fire Safety Act

The Fire Safety Regulations

The Wildfire Act

The Wildfire Regulations

28 Denison Mines Corp. Wheeler River Operation, Emergency Preparedness and Response Program, Version #1, July 2023

Denison Mines Corp.
Wheeler River Operation

Emergency Preparedness and Response Program

Document #13

Version 1

September 2023

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
Version 1	27-Sept-2023	For CNSC Review			

Revision History

Version	Date	Description of Revision
Version 1	27-Sept-2023	For CNSC Review

Table of Contents

Figures

1 Introduction

The *Emergency Preparedness and Response Program* (the Program) is one of the Program documents that comprise the Management System for the Wheeler River Operation (the Operation). The *Emergency Preparedness and Response Program* is preceded by the *Management System Program* within the document framework for the Operation as shown in Figure 1. Consistent with all other Program documents, the *Emergency Preparedness and Response Program* is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

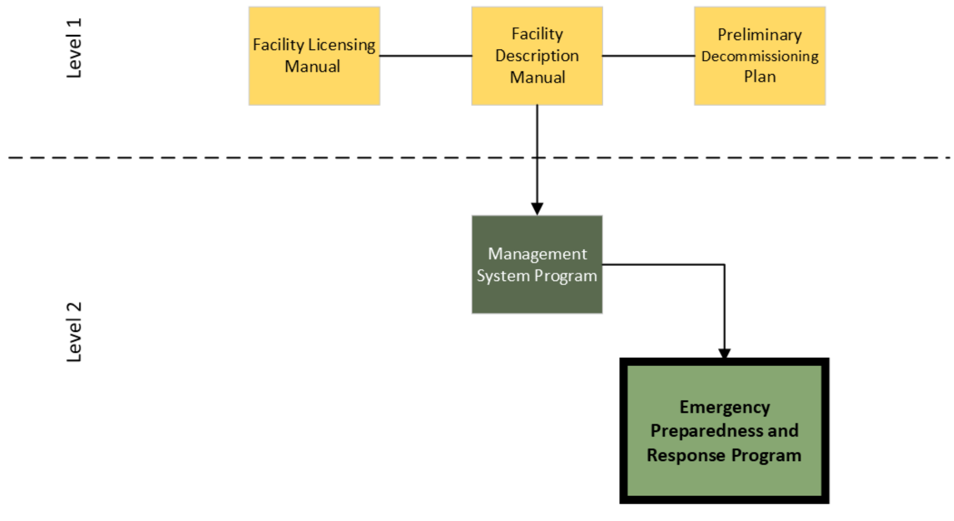


Figure 1: Program shown within Document Framework for the Wheeler River Operation

1.1 Purpose

The Program provides processes and structure for overall crisis planning efforts at the Operation. It further provides a framework for development of the site emergency response plan, processes, work instructions, and further supporting documentation at the Operation. The Program also identifies the plans, outlining specific requirements for emergency response, Wheeler River transportation emergency response, and corporate crisis management.

1.2 Scope

The Program addresses emergency events and situations that threaten the health and safety of workers, local Indigenous groups and communities, the environment, or Operation infrastructure. It applies to Operation emergency preparedness and response activities for on-site emergencies, accidents involving hazardous substances originating from the Operation, and mutual aid to offsite emergencies as directed by Denison management.

1.3 Program Overview and Principles

The Operation approach to emergency prevention, preparedness, response, and recovery is based on four fundamental principles. These principles, in order of importance are:

- Preserving the safety of the emergency response team;

- Protecting human life;
- Protecting the environment; and
- Protecting Operation property.

Due to the nature of Operation activities, workers are exposed to certain real and perceived safety, environmental, operational, and political risks. Exposure to these risks could result in a crisis.

In response to this exposure, the Program is implemented allowing to deal effectively with Operation emergencies, considering site-specific conditions and utilizing important expertise. In coordination with the Program, supporting documentation and processes include:

- *Crisis Management Plan*, including business continuity and pandemic plans;
- *Emergency Response Plan*; and
- *Transportation Emergency Response Plan*.

The Operation has established the *Management System Program* that provides the foundation for Denison's approach to health and safety, including emergency management.

The Program provides guidance to the Operation to:

- Establish objectives and targets consistent with applicable policies and EPRPs (Plan);
- Implement the process (Do);
- Monitor and measure (Check); and
- Continually improve on activities and controls to achieve the policy commitments (Act).

1.4 Compliance with Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act* and associated regulations, including the *General Nuclear Safety and Control Regulations,* and the *Uranium Mines and Mills Regulations.* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.10.1 *Nuclear Emergency Preparedness and Response.*

Additionally, the Program meets CSA N393 *Fire protection for facilities that process, handle, or store nuclear substances*, requirements of the *Environmental Emergency Regulations,* and provincial requirements including the *Occupational Health and Safety Regulations,* the *Fire Safety Act,* and *The Mines Regulations.*

1.5 Terminology

1.5.1 Definitions

Term	Definition
Emergency Drill	A coordinated and supervised activity including typical attributes of: a narrow focus, limited number of personnel, specific equipment, timely feedback, and a realistic environment.
Emergency Tabletop Exercises	Round table discussions of a potential emergency situation developed to practice elements of the emergency preparedness and response plan and structured to meet specific identified objectives.

Full-scale Emergency Exercises/Simulations	An exercise that typically takes place over several hours and tests the integrated performance of the emergency preparedness and response. Typical attributes of an emergency exercise include mobilization of apparatus and resources in a realistic environment over an extended period of time, demonstration of inter-agency cooperation, testing of communication systems and public information systems, and testing of emergency facilities and equipment readiness.

1.5.2 Acronyms and Abbreviations

Acronym or Abbreviation	Term
ERP	Emergency Response Plan
EPRP	Emergency Preparedness and Response Program
FPP	Fire Protection Plan
KPI	Key Performance Indicator
SAT	Systematic Approach to Training

2 Plan

2.1 Risk Management

The risk management process includes identifying Operation-related hazards that could result in emergency situations, determining the significance of the associated risks, and managing the risks to appropriate levels through the application of controls.

Identification and classification of potential health, safety, and environmental risks are an integral part of the Program. An appropriate level of risk assessment is conducted for identified incidents and used in classification of these potential events. The Program, in coordination with the *Crisis Management Plan* where required, outlines actions taken when specific emergency actions arise including:

- Identification of accidents and emergencies;
- Details of actions to be taken during the emergency;
- Measures to protect workers during an emergency or crisis;
- Incident command structure and delegation of authority to effectively manage both short-term and complex, lengthy, and large-scale emergencies and crisis;
- Evacuation procedure, including muster points;
- Identification and location of hazardous materials;
- Emergency response services, equipment, supplies, and facilities;
- Interface with external emergency services;
- Communications with statutory bodies;
- Communications with neighboring indigenous communities and the public;
- Protection of vital records and equipment;
- Availability of vital information during an emergency (e.g., plant drawings, applicable SDs, location of hazardous chemical storage);
- Recovery steps to restore the site to normal operations; and
- Mechanisms for evaluating the effectiveness of the Program and associated plans.

The manner and extent to which individual elements of the Program are applied at the Operation will depend on such factors as size of site, exiting documentation, the nature of activities and impacts, expected duration of projects, and operating conditions.

2.1.1 Hazard Identification

Preparing for emergencies begins with identifying natural or human-made hazards that could result in emergency events or situations. Following hazard identification, emergency risks are assessed with consideration for a range of factors.

Examples of natural hazards include:

- Lightning strikes;
- Flash flooding;
- Winter storms;
- Forest fire; and
- Sudden medical distress of worker (e.g., heart attack).

Examples of human-made hazards include:

- Chemical, biohazard, or radiological release;
- Structural collapse;
- Fire or explosion;
- Transport accident;
- Intentional violence or threats; and
- Technological failures.

Hazards are identified, documented, assessed, and tracked in a risk registry which is periodically reviewed and revised as necessary to confirm it remains current and accurate.

2.1.2 Risk Register

Denison uses a risk register to proactively identify and address significant radiation protection risk aspects, prioritize resources, and continuously improve its emergency management practices. The risk register is a central repository for recording and tracking information related to the significant training aspects.

Further details on the risk register are provided in the *Management System Program*.

2.1.3 Program-specific Risk Methodologies and Controls

Controls are used to eliminate, prevent, or reduce the risk of harm to workers, the public, the environment, and property during emergency events and situations. Controls are documented, tracked in a risk registry, and are periodically evaluated for effectiveness. Emergency risk controls include, but are not limited to:

- Emergency response teams;
- Emergency response equipment;
- Fire suppression systems and equipment;
- Fire guards;
- Ventilation systems;
- Proper segregation and storage of hazardous goods;
- Administrative controls such as emergency and crisis management plans, work instructions, training, and supervision;
- Mutual aid agreements; and
- Personal protective equipment.

Controls appropriate for the emergency hazard and corresponding level of risk are selected and implemented with consideration for the hierarchy of controls as outlined in the *Health and Safety Management Program*.

Controls are used, operated, and maintained in accordance with their design, limitations, and applicable training. Following appropriate procedures and training is critical in maintaining the effectiveness of controls.

The general process for identifying and applying controls is outlined in the *Management System Program.*

2.2 Objectives and Targets

The Operation is responsible for establishing, implementing, and documenting Program objectives and annual targets. Objectives and targets of this Program will be measurable, documented, and tracked. Performance against the objectives and targets will be communicated at regular intervals (i.e., during Management Review), and opportunities for continual improvement will be identified.

The process for setting overall objectives and targets is outlined in the *Management System Program* and supporting procedure.

2.3 Resources

Denison is committed to providing the necessary resources to support effective development, implementation, maintenance, and continual improvement of the Program, including achievement of its objectives and targets.

2.3.1 Roles and Responsibilities

This subsection outlines the specific roles and responsibilities within the Program, including EPRP Management and EPRP Coordinator, and other workers with various levels of responsibility.

For effective implementation of this Program, workers are informed of their roles and responsibilities and are accountable for comprehending and performing them. Executive and Leadership level roles and responsibilities are specified in the *Management System Program*.

<u>EPRP Management</u>

- Overseeing the development, implementation, and adherence to this Program;
- Detting objectives and targets, tracking performance using key performance indicators (KPIs), and preparing internal and external reports regarding EPRP activities and outcomes;
- Confirming compliance to regulatory and Operation requirements;
- Confirming appropriate resources are made available for competence, training, and awareness of EPRP requirements;
- Confirming accountability of the activities of EPRP coordination for carrying out this Program;
- Working with applicable departments to verify that Program roles and responsibilities are identified and outlined, and that those with specific responsibilities are qualified to fulfill their roles;
- Communicating with external stakeholders as appropriate;
- Reporting on EPRP performance and effectiveness to Operation Management;
- Facilitating management review of the EPRP and maintain associated records including tracking decisions and actions stemming from the review; and
- Maintaining continual improvement through EPRP evaluation.

<u>EPRP Coordinator</u>

- Demonstrating and promoting a positive health and safety culture;
- Leading the development, implementation of, and adherence to EPRP procedures and work instructions;
- Verifying 24-hour emergency response coverage is provided;

- Maintaining EPRP-specific data and records in a secure and controlled manner;
- Providing subject matter expertise and support;
- Confirming that workers meet and maintain required EPRP-specific training qualifications; and
- Reporting on Program performance as part of the annual management review process.

2.3.2 External Resources

In addition to using Operation workers, facilities, and equipment, external resources may be utilized to effectively manage emergency events and situations. Examples include, but are not limited to:

- Establishing mutual aid agreements with neighbouring communities;
- Using Saskatchewan Air Ambulance or Shock Trauma Air Rescue Service (STARS) for transporting patients for medical treatment; and
- Coordinating wildfire response with the Saskatchewan Public Safety Agency.

A list of potential external resources along with their contact information and the processes for engaging them are further defined in the *Emergency Response Plan*, the *Transportation Emergency Response Plan*, and the *Crisis Management Plan*.

2.3.3 Facilities and Equipment

Facilities and equipment used for emergency response will be identified, of sufficient size and quantity, properly maintained and in working condition at all times. However, facilities and equipment may be taken out of service for required maintenance if alternate provisions are put in place during these periods.

Denison provides facilities to support the effective implementation of the program and its associated processes. Examples of facilities and equipment used and maintained as part of this Program include:

- An emergency operations centre equipped with communication devices and administration aids (e.g., status boards and reference materials);
- Emergency response vehicles (e.g., ambulance, fire truck);
- Storage facilities for emergency response vehicles, equipment, and tools;
- Hazardous material response equipment and trailer;
- Wildfire protection of critical infrastructure (e.g., exterior permanent and portable sprinkler systems);
- An on-site medical center;
- First aid equipment
- Marked muster stations;
- Alarm systems;
- Emergency lighting and power;
- Critical isolation valves
- Communication equipment; and
- Fire suppression infrastructure (fire water pump, sprinklers, and fire extinguishers).

Facilities and equipment meet or exceed applicable Saskatchewan and federal health and safety standards, codes, and regulations. Additional information on the specific facilities and equipment used for emergency management are outlined in the supporting *Emergency Response Plan*, *Crisis Management Plan*, and *Transportation Emergency Response Plan*.

The process for procuring facilities and equipment is outlined in the *Facility and Equipment Management Program*.

2.3.4 Legal and Other Requirements

Denison is committed to complying with all applicable legal and other requirements related to the management of emergency preparedness and response. Types of legal requirements applicable to the Operation include:

- Federal and provincial acts and regulations; and
- Licensing obligations and commitments.

The process for managing legal and other requirements is outlined in the *Management System Program*. Denison has established procedures to ensure compliance with these requirements and that compliance obligations are regularly reviewed. Any changes relevant to training compliance obligations are monitored and evaluated to determine if updates to the *Emergency Preparedness and Response Program* and its supporting Plans, Procedures, and Work Instructions are required.

2.4 Training and Competence

A systematic approach to training (SAT) is used to educate, train, and qualify workers and contractors to perform assigned work. Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely. Program-specific training requirements are defined in the *Training Management Program*.

Records of training activities and competencies will be maintained as outlined in the *Training Management Program*.

2.4.1 Program-Specific Training

The Operation identifies the competency requirements for both workers and contractors who will be part of emergency response and confirm those workers are trained, aware, and competent to perform these duties in a safe and effective manner.

Contractors may volunteer to participate as a member of the emergency response team. Role-specific training and competency details are outlined in the procedure *Emergency Response Team.* Program specific training is developed, delivered, and maintained in accordance with the SAT process and with consideration for applicable provincial and federal regulatory requirements.

Workers performing emergency response tasks are competent based on appropriate education, training, and experience or are under the direct supervision of competent Operation personnel. Workers receive qualifications through Operation personnel or appropriate certifying bodies. Requirements for any necessary re-qualifications are tracked and training provided on appropriate schedules.

Operation workers, contractors, and visitors are required to participate in site orientation prior to work initiation. Site orientation includes general requirements for protecting personnel and the environment as well as important actions to follow during emergency events and situations.

2.5 Documentation and Records Management

Denison will establish and maintain documented Plans, Procedures and Work Instructions to ensure effective implementation of the Program. Documentation will be controlled, reviewed, and updated as necessary in accordance with the requirements in the *Management System Program*.

Documents and records will be generated as a result of implementation of the Program and completion of licensed activities. Examples of some records generated specific to the Program may include:

- Emergency preparedness and response plans;
- Emergency response action logs and response debriefs;
- Emergency response team training;
- Emergency drills, exercises, and debriefs;
- Worker selection, qualifications, and training for emergency preparedness and response;
- Records required by this Program; and
- Records of inspection, maintenance, and calibration of emergency response equipment.

Documentation and records are readily accessible to those who require them. Occupational exposure and health records associated with emergency response activities (e.g., radiation doses to workers during a response) are managed in accordance with applicable privacy legislation.

Information, including the identification of critical facilities and equipment, and documents and records generated for or because of emergency events and situations is managed to verify the information is accurate, available when needed, and protected from uncontrolled alteration.

2.6 Communication

Communication both with internal and external stakeholders is a critical element of the Program to promote a safe work culture that understands the importance of emergency preparedness and response. Relevant emergency response information such as plan performance data and improvement initiatives will be shared.

Internal and external communication processes specific to emergency events and situations are further outlined in the *Emergency Response Plan*, the *Transportation Emergency Response Plan*, and the *Crisis Management Plan*.

During and following emergency events and situations, information is communicated to and among various internal and external parties affected by, involved in, and interested in emergency events and situations. This includes, but is not limited to:

- Workers and contractors;
- Emergency response teams;
- Regulatory agencies; and
- Indigenous groups, local communities, and the public as required.

Only persons authorized by Denison Mines may communicate on behalf of the company. This includes communication with the media, regulators, customers, shareholders, suppliers, and the general public.

Communication principles and processes are further outlined in the *Management System Program,* and communication with indigenous groups, local communities, and the public is managed as outlined in the *Public and Indigenous Information Program.*

2.6.1 Internal Communication

Communication procedures are developed at the corporate and site level to identify and classify events that may adversely affect the health and safety of workers, verifying timely and appropriate communication to senior management. Such procedures confirm that when an unusual or unplanned event occurs, the appropriate levels and functions at the Operation and the corporate office are informed so that decisions and corrective action are carried out at the appropriate level of responsibility and authority.

The following types of Program related information is communicated internally among the various levels and functions at the Operation:

- How to activate the Operation's emergency response plans;
- Internal communication procedures during an emergency response, including communication procedures with the corporate crisis management team;
- Emergency response levels, risk assessment, and plans;
- Emergency response plan objectives, targets, and key performance indicators;
- Results of emergency response plan testing; and
- Program non-conformances and corrective actions taken in response.

2.6.2 External Communication

The Operation notifies the appropriate external authorities when assistance is required in responding to an emergency (e.g., mutual-aid agreements, contract emergency response providers). All other external communication (i.e., notifying the appropriate regulatory authorities during an emergency response) is managed as outlined in the *Crisis Management Plan*. Procedures for receiving, documenting, and responding to communication from external stakeholders are developed for use.

2.7 Change Management

Change is managed at the Operation to protect workers, the environment, and property, and to ensure that regulatory requirements are met. The Operation's change management process is outlined in the *Management System Program.*

Examples of changes captured by the process could include, but is not limited to changes to the:

- *Emergency Preparedness and Response Program* and supporting plans, procedures, and work instructions;
- Structures, systems, and components;
- Regulatory requirements related to emergency response;
- Emerging risks to workers; and
- Organizational changes.

3 Do

3.1 Supporting Plans

This Program is supported by documented plans that describe actions to be taken in the event of an emergency or crisis. Supporting documentation covers the following topics:

- Criteria and conditions that triggers the activation of response activities;
- Details of actions to be taken during the emergency or crisis including methods for continually assessing the emergency;
- Measures to protect workers during an emergency or crisis;
- Incident command structure and delegation of authority to effectively manage both short-term and complex, lengthy, and large-scale emergencies and crises;
- Responsibilities and duties during an emergency or crisis, including delegation of primary authority;
- Emergency response services, equipment, supplies, and facilities;
- Emergency radiation protection measures;
- Evacuation procedures including muster points;
- Availability of vital information during an emergency (e.g., operation drawings, information on hazardous substance and their locations);
- Response interface with external emergency services;
- Communication protocols including timelines with regulatory agencies, indigenous groups, local communities, and the public;
- Protection of vital records and equipment;
- Recovery steps to restore the site to normal operations; and
- Mechanisms for evaluating the effectiveness of the plan.

These plans and the supporting procedures are controlled documents. They are reviewed, updated, and maintained in accordance with the documented information process outlined in the *Management System Program*.

3.1.1 Emergency Response Plan

The *Emergency Response Plan* documents the approach for rapidly and efficiently responding to, controlling, and minimizing the effects of emergency events and situations that occur within the boundary of the Operation site. Emergency events or situations that occur beyond the Operation boundary, but threaten Operation safety or security, are also discussed. Examples of emergency events and situations covered by the *Emergency Response Plan* include but are not limited to:

- Serious medical emergencies;
- Surface fires;
- Wildfire threatening the Operation; and
- Major chemical or radiological release.

The *Emergency Response Plan* describes the resources that are available and accessible for emergency response operation; specific roles and responsibilities for incident command and emergency response team members; and protocols for responding to all foreseeable emergency events and situations. It outlines the actions to be taken during emergency events or situations, including actions taken in coordination with the *Transportation Emergency Response Plan* and the *Crisis Management Plan.*

3.1.2 Transportation Emergency Response Plan

The *Transportation Emergency Response Plan* provides direction to Operation emergency responders concerning ground transportation emergencies that occur along the Operation site access road or along Highway 914. The spatial extent and scope of response activities is further outlined within the plan.

The *Transportation Emergency Response Plan* is not a substitute for an *Emergency Response Assistance Plan* (ERAP) which is a regulatory requirement for transporting certain high-risk dangerous goods, including uranium concentrate. Transporting uranium concentrate beyond the Operation boundary is not within the scope of this Program or the construction and commissioning phase of the Operation. However, an ERAP developed in accordance with the *Transportation of Dangerous Goods Regulations* and approved by Transport Canada will be in place prior to commencement of operations.

Operation emergency responders may assist as first responders or in a technical advisory capacity. The decision to provide support depends on several factors, including the nature of the transportation emergency, weather conditions, the capacity and ability of team members to respond safely, and the proximity of the emergency to the site. Response activities may include, but are not limited to:

- Providing first aid for injuries suffered at an accident scene;
- Controlling and containing dangerous goods;
- Controlling access to the accident scene;
- Removing debris from the accident scene; and
- Supporting transportation logistics.

Assistance is provided in coordination with applicable authorities (e.g., RCMP, Saskatchewan Ministry of Environment) and transport carriers. Dangerous goods transported to the site are the sole responsibility of the transport carrier and the manufacturer of the dangerous goods until they reach the Operation property boundary.

3.1.3 Crisis Management

The purpose of the *Crisis Management Plan* is to provide an organized response to crisis events and situations involving Operation workers or assets and to provide a framework for maintaining, resuming, or recovering critical activities after a crisis is resolved.

A crisis is an abnormal event or situation which presents a significant risk to the Operation, draws media attention, and could threaten public trust. Crises can be situations that are unexpected, unstructured and outside the typical operational framework. Examples include, but are not limited to:

- Multiple serious injuries;
- A fatality;
- Significant security breach of the Operation site;
- Significant breach of information technology system;
- Receipt of a bomb threat;
- Serious civil disturbance on or adjacent to Operation site or Denison property; or

- A situation which poses an immediate threat to life or serious injury to persons at the Operation.

The *Crisis Management Plan* includes crisis assessment criteria that are used to activate crisis response measures and the contact information for key personnel responsible for activating the plan if required.

4 Check

4.1 Monitoring and Measurement

Emergency response and preparedness performance is monitored and measured against established objectives and targets (identified in Section 2.2). Denison will monitor, measure, analyze, and evaluate emergency response for the Operation based on a defined process outlined in the *Management System Program*.

Monitoring and measurement activities specific to the *Emergency Response and Preparedness Management Program* may include:

- Emergency response tabletop exercises, drills, or full-scale exercises;
- Frequency or trends in non-conformities, injuries, and incidents; and
- Evaluation of emergency responder training.

Exercises, drills, and full-scale exercises are carried out according to a predetermined schedule. Where appropriate, the participation of external emergency services in full-scale exercises is encouraged. A test emergency response plan defines the expected performance of the exercise and aids in measuring the Operation's emergency preparedness by:

- Documenting information to evaluate preparedness against expected or legislated performance and effectiveness measures; and
- Conforming with site objectives and targets.

Following the completion of any test of the emergency response plan, the effectiveness of the plan being tested is evaluated against expected measures and, where necessary, opportunities for improvement or nonconformances recommended and acted upon.

4.2 Inspections and Audits

Denison will conduct internal audits of the *Emergency Preparedness and Response Program* to assure compliance with the requirements set out in the Program and to determine if the Program is effectively implemented and maintained.

Audits are conducted by qualified personnel independent of the work being assessed and will follow the process and procedures outlined in the *Management System Program*.

In addition to audits, routine internal inspections of emergency response facilities and equipment are conducted by competent personnel to verify that controls are functioning and effective. This includes, but is not limited to, inspections of:

- Emergency response equipment and alarms;
- Fire suppression systems and equipment;
- Fire guards;
- Ventilation systems;
- Proper segregation and storage of hazardous goods; and
- Personal protective equipment.

4.3 Management Review

The *Emergency Response and Preparedness Program* will be reviewed by Denison management in accordance with a defined frequency to assure the Program is meeting its objectives, is effective or needs adjustment. The types of items related to emergency response that Denison management will review may include:

- Suitability, adequacy, and performance of emergency response objectives and targets;
- Upcoming or new legislation related to emergency response;
- Results of exercises and drills in relation to objectives and targets;
- Results of audits in relation to program performance objectives and targets;
- Identified opportunities for improvement based on emergency events, incident reports, and other sources;
- Communications from interested parties;
- Adequacy of resources; and
- Any needs for program adjustment.

Where necessary, Denison management will identify opportunities for improvement and establish action plans to implement change in accordance with the process outlined in the *Management System Program*.

4.4 Reporting

Denison will routinely report both internally and externally on the performance of the *Emergency Preparedness and Response Program*. External reporting can include reporting to regulators, the public, and Indigenous and local communities.

External reports including notification to appropriate regulatory authorities during an emergency response will be completed in accordance with regulatory requirements. As noted in section 2.8.2 this is managed as outlined in the *Crisis Management Plan.*

External reports to the public or Indigenous communities on the performance of the Program will be tailored to the interests of these groups as identified through community engagement activities. Reporting, disclosure, and communication to the public and Indigenous and local communities is discussed in more detail in the *Public and Indigenous Information Program.*

5 Act

5.1 Corrective Action

Non-conformities or areas for improvement are identified following the process outlined in the *Management System Program* and the supporting procedures. These non-conformities can include emergency events, incidents, near-misses, and deviations from the *Emergency Preparedness and Response Program.* Non-conformities can also be identified during inspections and audits.

Responses to identification of non-conformities include investigation of cause, and corrective action if appropriate. Corrective actions are planned, implemented, verified, and reviewed for effectiveness based on the process identified in the *Management System Program*.

5.2 Continual Improvement

Opportunities for improvement of this Program will be identified and addressed to enhance emergency preparedness and response. The continual improvement process for this Program follows the overall continual improvement process outlined in the *Management System* and the supporting procedures. Continual improvement may also include updating Program objectives and targets based on changing circumstances or new information. Improvement may involve benchmarking performance against other similar projects and facilities. Any changes identified through the continual improvement process will be implemented in a systematic and controlled manner.

With respect to emergency response, opportunities for continual improvement may be identified through review of monitoring results, incident investigations, lessons learned, worker experience, government and industry publications, and industry peer information exchanges.

6 References

6.1 Internal

Document Name
Management System Program
Emergency Response Plan
Transportation Emergency Response Plan
Crisis Management Plan
Training Program
Indigenous and Public Engagement Program
Health and Safety Program
Security Program
Asset Management Program
Contractor Management Program

6.2 External

Federal

Nuclear Safety and Control Act

Uranium Mines and Mills Regulations

Radiation Protection Regulations

Nuclear Substances and Radioactive Devices Regulations

General Nuclear Safety and Control Regulations

Canadian Nuclear Safety Commission*. REGDOC 2.10.1 Nuclear Emergency Preparedness and Response*

Canadian Nuclear Safety Commission*. REGDOC 2.10.2 Fire Protection*

Environmental Emergency Regulations

Transportation of Dangerous Goods Regulations

Provincial

The Saskatchewan Employment Act, 1993

The Occupational Health and Safety Regulations 1996

The Mines Regulations, 2018

The Fire Safety Act

The Fire Safety Regulations

The Wildfire Act

The Wildfire Regulations

The Environmental Management and Protection Act, 2010

The Hazardous Substances and Waste Dangerous Goods Regulations

Other

Mining Associated of Canada. Towards Sustainable Mining Crisis Management and Communications Protocol

National Fire Protection Association (NFPA). *600 – Standard on Facility Fire Brigades*

National Fire Protection Association (NFPA). *1561 – Standard on Emergency Services Incident Management System and Command Safety*

29 Denison Mines Corp. Wheeler River Operation, Fire Protection Design Criteria, Version #1, March 2025

Denison Mines

wood.

Design Criteria

Title:	Fire Protection	Doc. No.:	100382-3000-H-DSC-0003	Rev.	0

Project Name:	Wheeler River Project	Project No.:	100382 (261009)
Client:	Denison Mines Corp.	Plant/Area No.:	3000

Important Notice

Rev	Date	Issued For	Prepared	Checked	Tech Authority / Dept Manager	Approved	Client
A	17 Apr 2024	Squad Check and Review	J. Wionzek	J. Schultz	B. Holderness	D. Myers	
B	17 Jun 2024	Approval	J. Wionzek	J. Schultz	B. Holderness	D. Myers	
C	14 Jan 2025	Approval	J. Wionzek	J. Schultz	B. Holderness	D. Myers	B. Gibb
0	28 Jan 2025	Design	J. Wionzek	J. Schultz	B. Holderness	D. Myers	

Permit Stamp

ASSOCIATION OF PROFESSIONAL ENGINEERS
& GEOSCIENTISTS OF SASKATCHEWAN
CERTIFICATE OF AUTHORIZATION
Wood Canada Limited
NUMBER C0577
PERMISSION TO CONSULT HELD BY:

DISCIPLINE	Sk. Reg. No.	SIGNATURE

Engineer's Seal

Table of Contents

1 General

1.1 Purpose and Scope

The Fire Protection Design Criteria establishes the engineering standards and practices to be followed in the execution of design and shall govern the production and contents of the following documents:

- Technical specifications.
- Performance specifications.
- General arrangement drawings.
- Fire Protection arrangement drawings.
- Detail design and assembly drawings.

The focus of this document is to guide the design of active fire protection systems, which are engineered to provide immediate response to fire hazards through detection, suppression, and control including fire detection and alarm systems, automatic fire suppression systems, and firefighting equipment. For annunciation and detection refer to the Instrumentation and Controls Design Criteria (refer to Section 2.3 for the associated document number).

This document does not cover passive fire protection elements, such as fire separations, rated enclosures, or locally applied fire barriers. These aspects of fire protection should be addressed in relevant design documents such as the Building Finishes and Fire Safety Design Criteria (refer to Section 2.3 for the associated document number). For other measures like lightning protection or fluid containment, refer to the Electrical Design Criteria (refer to Section 2.3 for the associated document number), Process Design Criteria (refer to Section 2.3 for the associated document number) and applicable mechanical equipment specifications.

1.2 Language

The Fire Protection Design Criteria establishes the engineering standards and practices to be followed.

Engineering documents to be issued shall be prepared in English. All communication to the Owner shall be in English.

1.3 Units of Measurement

International System of Units (SI) shall be used for design, calculations, drawings, and any other document related to the project.

Imperial units shall be used for nominal pipe bores (inch), bolts (inch), motor power (hp), wire size (AWG) and electrical fittings (inch).

Refer to Site Conditions and Units of Measurement (refer to Section 2.3 for the associated document number) for project specific units of measure.

1.4 Radiation

Radiation protection features shall be considered and incorporated into all design work with the intention of keeping workers radiation doses As Low As Reasonably Achievable (ALARA). ALARA principles will also be incorporated with appropriate administrative controls and training. Design features that serve to reduce or eliminate a pathway of exposure to the radiation hazard include the following:

- Time – minimize the time in which workers are required to occupy areas of high radioactivity.
- Distance – maximize the distance between workers and areas of high radioactivity.
- Shielding – using materials or designs that reduce the transmission of ionizing radiation through them to reduce the effective dose to workers.
- Ventilation – removal of radioactive gases and particulate from the atmosphere in areas of human occupancy.

1.5 Health and Safety

Facilities are to be designed and constructed with consideration for worker health, safety, wellbeing, and compliance with legal requirements. A risk-based approach is to be followed and the hierarchy of controls used to effectively control health and safety risks throughout the design phase.

- Elimination – wherever possible, hazards should be removed completely (e.g., assemble components at lower elevations to eliminate working at height hazards).
- Substitution – after a risk assessment, items can be replaced with less hazardous ones (e.g., using a non-toxic or less toxic chemical rather than a toxic one, using a weaker acid instead of a concentrated acid).
- Engineering Controls – If eliminating or substituting a hazard is impractical, then risk may be mitigated with engineering controls. Engineering controls can include re-designing facilities and processes, equipment, or systems to reduce the exposure to the hazard (e.g., guards around moving parts, exhaust ventilation systems to remove gases or dust, interlocks).
- Administrative Controls – Administrative controls include written safety procedures, processes, and rules, along with supervision, training, signage, and work permits. Administrative controls are usually implemented together with other types of controls (e.g., engineering, substitution, PPE).
- Personal Protective Equipment – PPE is vital to worker safety when other controls cannot mitigate a health and safety risk to an acceptable level.

The life safety objectives of CSA N393 are achieved by complying with the fire and life safety requirements in the NBCC and NFCC, and by following the recommendations from the Fire Hazard Analysis (FHA) report.

1.6 Environmental

Facilities are to be designed and constructed with consideration for safeguarding the environment with regards to the prevention and control of unplanned releases. The implementation of control measures shall be based on the potential risk to the environment on a case-by-case basis. In general, the unplanned release of radioactive substance from its primary means of containment could be considered a reportable spill. Normal operations may require radioactive substances released to secondary containment from time to time, therefore a robust containment system and a means to manage the substance should be considered to minimize the risk of the substance entering the environment.

1.7 Defense-in-depth Principle

The Defense-in-depth principle shall be applied to achieve a high degree of fire protection by ensuring redundancy, diversity, and balance in fire protection measures. The elements of this principle are outlined in Clause 5.1.3 of CSA N393 or Section 5 of REGDOC-2.10.2.

2 Guidance Documents

The design, fabrication, field erection (where applicable), inspection, and testing shall comply with the latest edition and amendments (including addenda) of all laws, acts, regulations, and codes in the province of Saskatchewan at the commencement of the project, and the relevant parts of industry standards published by the following authorities and technical organizations.

2.1 Acts and Regulations

Canadian Environmental Protection Act, 1999

Saskatchewan Employment Act, Chapter S-15.1 of the Statutes of Saskatchewan, 2013 including amendments to 2021

Occupational Health and Safety Regulations, 2020 (Saskatchewan)

The Mines Regulations, 2018

Hazardous Substances and Waste Dangerous Goods Regulations – Regulation 25-92

Uranium Mines and Mills Regulations SOR/2000-206

Canadian Nuclear Safety Commission – REGDOC 2.10.2, Fire Protection

2.2 Codes and Standards

Design of the facilities shall be executed, as applicable, in accordance with local/provincial/federal regulations, laws, and codes having jurisdiction in the province of Saskatchewan at the commencement of the project, and the relevant parts of industry standards published by the following authorities and technical organizations.

Fire Protection design, materials and construction shall meet the applicable requirements of the following codes and standards, latest editions:

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Material
AWS	American Welding Society
AWWA	American Water Works Association
CGS	Canadian General Standards Board
CSA	Canadian Standards Association
CSA N393:22	Fire Protection for Facilities that Process, Handle, or Store Nuclear Substances
MSHA	Mine Safety and Health Administration

NACE	National Association of Corrosion Engineers
NBCC-2020	National Building Code of Canada
NFCC-2020	National Fire Code of Canada
NFPA	National Fire Protection Association
NFPA 10-2022	Standard for Portable Fire Extinguishers
NFPA 11-2024	Standard for Low-, Medium-, and High-Expansion Foam
NFPA 13-2022	Standard for the Installation of Sprinkler Systems
NFPA 13R-2022	Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies
NFPA 14-2014	Standard for the Installation of Standpipe and Hose Systems
NFPA 22-2023	Standard for Water Tanks for Private Fire Protection
NFPA 24-2022	Standard for the Installation of Private Fire Service Mains and Their Appurtenances
NFPA 2001-2022	Standard on Clean Agent Fire Extinguishing Systems
ULC	Underwriters Laboratories of Canada

Notes:

1) Where requirements in this document are more restrictive than the referenced codes and standards, requirements of this document shall govern.
2) Supplier/Contractor shall design and construct the plant in accordance with all local laws, as well as the codes and regulations applicable in the province of Saskatchewan.

2.3 Project Specifications

Project specifications will be required to be prepared during the detail engineering phase of the project to cover procurement of equipment design, fabrication, installation, testing, and commissioning for process systems.

The following design criteria and specifications are referenced herein as being applicable to the present document.

100382-3000-A-DSC-0001	Building Finishes and Fire Safety Design Criteria
100382-3000-C-DSC-0002	Civil Utility and Surface Piping Design Criteria
100382-3000-E-DSC-0001	Electrical Design Criteria
100382-3000-G-SPC-00230	Site Conditions and Units of Measurement
100382-3000-G-SPE-09900	Painting and Coatings Specification

100382-3000-H-DSC-0001	Heating, Ventilation and Air Conditioning Design Criteria
100382-3000-H-DSC-0002	Dust and Fume Collection Design Criteria
100382-3000-J-DSC-0001	Instrumentation and Controls Design Criteria
100382-3000-P-DSC-0001	Piping Design Criteria
100382-3000-R-DSC-0001	Process Design Criteria
100382-3000-S-DSC-0001	Structural Design Criteria

2.4 Site Geographic and Climatic Data

For site geographic and climatic data (wind, rainfall, seismic, etc.), refer to Site Conditions and Units of Measurement (refer to Section 2.3 for the associated document number).

2.5 Structural Design Loads

For structural design loads, refer to Structural Design Criteria (refer to Section 2.3 for the associated document number).

3 Fire Protection System Engineering and Design

3.1 General

The fire protection system requirements shall be designed considering the assumption that only one major emergency will occur at a time.

The firewater system shall be designed based on the single largest firewater flow requirement.

In general, the fire mitigation design shall follow the guidance in REGDOC-2.10.2, and the requirements of CSA N393, NBCC and NFCC. For area-specific recommendations refer to the site FHA report.

Personnel safety shall always take precedence. Fire protection that is required for personnel protection is mandatory, refer to Clause 5.3.2.1 of CSA N393.

Fire protection equipment design shall be the responsibility of the manufacturer unless specified. Equipment design shall meet the design requirements, standards, and referenced specifications and datasheets issued for quotation.

3.2 Design Life

In general, fire protection equipment shall be designed for a minimum service life of 15 years. It is understood that certain material may require maintenance and/or replacement at more frequent intervals.

3.3 Firewater Storage Requirements

Firewater storage shall comply with CSA N393 and NFPA 22 (where applicable).

CSA N393 requires that where tanks or reservoirs are used for firewater storage, separate tanks or reservoirs are required to provide full redundancy of the firewater storage capacity. However, the FHA has demonstrated that the planned water sources for the firewater storage will ensure there is sufficient redundancy to ensure the firefighting water can be maintained. Refer to Section 5.7.3.4 of the FHA.

Firewater storage capacity shall be calculated based on the largest expected flow rate for a minimum period of 2 hours. Where combined firewater and general water usage storage exists in tanks, the general water usage must be physically incapable of drawing from the firewater reserve.

3.4 Firewater Flow Requirements

Firewater flow requirements for buildings shall be based on the fire protection system water demands as determined by the requirements of NFPA 13, NFPA 13R (if applicable), NFPA 14, and NFPA 400. The pumping system to provide the flow requirements shall be designed and installed based on the requirements NFPA 20.

The water supply for firefighting shall be capable of providing the required firewater flows for any combination of hydrants, sprinkler systems, standpipe systems, and responding fire apparatus based on a single fire event.

The firewater distribution system shall be designed to supply the specified rate to each fire hazardous area, but not concurrently to more than one area.

Residual firewater pressures shall be a minimum of 700 kPa(g) at wall hydrants around process areas and should not exceed 865 kPa(g).

3.5 Automatic Sprinkler Systems (Wet and Dry)

Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13. In the camp areas, design and installation of automatic sprinkler systems will be in accordance with NFPA 13R (if applicable).

Wet pipe sprinkler systems shall be installed inside heated buildings and structures. Do not provide wet sprinkler systems in rooms or areas where sensitive electrical equipment may be present. Dry pipe sprinkler systems shall be installed in areas that may be subjected to freezing conditions. Pre-action systems shall be installed in areas where it is necessary to prevent accidental release of water, such as control rooms. Pre-action systems shall be activated by confirmed detection of smoke (2 or more detectors in alarm) within the protected area.

Sprinkler system control valves shall be located in accessible locations.

Sprinkler systems shall be equipped with water flow switches and valve tamper switches complete with Interface Devices reporting to a local fire alarm control panel.

A sprinkler head cabinet containing a minimum of six spare sprinkler heads of an appropriate type and temperature rating for the protected area shall be located at each alarm valve station or floor control valve station.

3.6 Auxiliary Firewater Systems and Components

3.6.1 Yard Hydrants

Yard hydrants will be provided in accordance with NFPA 24. Refer to Civil Utility and Surface Piping Design Criteria (refer to Section 2.3 for the associated document number) for specific design requirements.

3.6.2 Wall Hydrants

Design of wall hydrants shall be in accordance with NFPA 14. Wall hydrants will be provided in areas where it is impractical to install conventional dry barrel hydrants on buried fire mains.

The wall hydrants shall be located on the outside surface of perimeter walls of heated buildings and structures. Water supply for wall hydrants shall come directly from the firewater distribution main piping. Piping shall be insulated and electric heat traced to a minimum distance of 1500 mm inside the heated area or to upstream of the control valve, whichever dimension is greater, to prevent freezing of the control valve.

Where wall hydrants are subject to ice formation and build-up of drifted snow, an insulated and weather resistant box with access door shall be provided over the hydrant assembly.

3.6.3 Standpipe Systems

In general, standpipes and hose stations shall comply with NFPA 14.

Fire hose stations shall be located on independent standpipe risers or supplied directly from the firewater distribution loop main. In office areas, hose stations may be supplied from the sprinkler piping in accordance with the recommendations of NFPA 13 and NFPA 14. Water flow switches shall annunciate water flow in standpipes at the local fire alarm control panel.

Where system pressures exceed 689 kPa (100 psi), pressure regulating or pressure restricting type hose valves shall be provided.

All isolation valves controlling water to standpipe risers shall be chained and locked in open position.

Only Class II Standpipe systems shall be used.

All standpipe systems located outside of heated areas shall be semi-automatic preaction type with local pneumatic manual actuation controls. Where fire water supply pipe enters unheated space, provide a local insulated and heated enclosure. The heating equipment shall be provided with a remote trouble alarm.

Standpipes inside heated buildings shall be wet systems.

3.6.4 Fire Hose Cabinets

Hose cabinets will be spaced for full interior building coverage in accordance with NFPA 14, with allowances for 9 m nozzle discharge distance and 9 m for equipment obstruction of hose playout.

Hose cabinets shall be placed on each equipment structure platform level and distributed inside process buildings.

Fire hose cabinets shall be provided with 30 m of 1½" flat hose.

The hose shall be provided with an adjustable straight/fog stream nozzle.

Fire hose racks with hoses and accessories shall be housed in local fire hose cabinets.

Where specified, an indoor fire hose cabinet shall be provided to contain hose, hose rack or reel, hose valve, nozzle, and portable handheld extinguisher.

3.7 Handheld and Wheeled Fire Extinguishers

Hand-held and wheeled fire extinguishers shall comply with the requirements of NFPA 10, NBCC, and NFCC.

All extinguishers shall be specified for cold weather operation.

Process areas shall use 10 kg, cartridge operated, A:B:C dry chemical extinguishers.

Electrical rooms shall use 10 kg, pressurized CO2 extinguishers.

Non-process buildings shall use 9 kg, cartridge operated, A:B:C dry chemical extinguishers.

Control room areas shall use 10 kg, pressurized CO2 extinguishers.

Twenty-two kilogram wheeled carbon dioxide carts shall be used at lube oil use areas on the Process Plant operating floor.

3.8 Foam Fire Suppression System

If a foam fire suppression system is required, a high-expansion foam system, consisting of foam concentrate and high output foam generators will provide fire protection based on requirements in NFPA 11 Standard for Low-, Medium-, and High-Expansion Foam.

3.9 Clean Agent Systems

If required, clean agent systems shall use Novec 1230 extinguishing agent and shall be designed in accordance with NFPA 2001.

Clean agent systems may be used for protection of electrical and computer systems in control and rack rooms depending on the potential fire risk.

3.10 Painting

Painting of equipment shall be in accordance with the requirements of specification Painting and Coatings (refer to Section 2.3 for the associated document number).

Painting fabricated equipment supports and structures shall be in accordance with project specifications.

The specific paint system shall be specified on the drawings and individual equipment specifications or data sheets. The system specified shall be determined on the operating conditions and location of that equipment.

Miscellaneous steel shall be tagged with an appropriate permanent means identifying the B.O.M. number. All tag and match mark numbers shall be legible after application of specified coatings.

All exposed surfaces of carbon steel equipment shall be protected by painting in accordance with the project specifications.

Stainless steel equipment shall not be painted.

Fiberglass reinforced plastic (FRP) equipment shall not be painted.

END OF DOCUMENT

30 Denison Mines Corp. Wheeler River Operation, Preliminary Decommissioning Plan, Version 1, July 2023

Denison Mines Corp.

Wheeler River Operation

Preliminary Decommissioning and Reclamation Plan

Document # 3

Version # 1

January 2024

Approval for Use

Version	Date	Description of Activities	Personnel
1	January 2024	Preparation	Xavier Lu Dac, Project Execution Director Ryan Nagel, Licensing Lead and Environmental Compliance
1	January 2024	Contributions	Nathan Drake, Projects Manager Tracy Gaudry, Senior Coordinator Environment & Quality Management Systems
1	January 2024	Review	Nathan Drake, Projects Manager Xavier Lu Dac, Project Execution Director Janna Switzer, Vice President Environment, Sustainability, Regulatory Ryan Nagel, Licensing Lead and Environmental Compliance
1	January 2024	Approved	Kevin Himbeault, Vice President, Plant Operations and Regulatory Affairs

Revision History

Version	Date	Description of Revision
1	January 2024	Draft for CNSC review

Distribution List

Recipient	Number of Copies
Canadian Nuclear Safety Commission	Electronic

Table of Contents

Appendices

Tables

Figures

Acronyms and Abbreviations

Term	Definition
ALARA	As Low As Reasonably Achievable
AST	Above-Ground Storage Tanks
Bq	Becquerel
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
D&R	Decommissioning and Reclamation
DDP	Detailed Decommissioning Plan
Denison	Denison Mines Corp.
DWWTP	Domestic Wastewater Treatment Plant
EA	Environmental Assessment
EIS	Environmental Impact Statement
Freeze Hole	Bore hole in ground outfitted with sealed freeze pipe or temperature sensors
FS	Feasibility Study
HDPE	High Density Poly-Ethylene
HVAC	Heating, ventilation, air conditioning
IAEA	International Atomic Energy Association
ISR	In-Situ Recovery
IWWTP	Industrial Wastewater Treatment Plant
LLRW	Low-Level Radioactive Waste
Mining Solution	A solution prepared onsite by combining reagents such as sulphuric acid, hydrogen peroxide, ferric sulphate and water
Mlbs	Million Pounds
MPa	Megapascal
mSv	Millisievert
NORM	Naturally Occurring Radioactive Material
PAG	Potentially Acid Generating
PDCE	Preliminary Decommissioning Cost Estimate
PDP	Preliminary Decommissioning Plan
PWTP	Potable Water Treatment Plant
SKMOE	Saskatchewan Ministry of Environment
UBS	Uranium Bearing Solution
UST	Underground Storage Tanks
Well	Casing and screen constructed in a bore hole which is open to the natural ground formation in the screened interval

Yellowcake	Dried Uranium Concentrate

1 Introduction

1.1 Project Background

The draft Environmental Impact Statement (EIS) for the Wheeler River Project (the Project) proposed by Denison Mines Corp. (Denison) was issued for regulatory review and approval in October 2022. In August 2023 Denison released the independently authored Feasibility Study for the in-situ recovery (ISR) uranium mine and processing facility for the Phoenix deposit. Denison is advancing the Project towards construction and, as such a Preliminary Decommissioning Plan (PDP) is required as part of the federal and provincial licensing and permitting processes, respectively. The PDP is meant to provide a high-level evaluation of the requirements for decommissioning of the future assets and future disturbed lands required for the development of the mining and processing operation of the Phoenix deposit on the Wheeler River property. Figure 1-1 shows that the Wheeler River Property is located in the eastern part of the Athabasca Basin, approximately 4 kilometres (km) west of Highway 914 and 35 km north of the Key Lake Operation.

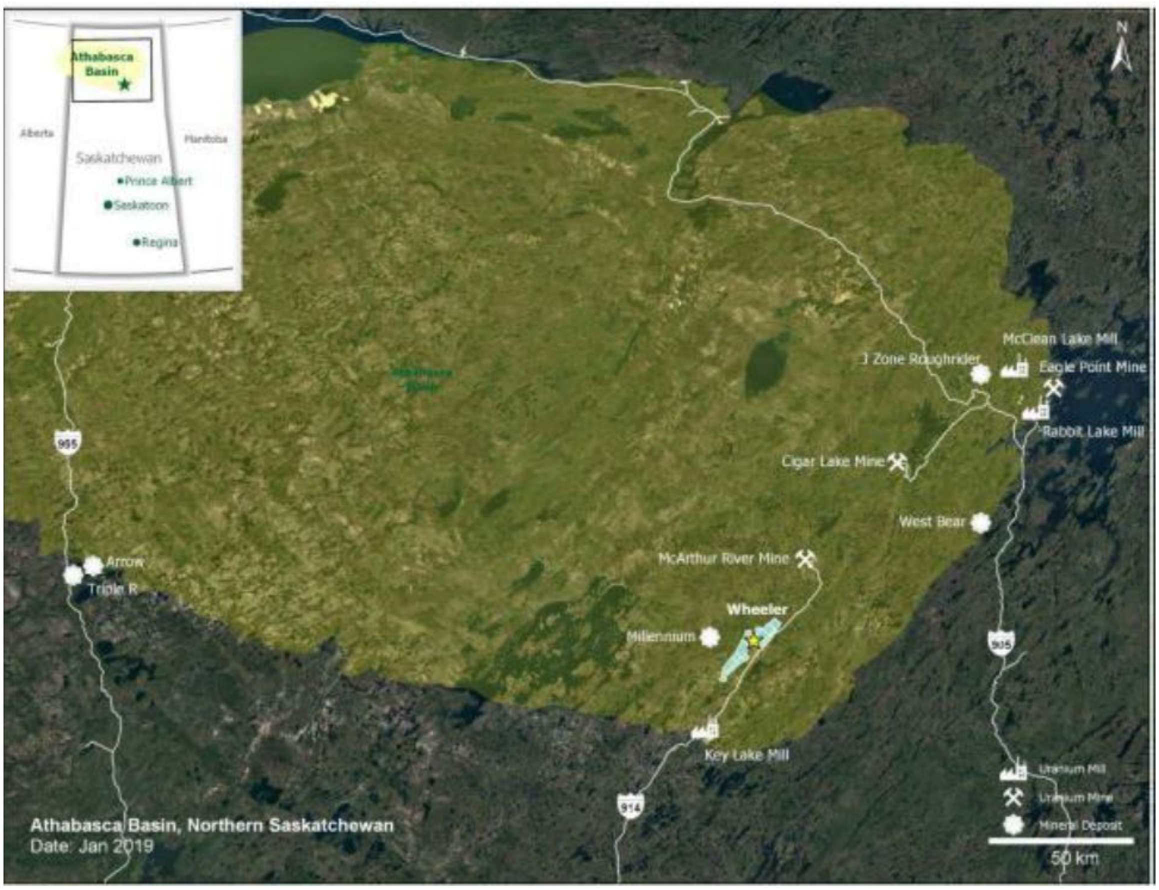


Figure 1-1: Wheeler River Property Location Within the Athabasca Basin

1.2 Regulatory Background

The PDP forms part of the legal obligation to perform an activity upon the retirement of a tangible, long lived asset based on a law, statute, or ordinance, a written or verbal agreement between parties, and a promise to a third party. The purpose of the initial PDP is to outline technically and environmentally sound methodologies for decommissioning the proposed mine and process facilities which will, in turn, be used to inform the amount of future financial assurance required by provincial and federal regulations.

This initial PDP will need to be reviewed and updated prior to construction of the proposed facilities. Additionally, it will also be reviewed and updated every five years during the life of the Project and/or if the Project is to undergo significant changes that were not foreseen at the time of preparation of the previous PDP.

The development of the PDP is part of the development process with the guidelines for the Preparation of Terms of Reference for a proposed project under the Environmental Assessment Act requiring a conceptual level PDP with the following:

- preferred procedures for decommissioning;
- target decommissioning objectives for the mining area;
- alternative procedures for decommissioning the site facilities, if applicable;
- decommissioning, reclamation and closure of all related works and surface disturbance;
- identification of acceptable post-operational land-use options for the Project site;
- post-operational landforms and hydrology;
- environmental impact mitigation and reclamation measures;
- proposed monitoring to determine if species will re-occupy the site; and
- proposed contingency measures.

In advance of the scheduled shutdown of the first step in the decommissioning and reclamation (D&R) process will be the preparation of a Detailed Decommissioning Plan (DDP) for regulatory approval prior to decommissioning. The CNSC Regulation Document (REGDOC)-2.11.2, Waste Management Decommissioning (CNSC 2021f) and the CSA N294 (CSA 2019) both provide guidance on the information to be included in the DDP, and these include:

- a description of the location of the facility;
- the purpose and description of the facility;
- the anticipated post-operational conditions;
- the decommissioning strategy;
- the plan for the decommissioning work;
- the hazardous monitoring and survey commitments;
- a waste management strategy;
- a commitment to prepare a DDP for CNSC acceptance prior to decommissioning;
- a commitment to periodically review and update the PDP in accordance with Section 6.1;
- the physical state of the facility at both end of operations and at the start of decommissioning;
- the records required for decommissioning;

- a public consultation plan, including a public information program and avenues for public participation as per the requirements and guidance of REGDOC-3.2.1 (CNSC 2018b);
- an Indigenous engagement plan as per the requirements and guidance of REGDOC-3.2.2 (CNSC 2022a)]; and
- the conservative cost estimate of decommissioning and a financial guarantee, as described in REGDOC-3.3.1 (CNSC 2021g).

The DDP will build on the last PDP and include detailed design drawings, comprehensive information on the proposed D&R approach and additional information that is not in the PDP such as a summary report on any public and indigenous consultation.

The DDP will form the basis of the submission to regulatory agencies for a decommissioning license. The CNSC indicates that obtaining a license for decommissioning will take about 24 months for the required regulatory review.

Once the decommissioning is complete and long-term monitoring has confirmed the successful completion of decommissioning, the Project will enter the post-decommissioning phase.

Post-decommissioning activities will be conducted once the decommissioning objectives have been met and active controls are no longer required, and the post-closure landforms and waste management areas are safe and stable. It is assumed that Denison will return the surface lease to the Government of Saskatchewan (GOS), and it will enter Saskatchewan's institutional control framework (GOS 2006). This framework allows for administrative controls to be placed on future land use to prevent redevelopment and ensure that the Site is monitored in perpetuity. The CNSC and provincial requirements that support the transfer of sites to institution control include, but are not limited to the following (GOS 2021):

- record keeping or archival of documentation that fully describes past operations (including contamination, spills, malfunctions, and accidents);
- decommissioning plans and assessments, final configurations, and release verification;
- post-closure site monitoring and verification;
- passive site management needs;
- land controls; and
- long-term financial liabilities for monitoring, reporting, care, and maintenance as well as possible contingency remediation.

1.3 Purpose

This initial PDP has been developed for licensing and will be used to develop a financial guarantee that provides adequate provision to safely decommission the Project and assurance of financial resources to fund all approved decommissioning activities should the licensee not be able to fulfill its obligations.

A Conceptual Decommissioning Plan was presented within the Wheeler River Draft Environmental Impact Statement which underwent considerable engagement and review by Indigenous communities, the public and Federal and Provincial regulatory agencies. The end-state objectives will continue to consider the preferences of Denison, communities, and regulators. It is expected that the approaches presented in this document will be discussed with the communities of interest as the Project evolves and will be refined as part of that process. The regulatory review, detailed engineering, future technical studies, and the ongoing EA will also influence subsequent versions of this document. This initial PDP is, therefore, preliminary and is designed to further D&R communications and discussions.

While PDPs generally assume a hypothetical ‘decommission tomorrow’ scenario in which the Project is closed with little warning, this Plan was developed for consideration of decommissioning at the end of the commissioning stage after initial mining and processing activities have begun. This means that all initial facilities are in existence and that the initial commissioning activities are complete so that some of the facilities have potentially been impacted by radioactive materials resulting from uranium mining and processing operations.

1.4 Scope

The development of the initial PDP can be discussed in terms of the following tasks:

- A description of proposed methods and procedures for the decommissioning and reclamation of various aspects of the Project.
- Identification of the material management approach for the surface infrastructure.
- Development of the reclamation approach to the subsurface ore zone.
- A time frame for monitoring the site for physical and chemical stability and methods for detecting spills or the release of pollutants during and after decommissioning and reclamation.
- Development of a decommissioning material balance.
- Development of the potential cost estimate required to complete the decommissioning and reclamation plan.

Potential disposal/decommissioning options were identified based on best management practices at other Saskatchewan uranium mines and mills. While there is vehicular access to the Wheeler River Project site via Provincial Highway 914, the Project site is relatively isolated, which limits the number of disposal/ decommissioning options that could be reasonably considered.

The decommissioning approach includes the management of radiation that may exist on any facilities or materials used during the Project to render them safe for return to the suppliers, for potential recycling and/or for disposal in an appropriate approved facility.

The reclamation of the Project site uses the generally accepted approaches that have been applied elsewhere in Saskatchewan (e.g., CNSC 2003). The subsurface reclamation makes use of previously conducted technical studies (e.g., SRK (2018) and Newmans Geotechnique Inc. (NGI) 2023) and field and laboratory testing conducted during the Feasibility Study (FS).

1.5 Methodology

The Project is currently in the developmental stage and, as a result, this Plan was based upon a detailed review of the proposed Project and its components. The primary sources of information for the study were information from the FS (Wood, August 2023), and the draft EIS (Denison, October 2022).

This work includes the development of verified strategies associated with similar/actual projects (e.g., *Comprehensive Study Report Cluff Lake Decommissioning Project, CNSC 2003)* wherever possible, along with professional experience and decommissioning planning for various other uranium facilities.

The PDP considers the buildings and facilities as they are currently proposed in the draft EIS and feasibility level engineering plans. The total infrastructure footprint is anticipated to be approximately 74.8 ha. Figure 1-2 details the preliminary site layout that was used to develop this PDP.

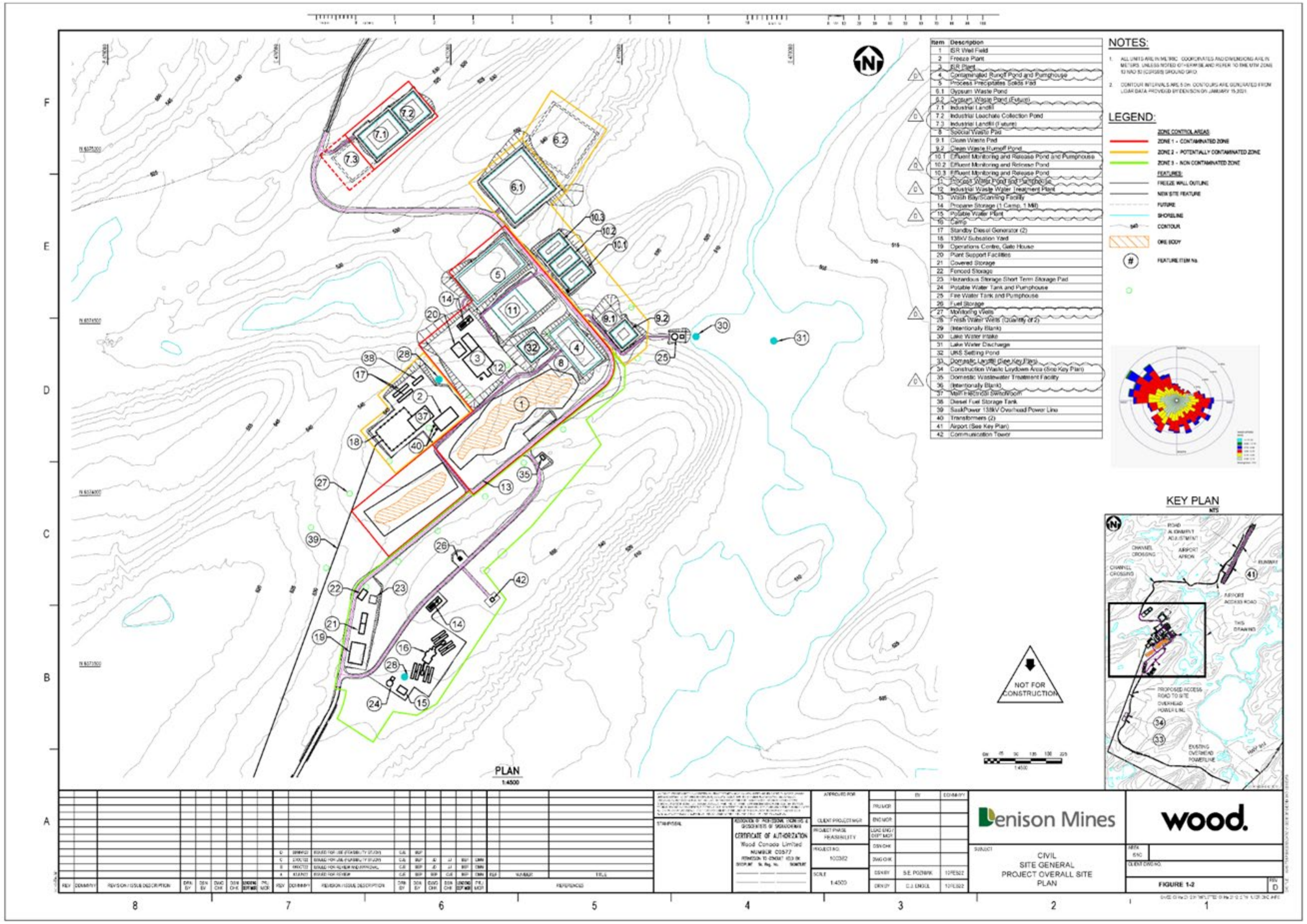


Figure 1-2: Wheeler River Property Site Layout (from Wood Canada Limited)

This Plan was developed to provide a reasonable set of preliminary D&R plans for the proposed facilities. It is recognized that during operations Denison will perform progressive reclamation. However, these activities and their impact have not yet been quantified and, therefore, are not considered at this time.

Once construction is underway, the development of the Project will consist of four phases. The phases and their expected duration are (Denison 2022):

- Construction – two years;
- Operations – up to fifteen years;
- Active Decommissioning – five years; and
- Post Decommissioning Monitoring – ten to fifteen years.

As previously indicated, this document assumes that the proposed D&R work that is considered in this Plan will be undertaken after Project commissioning which is the last stage of the construction phase. Using this assumption, some processing waste materials are assumed to be present on the surface, and all facilities are assumed to be built and operational.

D&R planning for the PDP considered the following end state objectives for the site:

- protective of key environmental features in and around the site (as described in the draft EIS (Denison 2022));
- removal or stabilization of all constructed structures; and,
- reclamation of disturbed areas such that:
    - the environment is safe for non-human biota and human use;
    - the long-term adverse effects are minimized;
    - the reclaimed landscape is stable and self-sustaining; and
    - restrictions on future land use are minimized.

The PDP assumes that post-decommissioning the site will have unrestricted access to support casual usage and/or traditional land use of the site for trapping, hunting, and fishing.

2 Project Components

The following section outlines the proposed mining and surface infrastructure that comprise the components of the project. For further detail and descriptions of components please refer to the Facility Description Manual (Denison, 2023).

2.1 Mining Infrastructure

2.1.1 In-Situ Recovery (ISR) Infrastructure

In-situ recovery (ISR) wellfield infrastructure will be developed to mine the uranium mineralization deposit. The ISR wellfield will be developed with a series of recovery and injection wells throughout the proposed phases of the deposit.

The well patterns are developed for a specific site, and installation for a given wellfield is based on the subsurface geometry of the ore deposit. Various pattern shapes are used, although a five-spot pattern will be the primary design layout. This arrangement includes one recovery well in the centre, surrounded by four injection wells. The spacing is anticipated to be approximately 5 to 10m. Ore body size and geometry will also influence the number of wells in a wellfield. The total wellfield will cover an area measuring 90m wide x 750m long. The wellfield will be constructed in a phased approach to match the freeze wall mining phases.

The pumping wells will have 5.5-inch casings. The injection wells can be either large diameter (5.5-inch casing) wells or small diameter (2.5-inch casing) wells. Additional phases of the wellfield will be completed during Project operations. The Phase 1 wellfield will include approximately:

- 12 large diameter recovery or pumping wells;
- seven large diameter injection wells; and
- nine narrow diameter injection wells.

The Phase 1 wellfield will be analyzed with monitoring wells and piezometers installed in and around the wellfield. The movement of groundwater and chemicals of potential concern within Phase 1 and the integrity of the freeze wall (discussed in Section 2.1.2) will be monitored throughout the Project. There will be two types of monitoring installations, monitoring wells that are cased and have an open screened section and vibrating wire piezometers that have a pressure transducer grouted into place. The monitoring wells will have either 2-inch or 2.5-inch diameter well casings. At the current time, the Phase 1 monitoring infrastructure will include the following:

- monitoring wells;
- existing monitoring wells that were previously completed;
- existing vibrating wire piezometers; and
- monitoring wells associated with the freeze wall.

2.1.2 Pumphouses

Two different types of pumphouses will be required: Injection Solution pumphouses and Recovered Solution pumphouses. A pumphouse is a small building located on the surface where pipes from injection and recovery wells are operated and mining solution flows are monitored.

Pumphouses will distribute the mining solution to the injection wells and collect the uranium bearing solution (UBS) from the recovery wells. Pumphouses will be connected to production pipelines. One of the pipelines will be used for receiving mining solution from the Processing Plant and the other will be used for returning UBS back to the Processing Plant.

Injection Solution Pumphouse

Injection Solution pumphouses will consist of an injection transfer tank, pumps, flow meters, control valves, piping and mixing systems which allow for mining solution to be delivered through the pipelines to the required injection wells at the appropriate reagent concentrations. The mining solution composed of hydrogen peroxide, ferric sulphate, sulphuric acid, and water will then enter the mining area and dissolve uranium in place.

Recovered Solution Pumphouse

The purpose of the Recovered Solution pumphouse will be to ensure that the solution being recovered from the wellfield downhole pumps is directed to the appropriate location within the Processing Plant. The recovered solution after being purged of radon gas will be directed to the UBS Holding Area, Industrial Wastewater Treatment Plant, or recycled back to the wellfield for further concentrating when the UBS uranium content is below target.

2.1.3 Ground Freezing Infrastructure

Denison will install a freeze wall to support a defense in depth containment strategy for mining solutions and to prevent the regional groundwater system from entering the mining zone. Once the freeze holes are constructed, the freezing process will be started, and allow for a 12-month development of the freeze wall before operations begin.

The freeze wall will be established by drilling vertical or steeply dipping holes from surface to the competent basement rock (over 410m below surface). The freeze holes will be spaced six meters apart. The ground will be frozen from the surface down to the competent basement rock to create a continuous freeze wall around the mining area that is completely contained from the surrounding regional area. The freeze wall will be a minimum of 10m thick and installed approximately 25m away from the uranium deposit.

A chilled brine solution (e.g., calcium chloride brine) will be circulate through the cased holes to remove heat from the ground. A freeze plant will be constructed on surface near the deposit where the freeze holes are collared. The freeze plant will be modular to allow for ease of installation and operation as more chiller units will be added as ground freezing needs increase. Each chiller unit produces refrigeration and contains an ammonia compound compressor. A total of six chiller units are expected to be required at peak load later in the mine life. The brine distribution system is handled by a mixing tank that can move brine to freeze holes at the required capacity.

Temperature monitoring holes will be installed in close vicinity to the freeze holes to monitor the thickness of the freeze wall and confirm that containment parameters are achieved.

The freeze wall will be monitored by the installation of temperature string pairs inside and outside of each phase, 4m on either side of the full 10m thick freeze wall, and single temperature strings installed in the cross freeze walls between adjacent phases. A total of 18 monitoring wells are planned amongst all phases and cross panels. These are designed to monitor the thickness of the freeze wall around each phase as well as the presence and absence of a freeze in the cross walls.

2.2 Surface Infrastructure

2.2.1 In-Situ Recovery (ISR) Process Plant Infrastructure

Infrastructure included within the Uranium Bearing Solution (UBS) Processing Plant Infrastructure Envelope is detailed in the following subsections.

Processing Plant

The Processing Plant will be located directly adjacent to the wellfield and will process all recovered solution into yellowcake and process precipitates. The Processing Plant will house all the tanks and equipment required for material processing.

At the Processing Plant, the first step is the removal of impurities such as iron (Fe) and radium (Ra) from the UBS as solids in the stage 1 precipitation circuit. The precipitated solids are dewatered, and the resulting filter cake is deposited in totes on a storage pad, for eventual reprocessing to recover low grade uranium values. Next, the purified solution is run through the stage 2 precipitation circuit. The circuit produces U_3O_8 (yellowcake) product solids which are dried and packaged for shipment.

The solution from the Yellowcake precipitation circuit is treated in the three phases of the industrial wastewater treatment circuit. The first phase neutralization precipitates the majority of the remaining radionuclides, the resulting solids from this stage are stored as filter cake in totes along with the stage 1 process precipitates at the process precipitates pad. The second phase neutralization removes the majority of the remaining dissolved solids, forming a waste solids stream composed mainly of gypsum. Second phase precipitates are pumped as a slurry to the gypsum waste pond for consolidation. The third stage ion exchange and electro reduction (IX/ER) circuit targets selenium (Se) removal. The small Se-bearing precipitates solids stream is blended with the gypsum waste for disposal. The treated effluent is then held in the effluent monitoring ponds for testing, to ensure it meets discharge requirements prior to release to the environment.

The Processing Plant will contain various facilities for the control and management of the mining solution, plant operations, and additional support facilities, including the following:

- radon purge tank;
- uranium bearing solution (UBS) holding area;
- two-stage precipitation process;
- yellowcake drying and packaging area;
- chemical bulk storage tanks;
- mining solution chemicals (e.g., sulfuric acid, iron sulphate, hydrogen peroxide);

- processing chemical storage (e.g., magnesium hydroxide, hydrogen peroxide); and
- industrial wastewater treatment plant (IWWTP), mixing tanks and chemical holding tanks (e.g., barium chloride, calcium hydroxide)

2.2.2 Process Containment Infrastructure

The Processing Plant will require various pads and ponds for the storage of waste materials from several of the above processes. The pads and ponds will be located outside of the Processing Plant. These structures are described below.

2.2.2.1 Uranium Bearing Solution Holding Area

Recovered high-grade UBS will be held in Recovered Solution Tank.

Process Precipitates Pond

The precipitates generated in the Processing Plant will be transferred to the process precipitates pond. Any radioactive precipitates generated during the first stage of the IWWTP will also be directed to the process precipitate pond. The precipitates will be stored in totes inside the pond. This pond design will allow the precipitate totes to be stored below ground level.

The process precipitates pond will have a geosynthetic composite liner system with leak detection capabilities and will be designed to hold up to 50,000 m^3 of precipitates. Any runoff collected in the pond will be directed to the process water pond and recycled through the plant.

Industrial Wastewater Treatment Plant Precipitate Pond

The Industrial Wastewater Treatment Pond (IWWTP) will initially be constructed to hold 50,000 m^3 of waste, with room for expansion to a storage capacity of 150,000 m^3. Gypsum waste material will be transported from the IWWTP by HDPE pipes welded by electro-fusion.

Process Water Pond and Pump House

The process water pond provides surge capacity in the event of an upset. The pond has the capacity to store two (2) weeks of off-specification process flow. Additionally, water collected from the process precipitate storage pad, special waste pad and a variety of mill areas will be sent to the process water pond. The pond will be double lined with leak detection and is designed to hold 30,000 m^3 of water. The pond is located adjacent to the processing plant. Water and sludges from this pond will be sent to the IWWTP for treatment.

Treated Effluent Monitoring and Release Ponds

The treated effluent produced by the IWWTP will be directed to one of three effluent monitoring and release ponds. The effluent monitoring ponds have been designed to hold effluent for 80 hours in order to verify effluent quality prior to discharge. The Project will include three (3) ponds for operational flexibility. The effluent discharge lines will be single walled with insulation/heat tracing to prevent freezing as a result of low temperatures.

2.2.3 Water Management Infrastructure

The infrastructure included within the Water Management Infrastructure Envelope is detailed below.

Wellfield Runoff Pond and Pump House

All runoff generated by the wellfield and other areas of the site, will be directed to the wellfield runoff pond. The pond is designed to hold 38,200 m^3 of water and will be lined with a double composite liner system with leak detection.

Potable Water Treatment Plant and Distribution

Potable water on-site will be generated by a prefabricated modular potable water treatment plant (PWTP). The PWTP will include a treatment plant, a 2,000 L storage tank, and a bottle filling station. Treated potable water will be piped to the main camp buildings, the fire water tank, the operations centre and the processing plant. The PWTP will be placed on a concrete pad.

Domestic Wastewater Treatment Plant and Distribution

The domestic wastewater treatment plant (DWWTP) will be a modular facility comprised of two heated and insulated units, a holding tank, ancillary filtration, ancillary treatment process equipment, and sludge handling system. A 5,000 m^3 pond with a composite liner system will be designed to receive treated effluent from the DWWTP (Denison 2022). The DWWTP will be placed on a concrete pad.

Supplementary Water Management Infrastructure

The following additional infrastructure is included within the water management infrastructure envelope:

- Fresh Water Wells (two);
- Lake Water Intake;
- Lake Water Discharge;
- Clean Waste Runoff Pond; and
- Sanitary Sewers.

2.2.4 Utilities and Essential Services

Infrastructure included within the Utilities, and Essential Services Envelope is detailed below:

SaskPower 138 kV Overhead Power Line

An overhead power line will be constructed to provide electrical service to the Project by an approximate 5-km extension tap from the existing 138 kV overhead transmission line that runs along Highway 914.

Firewater Tank, Pumps and Piping

The fire water tank is 500 m^3 and will include two electric fire water pumps and a backup diesel fire water pump. The firewater reservoir feeds an approximately 2,000 m long firewater pipe network of HDPE fire-main that is dispersed throughout the site as required for fire suppression.

Supplementary Infrastructure

The following additional infrastructure is included within the utilities and essential services infrastructure envelope:

- above ground piping;
- Standard Diesel Generators;
- 138 kV Substation;
- Main Electrical Switch Room;
- Transformers; and
- Communication Tower.

2.2.5 Waste Management Facilities

The domestic and industrial landfills will be the primary waste disposal facilities on the site. The nature and volume of waste material generated by decommissioning of the project are uncertain at this time. For this PDP, it is assumed that both low level radioactive waste (LLRW) and non-LLRW will be present on-site at the time of decommissioning and will require management.

In addition to the landfills, select ponds and pads have been designed to provide permanent storage of waste material. At the time of the DDP, Denison will review existing on-site infrastructure and waste materials and may elect to include additional facilities in its waste management strategy. The following facilities will be reviewed as potential permanent waste storage sites in addition to the domestic and industrial landfills:

- Process precipitates Pond;
- Industrial Wastewater Treatment Pond; and
- Special Waste Pad.

Key waste streams handled by these landfills include sediments, plastics, wood, concrete, metal, and general domestic waste.

Facilities included within the Waste Management Facilities Envelope are detailed below:

Industrial Landfill and Leachate Collection Pond

The industrial landfill will be designed to accept industrial waste generated on-site as a result of project activities. This will include wastes that have chemical and/or low-level radiological contamination. The landfill will initially be constructed to accept 50,000 m^3 of waste. The design of the landfill will include the ability for a potential expansion to 100,000 m^3 of waste storage capacity. The landfill will include a laydown area within the lined limits of the landfill. All material that cannot be cleaned to pass the minimum required radiological clearance will be disposed of within the industrial landfill or transported to an approved off-site facility. Waste will be contained within a double lined composite liner system with leak detection and leachate collection. A leachate collection pond will be constructed adjacent to the landfill and will collect leachate generated within the industrial landfill for management. The leachate collection pond will be double lined with a composite liner system. Any collected leachate will be pumped to the IWWTP. An area within the industrial landfill will be dedicated to cleaning contaminated material to allow for off-site removal.

Special Waste Pad

Mineralized cores and cutting from the wellfield development will be managed at the special waste pad. Waste directed to the pad will be uranium containing material. The pad is 2500 m^2 and designed to store approximately 2000 m^3 of special waste rock.

Clean Waste Pad

Sandstone cuttings and cores from the wellfield and drilling activities will be managed at the clean waste pad. Waste directed to the pad will be clean and free of contaminants. The pad is 2500 m^2 and designed to store approximately 7,800 m^3 of clean waste and will be lined with a single geomembrane. If required, a clean waste pond will be constructed to manage run-off from the clean waste pad.

Domestic Landfill and Leachate Collection Pond

Non-recyclable material, inert waste and contamination free materials will be disposed of within the domestic landfill on-site. The domestic landfill is designed to store 34,400 m^3 of waste and will be lined with a composite liner system with leak detection. A leachate collection pond will be constructed adjacent to the landfill and will collect leachate generated within the domestic landfill for management. The leachate collection pond will be double lined with a composite liner system.

Construction/Demolition Waste Laydown Area

A laydown area will be developed adjacent to the domestic landfill for the temporary storage of construction and demolition waste. Clean wood, plastics, metal, and concrete may be stored at the laydown. The construction laydown area will not be lined and will have a berm surrounding the area to minimize run-on and runoff. The base of this laydown will be scarified and recompacted prior to material laydown.

2.2.6 Surface Ancillary and Support Facilities

The main facilities included within the Surface Ancillary and Support Facilities Envelope include but are not limited to the following:

Wash Bay/Scanning Facility

A wash bay will be available to clean items, equipment, and vehicles that may have been in contact with potential contaminants. The wash bay area will have an impermeable floor and a lined water collection sump. Rinse water from the wash bay sump will be routed to the wellfield runoff pond or directly to the process water pond. Items that are too large for the wash bay can be cleaned at the industrial landfill laydown area (Denison 2022).

Camp

The camp will include both common areas such as the Kitchen and dining room and the sleeping trailers. The camp will be located southwest of the wellfield, and it is anticipated to be a turnkey building manufactured off-site and assembled and commissioned on-site. The building’s design will be sized to accommodate a peak load of about 190 individuals during Operation; however, due to its modularized design, additional modules can be easily installed should additional beds be required in the future (Denison 2022).

Operations Centre, Gate House

A weigh scale will be installed and will allow for verifying incoming and outgoing loads. The north gate is a simple gate and will not be staffed (Denison 2022).

Airstrip, Apron, and Terminal Buildings

The airstrip consists of a 1,600m long x 30m wide runway, and a 110m x 200m apron pad. The airstrip will be a gravel topped private strip that will be designed for daytime use. The airstrip will include an apron, terminal building, communication tower, small diesel generator and appropriate instrumentation and lighting for low visibility, and/or nighttime landing for emergency purposes.

Composting Facility

The composting system is expected to be in a sea can. After composting is complete, an outdoor curing phase will be required during the summer months. Based on experience with the proposed Brome composting system at other mine sites, the finished compost is not foreseen to be a wildlife attractant (Denison 2022).

Supplementary Infrastructure

The following additional infrastructure is included within the surface ancillary and support facilities infrastructure envelope:

- Covered Storage;
- Fenced Storage;
- Plant Support Facilities;
- Fire Water Tank and Pump House;
- Monitoring Wells (every 150m);
- Construction Trailers; and
- Laydown Areas (assumed and recycling area).

2.2.7 Industrial Waste and Hazardous Material Storage

Facilities and tanks included within the Industrial Waste and Hazardous Material Storage Envelope are detailed below.

Propane Storage Areas

The propane storage area will include: a 100,000 L storage tank, vaporizers, a propane bottle fill station, and a bottle weigh station.

Fuel storage Areas

Diesel, gasoline, and Jet A fuel will be stored on-site in approved fuel storage areas. Fuels will be stored in approved, above-ground, 25,000 L double-walled storage tank(s) equipped with secondary containment in accordance with provincial regulations and standards.

Supplementary Infrastructure

The following additional Infrastructure is included within the industrial waste and hazardous material storage envelope:

- Hazardous Storage Short Term Storage Pad.

Soil testing will be conducted in any areas of known contamination and/or potential spills, including areas around chemical, fuel, and industrial waste storage areas. Testing will be conducted according to industry standard procedures and compared to provincial and federal soil standards.

2.2.8 Site Roads and General Development

Facilities and structures that are included within the General Site Development Envelope are as follows:

- Roads – Primary;
- Roads – Secondary;
- Culverts;
- Chain Link Fence (m);
- Gates; and
- Disturbed Areas (including the borrow area).

Two full span water crossings will be required on the road to the airstrip. These crossings will be designed, constructed, and maintained to avoid causing harm to fish and fish habitat and will be clear span bridges (Denison 2022).

3 Waste Material Balance

This Plan includes a compilation of the design information from the FS to develop a list of preliminary material types for the decommissioning scenario. At this time, the most current data on the surface infrastructure is the information that is in the Site layout presented in Figure 1-2 from Wood Canada Limited, which was used to generate these estimates. Where appropriate, the information from the Denison draft EIS (Denison 2022; hereafter referred to as the "2022 Draft EIS") was also used as a source of data to develop the quantities used in this study.

The estimated decommissioning and reclamation quantities were based on the following:

- demolition and decommissioning of all existing Project structures, including buildings, process vessels, ponds, storage tanks, pipelines, roads, and power infrastructure at the end of the proposed development;
- reclaiming the Project area to a boreal forest land use; and
- reclaiming the subsurface to groundwater quality such that it is acceptable to the Saskatchewan Ministry of Environment (SkMOE) as determined through risk assessment and EA process and continual improvements activities.

The effect of the sale or recycling of any operating equipment was not considered in the estimation of the waste quantities. While it is expected that some recycling or reuse of some of this equipment will occur once they are no longer required on-site, the inclusion of this would be premature at this time.

3.1 Waste Streams

3.1.1 Demolition Waste

Demolition waste includes waste from the demolition of both buildings and other ancillary infrastructure associated with the Project. The size of buildings and the various surface infrastructure was established from available site plans. In the future, mechanical equipment lists can also be used to further refine the demolition waste quantities. All facilities include the required electrical, heating, ventilation, and air conditioning (HVAC), fire protection and other services.

Quantities of waste generated during decommissioning will vary depending on the design of the facility. All surface facilities on-site can be categorized as one of the following infrastructure types:

- ***Pre-engineered*** – all process and internal platforms/structures inside these buildings will be stick-built and either supported independently of the shell structure or tied to the pre-engineered columns where possible.
- ***Stick-built*** – each building and its internal platforms/structures will be designed as one structure.
- ***Modular*** – standalone structure fabricated off-site and shipped to site as a single unit or multiple sections supported on independent foundations on grade or on elevated structural platforms.

The amount of waste generated from the demolition of a building and its contents was determined by the volume of the building, the construction of the building, the density of materials, and the infrastructure and equipment contained within that building envelope. The building usage was therefore used to estimate the total volume of waste generated by the demolition of this structure using a waste factor (as a percent) for three different levels of use or density of internal infrastructure. These waste factors were applied to the total volume of the structure to determine the anticipated volume of waste generated from the demolition of that structure.

The waste factors for heavy, medium, and light usage buildings are presented in Table 3-1 below.

Table 3-1: Building Waste Factors

Building Type	Examples	Waste Factor (%)
Heavy density	Mill (or processing plant), associated piping and tanks	40
Medium density	Water treatment plant, freeze plant(s), repair shops, etc.	20
Low density	Office trailers, camp infrastructure, offices, small buildings etc.	10
Single Use	Pipes, liner, and wells	90

Non-hazardous waste materials, such as roofing materials, insulation, wood, co-mingled concrete, and light steel, may be disposed of on-site or off-site in a licensed landfill.

Low-level radioactive waste (LLRW) is defined as radioactive solid waste that contains material with radionuclide content above established clearance levels and exemption quantities but that generally has limited amounts of long-lived activity. LLRW includes both the demolition waste from buildings that either contain low-level radioactively contaminated equipment and/or have become radioactive themselves through the processing or storage of uranium bearing materials.

The amount of LLRW demolition waste will likely vary slightly during operations as facilities may become radiologically impacted during operations. To be conservative in this study, it has been assumed that the entire processing plant building, and associated infrastructure becomes impacted by LLRW during commissioning, meaning that it is classified as LLRW waste at the beginning of operations.

These LLRW wastes generally require special care and attention during all phases of a mine's life. During decommissioning, non-LLRW is kept separate from LLRW wastes.

3.1.2 Industrial Chemical Waste

At the time of decommissioning, it is assumed that project chemicals, residual industrial wastes, and hazardous materials will be present on-site in various quantities. Residual industrial wastes include the process precipitate solids, gypsum waste and all yellow cake product on-site at the time of decommissioning. The precipitate solids will contain approximately 2% to 3% uranium. This makes the process precipitates of economic value. Decommissioning will include the sale and removal of the process precipitate solids to an off-site facility as part of Decommissioning.

Outlined below in Table 3-2 are the project chemicals that may be on-site at the time of decommissioning. This includes the ISR solution, freeze plant brine and other industrial chemicals for the mill and IWWTP.

Table 3-2: Project Chemicals

Building Type	Examples	Waste Factor (%)
Ammonia	Freeze Plant Operation	Freeze plant piping and dedicated storage tank
Barium Chloride	Recovery Solution Processing and IWWTP Operation	Dedicated storage tank within the processing plant
Flocculant	Recovery Solution Processing	Dedicated storage tank within the processing plant
Hydrogen Peroxide	Mining and Recovery Solution Processing	Dedicated storage tank within the processing plant
Iron Sulphate	Mining and IWWTP Operation	Dedicated storage tank within the processing plant
Lime (Calcium Hydroxide)	Recovery Solution Processing and IWWTP Operation	Dedicated storage tank within the processing plant
Magnesium Hydroxide	Recovery Solution Processing	Dedicated storage tank within the processing plant
Sodium Bicarbonate	Neutralizing of solutions and wellfield	Dedicated storage tank within the processing plant
Sodium Hydroxide	Recovery Solution Processing	Dedicated storage tank within the processing plant
Sulphuric Acid	Mining and IWWTP Operation	Dedicated storage tank within the processing plant

Decommissioning includes the management of all hazardous substances associated with support facilities including fuel, paint, used oil, and chemicals. These hazardous substances will be managed in a safe and secure manner in line with Safety Data Sheets, permit conditions, and applicable regulations such as the Hazardous Substances and Waste Dangerous Goods Regulations. Where possible, chemicals will be mixed to produce a neutral solution and disposed of in an approved manner at the site. Hazardous materials, such as spent chemicals (that cannot be managed on-site), waste oil, and sludges, will be disposed of off-site at licensed facilities.

During operations, Denison will maintain an up-to-date record of the various hazardous substances on-site, Safety Data Sheets, and appropriate procedures for spill response. This list will serve as the starting point during decommissioning.

3.1.3 Recyclables

Recyclables will be generated during construction, operations, and decommissioning. During decommissioning the recyclable collection and disposal systems established during construction and operations will continue. Any recyclable material will go directly to the recycling bins at the recycling laydown area. During decommissioning, there will be an increased generation of recyclable materials including steel, plastics, wood, cardboard, and paper common household recyclables which will be managed at the recycling laydown area.

Recyclable material generated at the wellfield and processing plant that may have radiological contamination will be scanned where required, cleaned to allow for off-site removal or sent to the industrial laydown for additional potential decontamination. Recyclables that do not meet radiological clearance criteria following reasonable cleaning efforts will be disposed of in the industrial landfill. Where possible, all recyclables will be shipped off-site to approved recycling facilities (Denison 2022).

3.2 Estimated Waste Balance

A high-level review of the potential waste quantities generated during decommissioning was completed for this initial PDP. The estimated volumes of demolition wastes are outlined in Table 3-3. Table 3-3 shows both the estimated volume that will be disposed of on-site and the estimated volume for off-site management or disposal. In the event that a viable option for off-site management or disposal doesn't exist, then on-site disposal may be considered.

Table 3-3: Decommissioning Waste Balance

DECOMMISSIONING PLANNING ENVELOPE	NON-CONTAMINATED WASTE		CONTAMINATED (LLRW) Waste	
	ON-SITE DISPOSAL (m^3)	OFF-SITE MANAGEMENT(m^3)	ON-SITE DISPOSAL (m^3)	OFF-SITE MANAGEMENT (m^3) *1
Subsurface and ISR Mining Facilities	0	0	846	510
Processing Plant Infrastructure	7,936	0	21,829	722
Water Management Infrastructure	1,010	592	7,640	413
Utilities and Essential Services	1,264	1,414	0	0
Industrial Waste and Hazardous Materials Storage	785	785	315	40
Waste Management Facilities	275	0	2,562	0
Surface Ancillary and Support Facilities	3,635	2,512	240	60
Site Roads and General Site Development	714	664	0	0
Totals	**15,618**	**5,966**	**33,431**	**1,745**

*1 Footnote - Assumes that these wastes that are originally classified as LLRW can be effectively cleaned so that they can be shipped off-site, and a recycler would be willing to accept them.

Based on the preliminary decommissioning materials balance described above in Table 3-3, further analyses were conducted to determine if there is sufficient disposal capacity in the two on-site landfills for the estimated quantity of waste that is expected to be generated during the decommissioning of these facilities. These analyses are shown below in Table 3-4. Based on this analysis of the planned on-site volumes and the domestic landfill and industrial landfill space, these facilities will have sufficient capacity for the planned decommissioning activities.

Table 3-4: On-Site Disposal Balance

ITEM	VALUE	UNIT	NOTES
Domestic Landfill Airspace	34,400	m^3	Total airspace available in the domestic landfill for waste
Industrial Landfill Airspace	50,000	m^3	Total airspace available in the industrial landfill for waste
Non-Contaminated Waste to be Disposed of On-Site	15,618	m^3	Estimated volume of non-contaminated decommissioning waste to be disposed of on-site
Contaminated Waste to be Disposed of On-Site	33,431	m^3	Estimated volume of contaminated decommissioning waste to be disposed of on-site
Waste to Cover Ratio	5:1		Assumed waste to cover soil ratio for volume estimate.
Total Airspace Consumed Domestic Landfill	18,742	m^3	Including waste and cover soil
Total Airspace Consumed Industrial Landfill	40,118	m^3	Including waste and cover soil
Domestic Landfill Airspace Remaining After Decommissioning	15,658	m^3	
Industrial Landfill Airspace Remaining After Decommissioning	9,882	m^3	

4 Decommissioning Options

Potential disposal and decommissioning options were identified with consideration for both the ongoing waste management planning and D&R plans from other Saskatchewan uranium mines and mills. The PDPs for operating mines are not publicly available. However, there is detailed public information on the D&R planning of the AREVA (now Orano) Cluff Lake mine, which was used as a reference point (CNSC 2003). While there is vehicular access to the Project via Provincial Highway 914, the Project is relatively isolated, which limits the number of disposal/decommissioning options that could be reasonably considered.

Denison's decommissioning commitment is to return the land back to the Province of Saskatchewan for unrestricted surface land use post-closure. This PDP outlines how radiological, physical, and chemical risks will be managed during Decommissioning, so that no unreasonable risks remain. Denison will prioritize passive controls over active controls during D&R planning to reduce long-term risks.

4.1 Screening of Available Options

Potential decommissioning strategies or options for each waste type were identified for consideration. These options were reviewed relative to the methodology used at other facilities (industry standard), the methods proposed for operations, and against the following six evaluation categories:

- Environmental: Type of potential impact (e.g., water, air, land, wildlife), magnitude, the likelihood of potential impact or benefit, operating or decommissioning.
- Health and Safety: Type of potential impact (e.g., airborne, dust, water) magnitude, the likelihood of potential impact or benefit.
- Community: Indigenous and public perception, socio-economic impact, or benefit, any documented or articulated preference.
- Regulatory: Permitting required (initial and annual reporting) monitoring requirements.
- Engineering and Design: Complexity, implications on planned infrastructure; and
- Operations and Maintenance: Level of effort, frequency.

It is recognized that the use of the assessment criteria mentioned above is subjective and will change with time as more information on various categories becomes available and better understood. These assessment criteria may also evolve with time as considerations change and/or through discussions with either the regulators or the community.

The proposed use of ISR to mine this deposit will reduce the amount of waste rock that is generated during the mining compared to traditional mining methods. Traditional uranium mining generates a large volume of waste rock and other special waste (e.g., LLRW and/or potentially acid generating waste rock). The Project will generate some waste rock and LLRW as a result of the drilling process, the quantities will be much less than traditional methods. These small quantities of waste rock will be stored on the clean and special waste pads. After confirmatory radiation scanning, the clean waste rock will likely be utilized during operations as cover on the one or both landfills.

Denison aims to be a leader in environmental management for uranium mines during all phases of the Project. The general direction for the screening of potential decommissioning options includes the following:

- minimizing the post-decommissioning footprint to lessen potential impacts and to improve monitoring efficiency;
- contouring, covering in place and reclaiming all lagoons and/or ponds; and
- processing of all uranium bearing solution (UBS) through the processing plant and combining as much of the LLRW waste as possible in the contaminated landfill at closure.

Future discussions will be held with the local community to determine the amount of access to the area they wish to maintain in the future (post-decommissioning) and if they would prefer to assume ownership of any of the mine facilities (e.g., camp, airstrip, roads, etc.).

An initial screening relative to these criteria was conducted and the selected approaches for each infrastructure will be made. Additionally, Table A.1 compares the selected management approach with the approach used at the now decommissioned Cluff Lake site.

5 Decommissioning Approach

The PDP assumes that decommissioning and reclamation will be undertaken following the construction and initial operation of the site. The Operation Management System will contain the necessary procedures and work instructions to ensure the protection of workers and the environment with respect to radiation protection, hazardous materials handling, industrial safety, and environmental protection. Where specific decommissioning activities are identified that require additional protection or mitigation measures, documentation will be expanded to address these hazards during the detailed decommissioning planning stage.

The PDP assumes that the Project undergoes a sudden, unexpected closure. There will be an immediate post-operational phase where operations have ceased, and it is necessary to ensure the site and facilities are gradually shut down in a manner that ensures the site is transitioned to a safe and secure state in order to prepare for decommissioning. Under normal conditions, the DDP and associated licenses would be expected, however, these will not have been obtained for a sudden and unexpected closure scenario. As such, the decommissioning strategy assumes that decommissioning will begin immediately following the closure of the site, without any delays and will incorporate in-situ decommissioning strategies in its approach.

To facilitate potential changes to the D&R plan, management options and/or the underlying assumptions, seven planning envelopes were established:

1. Approvals Management
2. Active Decommissioning Management
3. Subsurface Remediation
4. ISR Mining / Freezing Facilities
5. Surface Buildings and Facilities
6. Environmental Monitoring and Reporting
7. Post-Decommissioning Monitoring

These planning envelopes were generally further subdivided into smaller groupings or subdivisions. These subdivisions provided a summary of required activities, individual buildings, and/or structures within each of the planning envelopes and allowed for detailed decommissioning and reclamation assessment of each component.

The general approaches and assumptions used during the preparation of this plan are summarized below:

1. Prior to decommissioning, the information presented in the last PDP shall be refined and expanded on and developed into a Detailed Decommissioning Plan (DDP). The DDP will outline the required scope and timing for regulatory approval and a plan to ensure compliance. Additionally, the DDP will address the preparation of all assessments/permits/license application(s) that will be required to execute the DDP for the Project.
2. Prior to off-site or on-site disposal, all materials will be checked for radioactive surface contamination. If these materials meet the IAEA Regulations for the Safe Transport of

Radioactive Materials (IAEA, TS-R-1) criteria for safe removal, they will be "green tagged" and hauled off-site. If the material exceeds this standard, the material shall be cleaned and retested until the standard is met. Off-site shipments of radioactively contaminated material will be minimized to the greatest extent possible. If the off-site transportation of materials is necessary, then the Transportation of Dangerous Goods Regulations will be followed, and the applications shall be made for the appropriate licenses.

3 Decommissioning activities will attempt to maximize the quantity of material that is recycled, reused, donated, or sold. The quantity of waste screened and identified for disposal will be minimized. All waste will be disposed of in an appropriate on-site containment facility or taken off-site to a licensed facility of the hauler. This includes all radioactive wastes, ASTs, and inert waste.

4 Materials that are to be taken off-site for disposal at a licensed facility include all hazardous wastes, regulated underground storage tanks (USTs) and above-ground storage tanks (ASTs). It is noted that the nearest licensed facility to receive the USTs and ASTs is Prince Albert, Saskatchewan.

5 After operations cease, proper management of all chemicals brought to the site will occur, with on-site neutralization and/or off-site shipment either to a licensed waste facility or return to the supplier.

6 All materials are to be taken off-site for management or disposal or deposited in an appropriate on-site containment facility.

7 In order to optimize future monitoring and management to the extent possible, similar and chemically compatible materials in ponds will be combined (to reduce the environmental footprint), and all liner systems will be hauled to one of the on-site landfills or placed in a related pond.

8 All surface infrastructure including tanks, piping, and electrical wiring will be emptied, cleaned, tested and then either taken off-site for disposal or deposited in an appropriate on-site containment facility. Any underground piping will be left in place, but piping will be broken up approximately every 5m.

9 Any wash water used in the cleaning of materials prior to shipping off-site will be contained in a lined area. During most of the decommissioning the cleaning will occur in the wash bay. Wash water will be treated by the IWWTP. Any sediment collected during this process will be contained in drums for subsequent disposal at an approved facility.

10 As a worst-case assumption, all roads are assumed to be reclaimed (scarified, contoured and revegetated), and all facilities are assumed to be demolished (i.e., no buildings left standing on-site). This will need to be discussed with the local communities to determine their preference regarding the roads, buildings, and airstrip.

11 On-site disposal facilities will be contoured, covered in place, and reclaimed. The covering of stockpiles, pads and ponds will depend in part on the levels of radioactivity encountered at the

time of decommissioning. This D&R scenario assumes a minimal level of radioactivity will be present on-site and that radioactive material will be mainly in the industrial landfill and/or if necessary, broken up and covered in place. The present plans are:

a. All non-radioactive stockpiles and materials will be contoured and then covered with clean soils and a 0.5m thick layer of growth media (crushed rock or clean fill);

b. All potentially radioactive stockpiles and materials will be disposed of within the industrial landfill; and

c. Once all stockpiles and materials have been covered and contoured, they will be revegetated.

12 The Project area will be surveyed for gamma radiation to identify any potential areas of radioactive contamination of the surficial soils. These soils will then either be buried beneath clean fill, landfilled on-site or hauled off-site to an approved facility. The PDP objective for surface radiation levels is 1 millisievert (mSv) per year above background levels.

13 At this time, it is assumed that the area will be reclaimed to boreal forest conditions.

14 All remaining on-site disposal and containment structures will be closed and reclaimed to minimize disturbance and integrate into the surrounding landscape.

15 Post decommissioning and reclamation activities and monitoring will be completed for 10 to 15 years following final site closure and reclamation.

16 The following subsections describe approaches that are specific to the identified planning envelopes.

5.1 Approvals Preparation and Management

Prior to decommissioning, a DDP shall be prepared for the Project. The decommissioning and reclamation of the Project will be completed in accordance with all provincial regulations and guidance documents, with the fundamental consideration being to ensure the physical and chemical stability of the site in order to protect human and ecological health and the environment.

It is assumed that various approvals, and permits will be required prior to proceeding into the active decommissioning phase. In addition, the proposed management options and the underlying assumptions will need to be reviewed, and the approaches will require further detailing and scheduling to allow for the successful completion of the Project.

The DDP and these approvals will also require reporting of the work after completion. Throughout this process, record keeping will be required. Setting up the required forms and systems to ensure that the records are sufficient and complete will be one focus of the initial approval preparation and management phase.

Routine environmental monitoring will be conducted during the active phases of these D&R activities to confirm and document that the activities are completed as planned. This monitoring will include the environmental, health and safety considerations, listed below.

- Radiation levels of surface facilities after cleaning;

- Radiation clearance for all materials that are to be taken off-site;
- Radiation survey of the facility footprints;
- Radiation survey of soil from areas with elevated radiation relative to background conditions;
- Worker radiation exposure (OSL dosimeter badges and real-time personal dosimeters);
- Decontamination operation monitoring to prevent spills, and to address, document, remediate and report on spills as necessary; and
- Record of all progressive decommissioning and reclamation activities.

During this stage, an initial site inspection will be conducted to confirm the status of the site and the equipment requiring decommissioning. This site inspection will also include a hazardous waste chemical survey to determine all chemical residues that may be present on-site, and that will need to be addressed in the subsequent stages.

During this stage of the project, detailed records of the constructed facilities, operations records, spill reports and waste handling manifests will be collected and digitized to form part of the permanent record of the facility.

It is anticipated that this stage will take up to approximately 18 months to complete.

5.2 Subsurface Remediation

During Operations, acidic lixiviant (mining solution) will be introduced into the ore zone via injection wells to leach and recover the uranium. The 2022 Draft EIS defined the mining zone as the area that is bounded by the freeze walls extending up 50 m above the ore zone (Denison 2022). The groundwater within the mining zone will be remediated as part of the D&R plan for this facility.

At the proposed time of these D&R activities, lixiviant will only have been added to the ore zone in the Phase 1 area (as part of wet commissioning). The freeze wall will be established around the Phase 1 area prior to the addition of lixiviant to the ore zone.

Groundwater remediation will likely be the first major stage in physical works in the PDP program. Remediation of the mining area will involve injecting water (generally expressed in terms of pore volumes of the zone being remediated) into the mining area through injection wells and recovering groundwater through recovery wells, similar to the proposed ISR mining technique.

Groundwater remediation that will occur during the subsurface remediation will include the following.

1. Rinsing Stage: the first step is to inject groundwater into the mineralized zone and recover it back to the surface.
2. Neutralization Stage: the second step is to inject a mild alkaline solution of sodium hydroxide and/or sodium bicarbonate and water and recover it back to the surface.

The recovery and injection rates will be similar to those that are anticipated for ISR operations. The recovered water will be treated by the IWWTP. The rates of groundwater remediation may be limited by the processing capacity of the IWWTP.

Mining area groundwater decommissioning objectives have been established for remediation of the mining zone to ensure groundwater quality in the ore zone requires little or no long-term monitoring and ensures no significant adverse effect on the environment. The mining area decommissioning objectives have been developed through groundwater modelling work and are achievable based on metallurgical testing. Numerical groundwater modelling was also applied to evaluate the fate and transport of the groundwater from the remediated mining area toward Whitefish Lake, the primary surface water receptor. Refinement of the mining area decommissioning objectives and the length of time to achieve these objectives are expected to continue to evolve as the Project progresses. The final acceptable mining area decommissioning objectives will be developed prior to initiation of groundwater remediation, either during operations and/or as part of the DDP. The current groundwater objectives for the mining area are shown in Table 5-1.

Table 5-5: Mining Area Decommissioning Objectives

PARAMETER	UNITS	RESTORED SOLUTION
pH	Unitless	4.3
Aluminum	mg/L	7
Arsenic mg/L 0.06	mg/L	0.06
Cadmium	mg/L	0.015
Cobalt	mg/L	2
Chromium	mg/L	0.05
Copper	mg/L	0.017
Iron mg/L 100	mg/L	100
Molybdenum	mg/L	0.1
Nickel	mg/L	9.7
Lead	mg/L	3.1
Sulphate	mg/L	703
Selenium	mg/L	0.08
Zinc	mg/L	1.4
Uranium	mg/L	100
Vanadium	mg/L	0.51
^{226}Radium	Bq/L	2.00E+02

During both stages of the groundwater remediation program, the use of one or more test wells and/or injection wells at various locations during this process will assist in ensuring the distribution of neutralized groundwater throughout the mining zone.

The success of the groundwater remediation will be documented through the:

- the monitoring of the groundwater pH and conductivity during the groundwater remediation steps; and

- the collection of groundwater samples from monitoring wells in and around the ore zone to document that the groundwater quality meets these objectives. During the active groundwater remediation groundwater monitoring will occur monthly.

Based on the analyses of laboratory and field test work conducted to date, it is assumed that approximately 35 pore volumes will be required to rinse the ore zone, and an additional 75 pore volumes will be required to neutralize the ore zone. It is conservatively assumed that this process will take up to 1 year of pumping for each mining phase.

Once the mining area decommissioning objectives have been met and maintained (i.e., stable) and all contaminants of potential concern are less than their objective, the perimeter freeze wall will be turned off and allowed to thaw. This will allow the eventual re-establishment of the pre-operational groundwater flow regime in the former mining area. Groundwater in the mining zone will be monitored to ensure that the groundwater quality continues to comply with the decommissioning objectives as the freeze wall thaws. At that time, the chiller units will be decommissioned and/or removed from the site and the remaining freeze wells and above ground piping will be decommissioned.

5.3 Mining Infrastructure

Following completion of the subsurface remediation once groundwater quality is stable and satisfies the remediation objectives detailed in Table 5-1, then the decommissioning mining infrastructure can begin.

The first step in the decommissioning of the mining infrastructure is the decommissioning of the chiller units, freeze wells, pumping systems and freeze solution handling facilities.

All wellheads, piping and electrical will be removed as part of the mining infrastructure prior to well abandonment. This will include the following:

- removal, decontamination, and disposal of all surface piping;
- decontamination and removal of the pumphouses;
- thawing of the freeze wall and decommissioning of all freeze pipes, and freeze plant units;
- removal, decontamination, and disposal of all electrical and monitoring cables; and
- recycling, sale of the asset demolition/infrastructure demolition waste as scrap, or disposal of waste in either the industrial landfill or off-site at an approved licensed facility.

It is expected that the chiller units will be cleaned and shipped off-site for reuse.

The decommissioning of the wells is anticipated to occur in two phases. The initial phase involves decommissioning the majority of the wells and vibrating wire piezometers. Selected wells will remain for ongoing monitoring and will be decommissioned as part of the second phase or left for post-decommissioning monitoring.

Decommissioning of the pumping, injection, freeze wells, and monitoring wells will generally consist of the following:

- The screened portion of the well will be filled with stable precipitates covered with sand from the base to just above the casing.

- The lower 15-20 m within the casing will be grouted with a bentonite clay-cement blend, cement grout and/or further capped at this level with a mechanical plug.
- Test the plug for proper shut-off by pressure-testing the plug and production casing to 7 MPa for at least 10 minutes.
- The remaining length of casing will be filled with bentonite – cement grout and/or alternating layers of sand and bentonite – cement grout.
- The well casings will be cut off about 1 m below the current ground surface and a cement–grout plug will be placed immediately over top of the casing to near the surface to inhibit water flow down the outside of the casing.
- The ground surface will then be built up by about 0.5 m with a combination of low permeability material and/or local fill amended with 5% bentonite to reduce hydraulic conductivity. These mounds will be graded away from each former well, to make sure no standing water accumulates immediately above the casings.

Mining surface infrastructure and facilities will be decommissioned in the same manner as all other surface infrastructure. As required, surface infrastructure will be broken into pieces that can be easily handled and screened for residual radiation. If necessary, materials will be cleaned and then either shipped off-site for disposal or recycling or disposed of on-site.

5.4 Surface Infrastructure and Decontamination

Permanent structures that remain after asset removal will require demolition. Prior to demolition, process equipment and non-supporting structures will be removed from buildings. At the time of decommissioning, all Project infrastructure will be screened and subsequently prepared for either further cleaning, on-site disposal or shipment off-site. During demolition, an initial wash of the infrastructure to be demolished will be required along with dust control using water. The requirement and duration of dust control will be determined on a case-by-case basis.

Denison will recycle materials and components to the greatest extent possible. Appropriate materials will be transferred to a licensed waste recycler, sold, or donated to local communities, should the materials be desired and if appropriate.

A review prior to the start of demolition will identify areas requiring additional procedures. Where possible, dust generating materials will be removed prior to demolition. Appropriate personal protective equipment and personnel decontamination procedures will be employed. Valuable recyclable materials will be separated and processed for transport and sale concurrent with demolition. Excavators equipped with grapples will sort the recyclable products from the non-recyclables. Shears will be used to size recyclables for shipping and sale. Cleaning procedures of recyclables will be integrated into procedures demolition, as necessary.

Larger concrete foundations (i.e., beneath the Processing Plant) will be left in place. Any portion s of concrete foundations remaining above grade will be levelled and rebar will be cut-off at grade. Large slabs will be perforated on a 2-m grid to permit drainage. Concrete slabs will be covered with 0.5m of development rock or locally stockpiled till. Smaller concrete slabs may be moved to the landfill.

For the purpose of this PDP plan, it has been assumed that the surface infrastructure outlined in the planning tables is assumed to be constructed and requires action to make them safe for removal, disposal, donation and/or reuse.

The Plan summarizes the preliminary decommissioning and reclamation plan for the surface infrastructure. The Plan was developed after consideration of various other decommissioning options and approaches. The plan focuses on returning the site to boreal forest type conditions and the disposal and removal of all waste, buildings, equipment, and material that are on-site. The preliminary decommissioning approach will consider the reuse, donation, and recycling of materials to the greatest extent possible.

The demolition process will produce; saleable recyclable materials (e.g., steel, stainless steel, copper, steel sections, and sheet metal), hazardous materials, (including contaminated material that cannot be decontaminated); building materials (including steel, wood, shingles, insulation, and concrete). All materials will be checked for residual radiation to confirm that they are safe to be disposed of, removed from the site or reused. Every load leaving the site shall be checked and "green tagged" to be free of significant residual radiation as per the Denison Radiation Protection Plan (RPP) (Denison 2022).

Surplus chemicals and other hazardous materials will be removed and stored in designated temporary storage facilities. All hazardous materials will be disposed of at approved off-site facilities. All radiologically contaminated material will be washed and decontaminated on-site. Once decontaminated, materials and facilities shall be disposed of on-site or transported off-site for salvage or disposal. All other contaminated material shall be managed on-site. Soils or material with hydrocarbon contamination shall be remediated at designated areas within the landfill. Remediation will be completed in line with industry best practices to the greatest extent possible, following remediation material will be disposed of or utilized as intermediate cover within the landfill.

The timing of the closure of these facilities will need to be planned out in detail during the DDP stage, as some of the facilities will be required during the planned remediation of other facilities at the site.

5.4.1 Decontamination Procedure

Any infrastructure or facilities that may be contaminated with LLRW will be decontaminated, as necessary, in accordance with Denison's Radiation Protection Plan (RPP).

Denison has been able to clean all materials as per its RPP to a level of 0.3 becquerels per square centimetre (Bq/cm^2) to date (based upon previous work at the site). Materials that are cleaned to 0.3 Bg/cm^2 are safe to be transported off-site.

Removal of surface facilities will incorporate the following steps:

1. Utilizing existing single access control points for the site so that all items, equipment, vehicles, and individuals can be scanned for contamination prior to leaving the site.
2. Maintaining established radiation control zones to minimize the potential spread of contamination.
3. Any contaminated materials (i.e., tanks, piping) will be cleaned and disposed of on-site or transported to an approved facility.

4 Radioactively contaminated material will be washed in appropriate lined area(s). Cleaned materials will be surveyed, "green tagged" and disposed of on-site or transported to an approved facility.

5.5 Radioactively Contaminated Waste

All surface facilities, equipment, and materials generated during the decommissioning will be systematically surveyed and decontaminated as necessary. Decontamination can include cleaning via dry blasting, sand blasting, and/or high pressure washing. Based on historical experience, it can be assumed that all facilities, materials, and equipment that may become radiologically contaminated can be cleaned on-site. However, alternatives have been considered if materials cannot be sufficiently decontaminated.

If the levels of radiation of one or more pieces of equipment cannot be sufficiently reduced for release from site as non-radioactive, other management alternatives can be considered. While this is not expected, the following contingency plan has been prepared should the management of radioactive waste be required. The proposed procedures to address this potential waste are listed below.

1 Materials classified as radioactive that cannot be cleaned shall be temporarily placed in an impermeable radioactive waste storage area with a secondary containment system prior to management off-site.

2 Testing of these materials will be conducted to determine the correct protocols for off-site transportation. Shipments of naturally occurring radioactive material (NORM) contamination may fall under federal transportation regulations, the Packaging and Transport of Nuclear Substances Regulations (PTNSR) and/or the Transportation of Dangerous Goods Regulations (TDGR). Before every shipment of contaminated material leaves the site, the level of radioactivity must be assessed to determine the level of activity and the appropriate transportation class.

3 Radioactive materials can be brought to a licensed facility for disposal and/or to a site for additional decontamination and potential disposal. An appropriate facility could include one of the local uranium mines or mills and/or a decontamination facility (e.g., the NORM management facility operated by Secure Energy in Standard, Alberta or disposal facilities in Unity, SK, and Pembina, AB).

5.5.1 Process Precipitate Management

The PDP estimate assumes that proposed D&R activities will begin at the end of wet commissioning and the start of facility operation. Therefore, at this time, the PDP assumes that a small volume of process precipitates will be present on-site.

Process precipitate solids are produced in the processing plant during the production of uranium. These wastes will contain economically extractable uranium and therefore, it is assumed that Denison will ship these precipitates to a licensed facility for processing.

Prior to shipping, mineralized precipitates must be transferred into shipping containers that meet the federal Transportation of Dangerous Goods Regulations. These containers are currently assumed to be rented containers approved for the transportation of radioactive slurry.

5.6 Confirmatory Radiation Survey

A gamma radiation survey shall be performed of the Project site and the adjacent areas to assess the residual radiation levels in the area after all the infrastructure has been removed and after initial grading has occurred. The confirmatory gamma survey will identify any areas of radiation contamination that may still be present at the surface.

The survey shall be performed using a suitably calibrated gamma radiation dose rate meter and will be conducted at a height of 1m above the ground surface. The entire area, including the perimeter, shall be scanned at a suitable spacing distance to meet the survey requirements in "Northern Mine Decommissioning and Reclamation Guidelines" EPB 38 (SkMOE 2008).

A decommissioning objective of 1 mSv per year above background levels has been used for projects that have been through an Environmental Assessment (EA). As such, this project's PDP objective for the surface radiation levels is 1 mSv per year above background levels.

Survey data shall be recorded at a rate of at least one measurement for every 100 m^2 surveyed across potentially contaminated areas and random spot checks throughout the rest of the project site. Any areas with readings exceeding the criteria shall be remediated to meet those criteria. The first step in remediation of the contaminated area will be to determine the source of the elevated readings and then the area and depth extent of the source of these readings. Impacted soils or material will then be disposed of within an approved on-site containment facility or buried beneath a suitable thickness of soil cover. An appropriate thickness of clean fill is assumed to be between 0.5m and 1m. It is expected that remediation will achieve acceptable gamma radiation exposure rates.

5.7 Site Reclamation

Denison is planning to utilize the As Low As Reasonably Achievable (ALARA) principles to establish the post-decommissioning radiation levels on the surface. The surface radiation decommissioning objective will be to restore impacted areas to a level such that the incremental effective doses to traditional land users do not exceed 1 mSv per year above natural background levels, based on the annual acceptable dose for the general public for one year from Radiation Protection Regulations (CNSC 2021a). Radiological release criteria will be developed as part of the DDP and will be used in future discussions with local stakeholders in the region.

Following the completion of the confirmatory radiation survey, the site will undergo final reclamation to return the area back to pre-project conditions.

Final grading of the area will be conducted to recontour the site to match existing ground profiles and promote surface water drainage and reduce erosion. Efforts will be taken to reduce straight lines of sight and promote a return to natural conditions.

Upon the development of a reclaimed surface, an elevation and location survey shall be completed on-site to capture post decommissioning and reclamation conditions and to assist with future monitoring. Final site reclamation will include consideration for the following:

1. a safe environment for ongoing traditional uses;
2. long-term adverse effects are minimized;
3. reclaimed landscape is stable and self-sustaining; and

4 restrictions on future land use are minimized.

5.8 Equipment Requirements During Decommissioning

The equipment selection will be determined by the prospective contractor during the contracting stage of this plan. At this time, based on the list of proposed activities and the available timelines, the following equipment has been included within the PDP decommissioning assumptions and will be required for all or a portion of the proposed decommissioning and reclamation work:

- Excavator or backhoe equipped with bucket and thumb;
- High reach excavator equipped with jackhammer and shear;
- Tractor *;
- Tracked skid steer *;
- D8 dozer with ripper *;
- D6 dozer with ripper and GPS;
- Articulating rock trucks *;
- Loader with a fork and bucket *;
- Four-wheel articulated pad foot compactor;
- Vacuum truck *;
- Highway transport trucks and trailers.
- Pressure water type cleaning unit(s) *;
- Clean water tank(s), piping and pumps *; and
- Waste and recycling storage bins *.

*Note: * - Denotes Items that are anticipated to be purchased by Denison during the construction phase and are therefore assumed to be available to be utilized by the Contractor during the decommissioning process. Maintenance and operation of this equipment are considered.*

5.9 Records, Monitoring, and Reporting

As indicated above, during the Approvals Preparation and Management stage of this PDP, detailed records of the constructed facilities, operations records, any spill reports and waste handling manifests will be collected and digitized to form part of the permanent record of the facility.

Monitoring described below will be conducted during all decommissioning activities and during the post-decommissioning period in order to record the results of the work and to ensure environmental protection.

5.9.1 Decommissioning Monitoring

Decommissioning period monitoring at the site is that period of time, under a “decommission tomorrow” scenario that covers the approvals period (1.5 years) and the active decommissioning period (5 years).

Subsurface remediation will likely be one of the first decommissioning phase of the D&R plan. Subsurface monitoring during remediation will focus on the area in the immediate vicinity of the ore zone. Groundwater monitoring during remediation will be conducted to demonstrate that the groundwater quality in this area has met or exceeded the remediation criteria (see Table 5-1). Monitoring will ensure that there are no environmental impacts on any environmental receptors. During the subsurface remediation phase, the decommissioning monitoring will include both field measurements of groundwater quality (e.g., pH, specific gravity, and conductivity) and, at a minimum, quarterly sets of groundwater sampling submitted to a laboratory for analysis.

Demolition of surface facilities will likely start during the subsurface remediation process. Demolition monitoring will also include a record of the ways the facilities are demolished, when it was demolished, the equipment used, any unforeseen events, radiation scanning results and where the waste material was placed on-site or if it was shipped off-site. Waste manifests will also be maintained for the Project and each decommissioning envelope.

Environmental monitoring will include both appropriate radiation monitoring (e.g., gamma monitoring) and monitoring of environmental quality (air, surface water and groundwater). Ongoing monitoring will also be conducted for occupational health and safety purposes.

Decommissioning period monitoring will include the following:

- surface water quality;
- ambient air quality (e.g., passive radon monitoring); and
- groundwater quality (both in the ore zone and along the flow path to Whitefish Lake).

The primary goal of monitoring during the decommissioning period is to confirm impacts on the environment are not detrimental and to monitor the change in contaminant concentrations over time.

Monitoring reports will be provided to the SkMOE and any other necessary regulatory agencies at an agreed upon frequency.

5.9.2 Post-Decommissioning Monitoring

Post-decommissioning period monitoring will continue following decommissioning period monitoring until such time that an agreement is reached with the regulatory authorities to stop monitoring or until the regulatory agencies choose to take over these responsibilities.

The frequency and scope of post-decommissioning monitoring are expected to decrease over time. Initial monitoring events will occur at a higher frequency and include a more intensive program than final monitoring events. The monitoring program is expected to decrease in frequency with time. Post-decommissioning monitoring shall include the following:

- surface water quality;
- ambient air quality;
- groundwater quality;
- geotechnical stability of all landforms and waste stockpiles; and
- inspection of the revegetated areas.

It is assumed that the post-decommissioning monitoring period will be ten (10) to fifteen (15) years following decommissioning and include ten (10) monitoring events during this period.

6 Project Schedule

The Feasibility Study completed for the WR project identifies the following Project Schedule for the Phoenix Deposit:

Table 6-6: Phoenix Deposit Project Schedule

YEAR	CONSTRUCTION	PRODUCTION	D & R
Year 1	X		
Year 2	X		
Year 3		X	
Year 4		X	
Year 5		X	
Year 6		X	
Year 7		X	X
Year 8		X	X
Year 9		X	X
Year 10		X	X
Year 11		X	X
Year 12		X	X
Year 13			X
Year 14			X
Year 15			X

The construction phase is expected to take two years. The operation phase is expected to last ten years and will consist of the sequential recovery of uranium using ISR techniques in five mining phases.

Progressive reclamation is expected to be completed as operations within the mining phases are completed. The operation and subsequent progressive reclamation schedule from the feasibility study for each mining phase are shown below.

Table 6-7: Proposed Schedule for the Operations and Progressive Rehabilitation of the Subsurface

MINING PHASE	PERIOD OF OPERATIONS	PERIOD FOR SUBSURFACE RECLAMATION
Phase 1	Years 3 to 8	Years 7 to 11
Phase 2	Years 5 to 9	Years 9 to 12
Phase 3	Years 7 to 12	Years 12 to 15
Phase 4	Years 7 to 12	Years 12 to 15
Phase 5	Years 9 to 12	Years 12 to 15

Table 6-1 indicates that the proposed progressive reclamation of the subsurface will occur immediately after the completion of operations in each mining phase. This reclamation is expected to consist of first rinsing the subsurface with water and then introducing a basic solution to neutralize the subsurface to near natural conditions. The subsurface remediation process is described in Section 5.2. Table 5-1 presents the current objectives for the remediation of the mining zone. The subsurface remediation phase of the D&R plan is expected to take up to five years, with ongoing environmental monitoring occurring for this duration. This active decommissioning phase includes the development of the DDP and obtaining the CNSC license to decommission along with provincial approvals. Work on these applications should start during the operations phase.

Once mining operations cease in year 12, asset removal, remediation and other aspects described in this PDP will occur. All aspect of this D&R plan is expected to be completed by year 15.

Post-decommissioning and reclamation monitoring will be required for ten (10) to fifteen (15) years or until the agreed upon endpoint objectives have been met for the Project site. Monitoring the site will be continued until it has demonstrated physical and chemical stability, both during and after decommissioning and reclamation activities. Monitoring will be used to confirm the environmental concentrations predictions made prior to and during decommissioning.

7 Preliminary Decommissioning Cost Estimate

The estimated preliminary cost estimate (PDCE) will be developed to support the licensing process. Information from the future detailed engineering design phase will provide input into the decommissioning of proposed facilities. The considerations outlined below will affect the PDCE as the Project progresses towards the construction phase.

As previously indicated, this document assumes that the proposed D&R work will be undertaken after Project commissioning which is the last stage of the construction phase. Using this assumption, some process waste materials are assumed to be present on the surface, and all facilities are assumed to be built and operational. This time horizon was selected as it follows the SkMOE guidance.

The key changes between this PDP and subsequent PDPs that are for later time horizons are the following:

- There will be slightly more contaminated materials on the surface to manage.
- There will be some additional structures, such as the gypsum pond expansion and the expansion of the industrial landfill.
- The areas and volume of the subsurface that would require remediation will vary with time.
- The number of wells (production wells, monitoring wells and freeze wells) that require remediation will vary with time.

This PDP considers the scanning of materials for radiation contamination and the cleaning of any materials. The additional radiation contaminated material present for future PDP's may be disposed of in an existing pond on-site. As the lining of some of the ponds will be similar to the industrial landfill, this is not expected to be a major effort. Any new facilities that require expansion will be dealt with in a similar fashion to the original facility type.

The biggest potential change in future PDP revisions will be the phases and volumes of the mining zone that require remediation. Table 6-1 indicates the phases of the deposit that will require remediation. To operate or leach a phase of the deposit will require that all the associated wells and piping are available. The remediation of the various areas of the deposit will utilize the same equipment and procedures.

The subsurface rate of the remediation in any decommissioning scenario is only limited by the treatment capacity of the industrial water treatment plant. The maximum rate of remediation is therefore about 40 m^3/hr after operations. During operations, the treating of the production waters will take precedence so the available capacity will likely be limited to less than 10 m^3/hr. So, while the subsurface remediation will take more time to complete, it is expected that progressive reclamation is conducted, the subsurface remediation during decommissioning will likely be able to be completed within about three years.

The decommissioning of the additional wells will occur in parallel to the subsurface remediation. Once an area has met and maintained water quality that is as good as or better than the remediation objectives, then and only then will the wells in that area be decommissioned. This will mean that wells will likely be decommissioned in an annual or semi-annual campaign.

8 Ongoing Decommissioning Planning Requirements

8.1 Ongoing Development of PDP

The results of this Plan should be considered preliminary and will be updated at a later date. PDPs are conceptual in nature and are refined as they are updated and revised following detailed design, community consultation, and during the eventual detailed decommissioning planning stage. These plans will be reviewed and updated every five years or if developments to the Project occur that would result in significant additional effort or changes in approach.

8.2 Engagement

Ongoing permitting, construction, and decommissioning planning and development will involve engagement with project stakeholders on many subjects. Engagement efforts will likely include discussions around decommissioning planning. The following groups may be engaged with:

- Local First Nation and Metis Communities;
- Neighbouring lease holders;
- Local governments;
- Local and regional businesses and service providers; and
- Non-governmental organizations.

9 References

Canadian Council of Ministers of the Environment (CCME). 2007 and as updated subsequently. *Canadian Environmental Quality Guidelines*. Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2003. *Comprehensive Study Report Cluff Lake Decommissioning Project*. Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2015. *General Nuclear Safety and Control Regulations*. June 2015, Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2017a, *Canadian Nuclear Safety and Control Act, January 01, 2017*. Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2017b. *Uranium Mines and Mills Regulations (UMMR), SOR/ 2000-206*

Canadian Nuclear Safety Commission (CNSC). 2018a. *REGDOC-2.11.1, Waste Management, Volume II: Management of Uranium Mine Waste Rock and Mill Tailings*. November 2018, Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2018b. *REGDOC-3.2.1, Public Information and Disclosure*.

Canadian Nuclear Safety Commission (CNSC). 2022a. *REGDOC-3.2.2, Indigenous Engagement, Version 1.2*.

Canadian Nuclear Safety Commission (CNSC). 2020a. *Regulatory Document (REGDOC)-2.9.1 Environmental Protection Environmental Principles, Assessments and Protection Measures*. September 2020, Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2021a. *SOR/2000-203, Radiation Protection Regulations, last amended on 2021-01-01.*

Canadian Nuclear Safety Commission (CNSC). 2021b. *Regulation Document (REGDOC), REGDOC-2.7.1, Radiation Protection.* July 2021.

Canadian Nuclear Safety Commission (CNSC). 2021c. *REGDOC-2.11, Version 2, Waste Management Framework for Radioactive Waste Management and Decommissioning in Canada*. March 2021.

Canadian Nuclear Safety Commission (CNSC). 2021d. *REGDOC)-2.11.1, Waste Management, Volume I: Management of Radioactive Waste*. January 2021, Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2021e. *REGDOC-2.11.1, Waste Management, Volume III, Version 2*. January 2021, Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2021f. *REGDOC-2.11.2, Waste Management Decommissioning.* January 2021, Ottawa, Ontario.

Canadian Nuclear Safety Commission (CNSC). 2021g. *REGDOC-3.3.1, Financial Guarantees for Decommissioning of Nuclear Facilities and Termination of Licensed Activities*.

Canadian Nuclear Safety Commission (CNSC), 2022, REGDOC-3.5.1, Licensing Process for Class I Nuclear Facilities and Uranium Mines and Mills, Version 2.1, February 2022. (CNSC 2022b).

Canadian Standards Association (CSA). 2014a. *N292.0-14, General Principles for the Management of Radioactive Waste and Irradiated Fuel*.

Canadian Standards Association (CSA). 2014b. *N292.3-14, Management of Low- and Intermediate-Level Radioactive Waste*.

Canadian Standards Association (CSA). 2019. Standard N294-09 (R2019) - Decommissioning of Facilities Containing Nuclear Substances. Toronto, Ontario.

Denison Mines Corp. (Denison). October 2022b. Wheeler River Project Draft Environmental Impact Statement (EIS).

Government of Saskatchewan (GOS). 1989. Hazardous Substances and Waste Dangerous Goods Regulations being Chapter E-10.2 Reg 3 (effective April 1, 1989) as amended by Saskatchewan.

Government of Saskatchewan (GOS). 2006. The Reclaimed Industrial Sites Act, Chapter R-4.21 of the Statutes of Saskatchewan (effective March 1, 2007), last amended in 2018.

Government of Saskatchewan (GOS). 2018a. Environmental Assessment Act, Chapter E-10.1 of the Statutes of Saskatchewan 1979-80 (effective August 25, 1980) last amended in 2018.

Government of Saskatchewan (GOS). 2018b. Environmental Management and Protection Act, Chapter E-10.22 of the Statutes of Saskatchewan (effective June 1, 2015), last amended in 2018.

Government of Saskatchewan (GOS). 2021. Post Closure Management of Decommissioned Mine/Mill Properties Located on Crown Land in Saskatchewan (Institutional Control Program).

International Atomic Energy Agency (IAEA). 2018. Regulations for the Safe Transport of Radioactive Materials, (IAEA, TS-R-1) No. SSR-6 (Rev. 1). 2018 Edition.

Newmans Geotechnique Inc. (NGI). 2020. Wheeler River In-situ Leach Surface Freezing Option Pre-Feasibility. Submitted to: Denison Mines Ltd., NGI Project No: NGI-020-090, August 13, 2020, Revision 0, Saskatoon, Saskatchewan.

Newmans Geotechnique Inc. (NGI). 2023. 2022 Denison Phoenix Deposit ISR Freeze Wall Feasibility Study (Revision 2). February 2023.

Saskatchewan Ministry of Environment (SkMOE). 1996. The Mineral Industry Environmental Protection Regulations Chapter E-10.2 Reg 7. effective March 6, 1996, Regina, Saskatchewan.

Saskatchewan Ministry of Environment (SkMOE). 2008. Northern Mine Decommissioning and Reclamation Guidelines, EPB 381, Version 6, November 2008, Regina, Saskatchewan.

Saskatchewan Ministry of Environment (SkMOE). 2015. Environmental Management and Protection (Saskatchewan Environmental Code Adoption) Regulations, E-10.22 Reg 2, Regina, Saskatchewan.

Saskatchewan Ministry of Environment (SkMOE). 2021. The Reclaimed Industrial Sites Regulations (MEnv, last amended in 2021, Regina, Saskatchewan.

SRK Consulting Canada Inc (SRK). 2018. Prefeasibility Study Report for the Wheeler River Uranium Project Saskatchewan, Canada.

Appendix A Waste Estimates and Decommissioning Approaches

Table A.1 8: Decommissioning Management Options

CATEGORY	MANAGEMENT OPTION	SELECTED MANAGEMENT OPTION	
		CLUFF LAKE	WHEELER RIVER
Radiologically Contaminated Material	Repurpose and reuse material on-site		
	On-site surface burial and containment in open pits	X	
	Processing on-site for off-site shipment and management		
	On-Site Disposal		X
Special Wastes Pile, Precipitates and LLRW Sludges	On-site surface burial and containment	X	X
	Ship off-site for processing at another licensed facility Processing on-site for off-site shipment and management		X
	Processing on-site for on-site disposal		
	Off-Site Disposal		
Clean Waste Rock	On-site surface burial and containment		
	Processing on-site for on-site disposal		
	On-site burial and/or use	X	X
	Off-Site disposal		
Hazardous Waste	Ship off-site for processing at another licensed facility Processing on-site for off-site shipment and management	X	X
	Processing on-site for on-site disposal		
	On-site disposal	X	X
	Off-site disposal		
Processing Buildings (LLRW)	Processing on-site for off-site shipment and management		
	Processing on-site for on-site disposal		
	On-site disposal	X	X
	Off-site disposal		

Disposal of Support Facilities and Non-LLRW Buildings	Processing on-site for off-site shipment and management		X
	Processing on-site for on-site disposal	X	X
	On-site disposal		
	Off-site disposal		

31 Denison Mines Corp. Wheeler River Operation, Waste Management Program, Version 1, July 2023

Denison Mines Corp.
Wheeler River Operation

Waste Management Program

Document # 10

Version 1

October 2023

Approval for Use

Version	Date	Description of Activities	Author	Reviewer	Approver
Version 1	6-Oct-2023	For CNSC Review			

Revision History

Version	Date	Description of Revision
Version 1	6-Oct-2023	For CNSC Review

Table of Contents

Figures

1 Introduction

The *Waste Management Program* (the Program) is one of twelve Program documents that comprise the Management System for the Wheeler River Operation (the Operation). The *Waste Management Program* is preceded by the *Management System Program* within the document framework for the Operation as shown in Figure 1. Consistent with all other Program documents, the Program is organized according to the 'Plan-Do-Check-Act' iterative process to incorporate continual improvement in all stages of the Program.

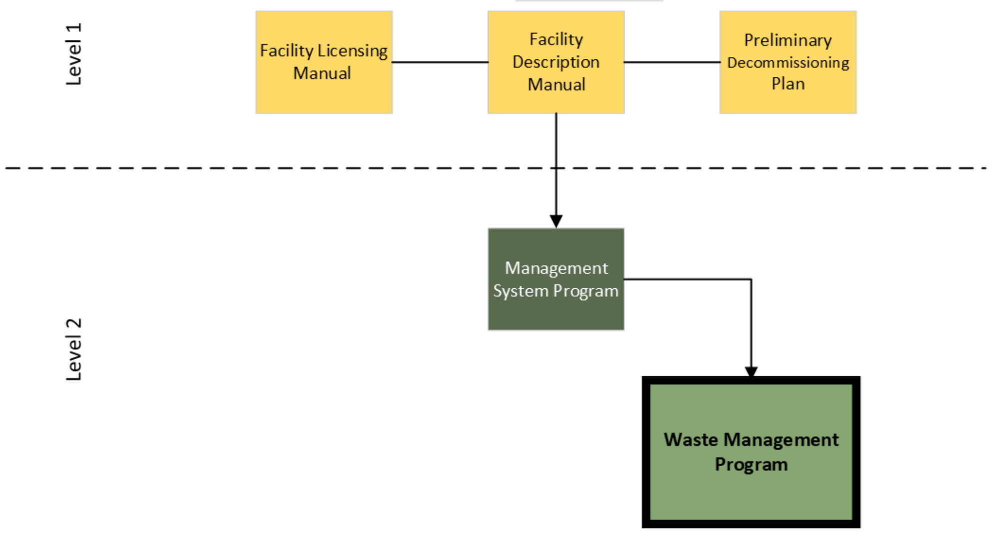


Figure 1: Program showing within Document Framework for the Wheeler River Operation

1.1 Purpose

The purpose of this Program is to describe and document Denison's *Waste Management Program* which governs the waste management practices and proposes effective strategies for minimizing waste generation, improving waste segregation, and implementing sustainable waste management techniques.

The Program uses a risk-based approach to identify waste management measures, which is informed by and commensurate with the risk arising from the potential interactions of Operation waste streams and the workplace and environment.

1.2 Scope

The Program is used to integrate Denison's waste management measures into a documented, managed, and auditable process, and encompasses:

- Waste characterization;
- Waste minimization;
- Waste management; and

- Decommissioning plans.

The scope of the Program extends to both radioactive and non-radioactive waste streams generated during construction and operation of the Operation.

1.3 Program Principles and Denison's Environment, Health, Safety & Sustainability Policy

Denison's commitments around waste management are aligned with its corporate Environment, Health, Safety & Sustainability Policy, applicable to all its facilities. The *Waste Management Program* is based on the principles outlined in that policy, which can be found in the *Management System Program* as well as at the following website:

Environment, Health, Safety & Sustainability Policy

The principles of the *Waste Management Program* focus on presenting well-defined strategies aimed at minimizing waste generation, enhancing waste segregation practices, and implementing sustainable waste management techniques. The Program establishes a practical roadmap that effectively mitigates the environmental consequences associated with waste, optimizes resource allocation, fosters recycling and reuse initiatives, and improves overall waste management efficiency. By successfully addressing these principles, the Program aims to actively contribute to the creation of a cleaner, healthier, and more sustainable environment for the community and stakeholders.

1.4 Compliance with Regulatory Requirements

This Program is compliant with the *Nuclear Safety and Control Act* and associated regulations, including the *General Nuclear Safety and Control Regulations,* the *Uranium Mines and Mills Regulations.* The Program also follows guidance and requirements in the Canadian Nuclear Safety Commission (CNSC) REGDOC 2.11, *Framework for Radioactive Waste Management and Decommissioning in Canada,* REGDOC 2.11.1, *Waste Management, Volume I: Management of Radioactive Waste,* REGDOC 2.11.1, *Waste Management, Volume II: Management of Uranium Mine Waste Rock and Mill Tailings,* and REGDOC 2.11.2, *Decommissioning.*

Additionally, the Program meets CSA N288.4, *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills,* CSA N288.5, *Effluent Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills,* the *Transportation of Dangerous Goods Regulations,* and provincial requirements including the *Environmental Management and Protection Act,* and the *Saskatchewan Hazardous Substances and Waste Dangerous Goods Regulations, Chapter E-10.2 Reg 3.*

1.5 Terminology

1.5.1 Definitions

Term	Definition
Clean waste rock	Waste rock generated as sandstone cuttings and core from drilling activities associated with well and freeze hole development that does not have uranium containing materials.
Conventional waste	Includes: clean waste rock, domestic waste including recyclable waste, non-radioactive chemically contaminated waste, hazardous substances, domestic wastewater, site runoff, and dust.
Domestic Waste	Non-recyclable waste materials that are generated from the camp facility and offices other non-contaminated areas.
Domestic Wastewater Treatment Plant	The wastewater facility for the treatment of domestic wastewater, i.e., greywater (e.g., water drained from sinks, showers, washing machines) and blackwater (i.e., sewage).
Hazardous substances or hazardous waste	Waste dangerous goods designated as hazardous substances as per Appendix D of the Saskatchewan *The Hazardous Substances and Waste Dangerous Goods Regulations* (e.g., contaminated soil, waste oil, paints, solvents, hydrocarbons).
Industrial Waste	Industrial waste at the Operation is defined as waste with chemical or radiological contamination. Waste classified as Industrial waste is disposed of in the Industrial Waste Landfill.
Industrial Wastewater Treatment Plant	The wastewater facility for the treatment of industrial wastewater, including wastewaters produced in the processing plant during uranium extraction and from other various sources (e.g., wash bay sump water, leachate from the industrial landfill, wellfield runoff pond).
Radioactive Waste	Includes: radiologically contaminated water, radiologically contaminated drilling muds and products used in the drilling process, special waste, radioactive gaseous emissions/radon, and low-level radiologically contaminated waste.
Special Waste	Includes mineralized core and cuttings from well development that have uranium containing materials.

1.5.2 Acronyms and Abbreviations

Acronym or Abbreviation	Term
CNA	Canadian Nuclear Association
CNSC	Canadian Nuclear Safety Commission
DWWTP	Domestic Wastewater Treatment Plant

GCL	Geosynthetic Composite Liner
GM	Geomembrane
HDPE	High-Density Polyethylene
IWWTP	Industrial Wastewater Treatment Plant
KPI	Key Performance Indicator
MAC	Mining Association of Canada
PAG	Potential Acid Generation

2 Plan

2.1 Risk Management

Risk management identifies, assesses, and controls risks to workers, the environment, systems, facilities, and equipment associated with a task or process. The Operation adopts a consistent and integrated approach to risk management to identify, manage, and mitigate risk.

This process includes identifying waste management hazards that could affect workers, the environment, or the public, determining the significance of any associated risks, and mitigating the risks to acceptable levels by applying controls.

2.1.1 Hazard Identification

The hazard identification process will assess the origins of hazards, such as hazardous waste, as well as the initiating events that give rise to hazardous situations. These events may encompass technological factors, human performance-related issues, or natural events.

Denison employs a systematic approach to identify hazards that pose risks to workers, the general public, and the environment. Hazards are identified using appropriate types of assessment which are documented and tracked. Typical assessments include job hazard analyses (JHAs) and field level hazard assessments (FLHAs).

Procedures or processes involving identification and control of ionizing radiation are discussed in the *Radiation Protection Program*.

2.1.2 Risk Assessment

Denison evaluates the risks associated with identified hazards related to its waste management practices and activities. This evaluation encompasses an assessment of the likelihood of hazardous events and an evaluation of the potential consequences of these hazards for workers, the general public, and the environment. The assessment of consequences involves an examination of the fate and pathways of exposure to hazardous waste during routine operations, as well as during accidents and malfunctions. Denison utilizes a corporate risk matrix to characterize these risks.

Further information regarding the risk assessment process is detailed in the *Management System Program.*

2.1.3 Risk Register

Denison uses a risk register to proactively identify and address significant waste management risk aspects, prioritize resources, and continuously improve its risk management practices. The risk register is a central repository for recording and tracking information related to the significant waste management aspects.

The risk register may include information such as: risk identification, risk assessment, risk analysis, risk evaluation, risk prioritization, risk mitigation, risk monitoring and review. Further details on the risk register are provided in the *Management System Program*.

2.2 Objectives and Targets

Objectives and targets of this Program will be measurable, documented, and tracked. Performance against the objectives and targets will be communicated at regular intervals (i.e., during Management Review), and opportunities for continual improvement will be identified.

The Program follows targets to guide and measure the progress and effectiveness of waste management efforts. These targets are specific, measurable, achievable, relevant, and time-bound (SMART) and serve as specific objectives that the Program aims to achieve within a defined timeframe. The targets may vary depending on the specific goals and priorities of the organization or jurisdiction.

Common targets of the *Waste Management Program* may include, but are not limited to:

- Waste reduction targets;
- Wastewater management targets;
- Hazardous waste management targets;
- Waste rock management targets;
- Airborne emissions reduction targets; and
- Recycling and composting targets.

The process for setting overall objectives and targets is outlined in the *Management System Program* and supporting procedure.

2.3 Resources

Denison is committed to providing the necessary resources to support effective development, implementation, maintenance, and continual improvement of the Program, including achievement of its objectives and targets.

2.3.1 Roles and Responsibilities

This subsection outlines the specific roles and responsibilities within the Program, including the Environment Manager, the Operations Manager, Department Supervisors, and other workers with various levels of responsibility.

For effective implementation of this Program, workers are informed of their roles and responsibilities and are accountable for comprehending and performing them. Executive and Leadership level roles and responsibilities are specified in the *Management System Program*.

<u>Environment Manager</u>

- Responsibility for compliance with waste management requirements arising from legislation, regulations, licences, permits, and other legal requirements;
- Ensuring compilation of waste inventory for reporting as required; and
- Ensuring identification and promotion of waste management requirements to management and workers is completed, and supports continual improvement; and
- Facilitating management review of this Program.

<u>Operations Manager</u>

- Overseeing the development, implementation, and adherence to this Program and it's plans and procedures;
- Managing and monitoring the effectiveness of this Program*;*
- Allocating adequate and appropriate resources to fulfill Program implementation;
- Working with applicable departments to verify Program roles and responsibilities are qualified to fulfill their roles; and
- Participating in the management review process of this Program.

<u>Department Supervisors</u>

- Overseeing the implementation, and adherence to this Program and it's plans and procedures;
- Communicate requirements for waste management on a job specific basis to workers; and
- Ensure workers effectively follow requirements of this Program.

<u>Workers</u>

- Follow work plans and instructions as they apply to the applicable area of the Operation;
- Performing duties safely with attention to approved protection procedures; and
- Document waste inventory, volumes, and transportation off-site as required.

2.3.2 Facilities and Equipment

Facilities and equipment to support the effective implementation of the Program and its related practices are provided to Program staff and applicable workers.

Examples of facilities and equipment used and maintained as part of the Program include:

- Waste treatment facilities;
- Various waste rock storage pads;
- Dust control equipment;
- Airborne emission control systems;
- Disposal facilities, including landfill; and
- Personal protective equipment.

The *Waste Management Plan* offers operational details for relevant facilities and equipment.

2.4 Training and Competence

A systematic approach to training (SAT) is used to educate, train, and qualify workers and contractors to perform assigned work. Training requirements are monitored to verify workers have necessary training when needed to maintain competency and work safely.

Records of training activities and competencies will be maintained as outlined in the *Training Management Program*.

2.4.1 Program-Specific Training

Training specific to the *Waste Management Program* will be defined for Denison employees and contractors according to the SAT process. Denison will ensure that workers identified under the Program have prior training or relevant work experience in a related field. As well, ongoing professional development will be defined, appropriate to their role.

Denison will also develop and deliver training and awareness programs to enhance hazardous waste knowledge, and skills. To ensure awareness and understanding, Denison will regularly communicate hazardous waste information, policies, and procedures to relevant staff.

2.5 Documentation and Record Management

Denison will establish and maintain documented Plans, Procedures and Work Instructions to ensure effective implementation of the Program. Documentation will be controlled, reviewed, and updated as necessary in accordance with the requirements in the *Management System Program*.

Documents and records will be generated as a result of implementation of the Program and completion of licensed activities. Examples of some records generated specific to the Program may include:

- Environmental and waste monitoring data;
- Program specific training records;
- Waste manifests;
- Waste characterization and lab analysis records;
- Waste volume and inventory records;
- Waste transportation records; and
- Waste treatment records

Further information on documentation and records management is provided in the *Management System Program.*

2.6 Communication

Communication both with internal and external stakeholders is a critical element of the Program to promote a safe work culture that fosters best waste management practices. Relevant information covering topics such as waste generation, segregation, storage, treatment, and disposal practices will be shared.

Communication principles and processes are further outlined in the *Management System Program,* and communication with indigenous communities, local communities, and the public is managed as outlined in the *Public and Indigenous Information Program.*

2.7 Change Management

Change is managed at the Operation to protect workers, the environment, and property, and to ensure that regulatory requirements are met. The Operation's change management process is outlined in the *Management System Program.*

Examples of changes captured by the process could include, but is not limited to changes to the:

- *Waste Management Program* and supporting plans, procedures, and work instructions;

- Structures, systems, and components;
- Changes to the types, volumes, and concentrations of waste streams;
- Relevant regulatory requirements;
- Emerging risks to workers; and
- Organizational changes.

3 Do

3.1 Waste Characterization

The *Waste Management Program* addresses both conventional and radioactive waste. Waste characterization follows the process outlined in the *Waste Management Plan.* All solid, liquid, and gaseous wastes expected to be produced at the Operation are classified as per the plan.

3.1.1 Waste Classification

Wastes are generally classified as:

- Radioactive Waste; or
- Conventional waste.

Radioactive waste can include:

- Radiologically contaminated water;
- Radiologically contaminated drilling muds and products used in the drilling process;
- Special waste;
- Radioactive gaseous emissions/radon; and
- Low-level radiologically contaminated waste.

It should be noted that clean or special waste rock could have very low-level of radioactivity or could be free of radioactivity.

Conventional waste can include:

- Clean waste rock;
- Domestic waste including recyclable waste;
- Non-radioactive chemically contaminated waste;
- Hazardous substances or waste dangerous goods as described in Appendix D of Saskatchewan *Hazardous Substances and Waste Dangerous Goods Regulations*.
- Domestic wastewater;
- Site runoff; and
- Dust.

3.2 Waste Minimization

Waste minimization consists of the processes, practices, materials, products, substances, or energy that avoid or minimize the creation of waste. The *Waste Management Plan* outlines waste minimization measures for the various classes of waste identified in the previous section.

3.3 Waste Management

The waste management practices are tailored to each specific waste stream. The following subsections outline Denison's waste minimization practices for all Operation waste streams.

3.3.1 Special Waste

Special waste is defined as mineralized materials that cannot be disposed of in the clean waste pile. It is primarily made of drill cores, cuttings, muds, and related drilling products from wellfield development.

Special waste will be determined by a radiometric scan and sorted onto the special waste pad. The details of the mineralized/special waste rock and overburden are provided in the *Waste Rock Management Plan*. Anticipated volumes of mineralized/special waste material generated from the wellfield are provided in the *Waste Management Plan* and its supporting documents.

3.3.2 Clean Waste

Clean waste rock will be generated as sandstone cuttings from drilling activities. Clean waste rock will be stored on the clean waste rock pad. Clean waste is expected to be encountered from surface to 300 meters below surface. The clean waste pile will be assayed and tested for Potential Acid Generation (PAG) during operations to ensure the material can be re-used when required. Further details of the clean waste rock are provided in the *Waste Rock Management Plan*. Anticipated volumes of clean waste material generated from the wellfield are provided in in the *Waste Management Plan* and its supporting documents.

3.3.3 Industrial Effluent

The Industrial Wastewater Treatment Plant (IWWTP) receives overflow solution from the Yellowcake Thickener and other sources of contaminated solution on-site and removes dissolved metals and suspended solids to produce an effluent that meets environmental quality requirements.

The IWWTP will consist of three treatment stages, Effluent Treatment Stage One, Effluent Treatment Stage Two and Effluent Treatment Stage Three. Details of the treatment stages are provided in the *Facility Description Manual* as well as the *Waste Management Plan*.

3.3.3.1 Release Ponds

The release ponds consist of three effluent monitoring and release ponds. The ponds will receive water from the IWWTP.

<u>Site preparation and Construction</u>

The water received by the release ponds from the industrial treatment plant will be retained in ponds and will not be released into the environment until commercial operation commences.

<u>Operation Phase</u>

During Operation phase each pond will be operated with the following three stages: filling, holding (while awaiting quality confirmation), and free release to Whitefish Lake (once water quality is confirmed to meet discharge limits).

If necessary, water from the ponds can be recycled back to the processing plant via the process water pond.

3.3.4 Domestic Wastewater

Water drained from sinks, showers, washing machines, and sewage will be generated at the camp, processing plant, airstrip terminal, and operations centre. Domestic wastewater from camp, processing plant, and operations centre will be piped directly to a domestic wastewater treatment plant (DWWTP) for on-site treatment. For the remainder of the areas there will be holding tanks installed in those buildings and domestic wastewater will be transported to the DWWTP by vacuum truck for treatment.

Reject solids from DWWTP will be collected, dewatered, and disposed of at an onsite landfill or the site composting system.

3.3.5 Domestic Waste

Domestic waste is defined as waste materials that are generated from the camp facility and offices other non-contaminated areas. Domestic waste is collected in garbage bins and recycling bins distributed around the site. Recyclable materials are collected and sent to an approved recycling depot. Clean burnables may be burned only when authorized by a provincial *Permit to Burn.*

Denison proposes to use a composter for the disposal of food wastes, this will be a Brome composting system, which is enclosed in a sea container. After composting is complete, an outdoor curing phase will be required during the summer months.

A domestic waste landfill will be used to manage non-recyclable, inert wastes (including non-recyclable plastics, broken furniture, textiles, and other non-recyclable items from the camp and operations site).

The landfill will be developed as per the regulations set out by the *Saskatchewan Ministry of Environment.*

3.3.6 Recyclables

The implementation of the recycling practice involves the establishment of a source separation system, which includes providing easily identifiable and accessible recycling bins for various materials such as paper, plastic, glass, and metal. Additionally, a well-designed collection infrastructure is put in place to ensure the efficient retrieval of recyclable materials from locations within the mine, offices, and the camp. This will involve collaborating with third-party recycling facilities or material recovery facilities to process and sort the collected recyclables effectively.

3.3.7 Industrial Waste

Industrial waste is defined as waste with chemical or radiological contamination. The industrial waste landfill will meet the requirements as set out by the *Canadian Nuclear Safety Commission*, as well as National and International Standards from the*:*

- Canadian Standards Association;
- Environment and Climate Change Canada; and
- International Atomic Energy Agency.

More details of industrial waste are provided in the *Waste Management Plan* and its supporting documents.

3.3.8 Hazardous Waste

Hazardous waste could include chemical contaminated waste such as non-radiologically contaminated soil and waste oil. Waste oil is collected as well as hazardous waste such as paints, solvents, and hydrocarbons and will be temporarily stored on a lined pad. Hazardous waste will be removed by a licensed carrier and delivered to a licensed receiver for recycling. Details of the hazardous waste management stages are provided in the *Waste Management Plan* and its supporting documents.

3.3.9 Site Runoff

Site runoff from non-contaminated areas will be diverted away from the facilities. Site runoff from potentially contaminated areas, such as the process precipitates storage pad and special waste pad will be collected and stored in double lined ponds prior to treatment in the IWWTP.

3.4 Decommissioning Plans

CNSC REGDOC 2.11.2, Decommissioning, which is a part of the CNSC's waste management series requires that the *Waste Management Program* should consider all stages of decommissioning including Planning, preparation, execution, and completion of decommissioning.

The decommissioning planning requires a waste management strategy that identifies the categories and estimated quantities of all waste streams that will be generated and managed during decommissioning, and the planned disposition path.

Preparation of decommissioning requires a waste management plan that considers the waste hierarchy, including waste minimization, reducing radioactivity, reusing and recycling materials and components, and disposing of the waste. The *Waste Management Plan* shall describe the systematic process for how the waste will be moved from the decontamination and dismantling areas to the areas for subsequent steps of waste management. The monitoring and processing areas should be designed and operated to keep recyclable and reusable materials separate from waste materials.

Prior to execution of decommissioning the availability of packages for radioactive waste, the disposition path of radioactive waste arising from decommissioning activities, and the ability of those disposition paths to accommodate the types and volumes of material should be evaluated and ensured.

4 Check

4.1 Monitoring and Measurements

Waste management performance is monitored and measured against established objectives and targets (identified in Section 2.2). Denison will monitor, measure, analyze, and evaluate its performance based on a defined process outlined in the *Management System Program*.

Monitoring and measurement activities specific to the *Waste Management Program* include waste and environmental monitoring and measurements for various waste streams, as outlined in the *Waste Management Plan* and its supporting documents.

The results of monitoring and measurement activities are communicated internally and externally and documented as part of the *Records Management* process outlined in the *Management System Program.*

4.2 Inspections and Audits

Denison will conduct internal audits of the *Waste Management Program* to assure compliance with the requirements set out in the Program and to determine if the Program is being effectively implemented and maintained.

The internal audits will follow the process and procedures outlined in the *Management System Program*.

4.3 Management Review

The *Waste Management Program* will be reviewed by Denison management in accordance with a defined frequency to assure the program is meeting its objectives, is effective or needs adjustment. The types of items related to waste management that Denison management will review may include:

- Suitability, adequacy, and performance of Program objectives and targets;
- Upcoming or new legislation related to waste management;
- Results of monitoring in relation to meeting performance objectives and targets;
- Results of audits and inspections in relation to meeting performance objectives and targets;
- Identified opportunities for improvement based on incident reports and other sources;
- Communications from interested parties;
- Adequacy of resources; and
- Any needs for Program adjustments.

Where necessary, Denison management will identify opportunities for improvement and establish action plans to implement change in accordance with the process outline in the *Management System Program.*

4.4 Reporting

Denison will routinely report both internally and externally on the performance of the *Waste Management Program*. External reporting can include reporting to regulators, the public, and Indigenous and local communities.

External reports to regulators will be produced in accordance with regulatory requirements.

External reports to the public or Indigenous communities on the performance of the Program will be tailored to the interests of these groups as identified through community engagement activities. Reporting, disclosure, and communication to the public and Indigenous and local communities is discussed in more detail in the *Public and Indigenous Information Program.*

5 Act

5.1 Corrective Action

Non-conformities or areas for improvement are identified following the process outlined in the *Management System* and supporting procedures. These non-conformities can include hazardous waste related incidents, environmental incidents, near-misses, and deviations from the *Waste Management System Program.* Non-conformities can also be identified during inspections and audits.

Responses to identification of non-conformities include investigation of cause, and corrective action if appropriate. Corrective actions are planned, implemented, verified, and reviewed for effectiveness based on the process identified in the *Management System Program*.

5.2 Continual Improvement

Opportunities for improvement of this Program will be identified and addressed to enhance waste management performance. The continual improvement process for this Program follows the overall continual improvement process outlined in the *Management System* Program and the supporting procedures. Continual improvement may also include updating Program objectives and targets based on changing circumstances or new information. Improvement may involve benchmarking performance against other similar projects and facilities. Any changes identified through the continual improvement process will be implemented in a systematic and controlled manner.

With respect to waste management, opportunities for continual improvement may be identified through review of techniques, processes, and procedures ensuring effective control of effluent and waste generation.

6 References

6.1 Internal

Document Name
Management System Program
Environmental Management Program
Radiation Protection Program
Training Management Program
Waste Management Plan
Waste Rock Management Plan
Decommissioning Plan

6.2 External

Canadian Nuclear Safety Commission (CNSC). 2021. Waste Management, Volume I: Management of Radioactive Waste, REGDOC-2.11.1.

Canadian Nuclear Safety Commission (CNSC). 2021. Decommissioning, REGDOC-2.11.2.

Canadian Nuclear Safety Commission (CNSC). 2018. Framework for Radioactive Waste Management and Decommissioning in Canada, REGDOC-2.11.

Canadian Nuclear Safety Commission (CNSC). 2018. Waste Management, Volume II: Management of Uranium Mine Waste Rock and Mill Tailings, REGDOC-2.11.1.

CNSC. 2010. Licensing Process for New Uranium Mines and Mills in Canada, INFO-0759

Government of Canada. 2017. Uranium Mines and Mills Regulations, SOR/2000-206

32 CSA Group Standard, N294 - Decommissioning of Facilities Containing Nuclear Substances, 2019 Version

This reference document is subject to copyright. A subscription is required to view this document. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca).

33 Denison Mines Corp. Wheeler River Operation, Security Management Program, Version #1,

The information in this reference document is subject to a request for confidentiality under rule 12 of the *Canadian Nuclear Safety Commission Rules of Procedure*. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca) for more information concerning confidentiality.

34 Denison Mines Corp. Wheeler River Operation, Nuclear Substances and Radiation Devices Management Procedure

Purpose:

This procedure ensures safe handling, use, storage and disposal of nuclear substances in compliance with applicable regulations. The use of nuclear density gauges is not presently planned for Wheeler River Operation. If the requirement for the use of nuclear gauges is required and approved for use in the future, this procedure will be revised accordingly.

Applicable:

This procedure applies to all personnel and activities associated with handling management, or oversight of nuclear substances, specifically the existing Uranium material stored in the tanks associated with the Feasibility Field Test (FFT) currently licensed under nuclear substances regulations.

Responsibilities:

Radiation Safety Officer:

- Ensure compliance with CNSC regulations concerning nuclear substances.
- Ensure records are maintained on transfer and disposals of nuclear substances.

Workers:

- Follow all safety protocols related to handling nuclear substances.
- Report any incident, losses, or irregularities involving nuclear substances to the RSO immediately.

Procedure:

Storage of nuclear substances

- All nuclear substances will be stored and secured; in an area accessible only to authorized personnel.
- A radiation work permit process will be implemented to aid in tracking and monitoring activities within the FFT area. Refer to the Radiation Work permit work instruction.

Radiation Hazard Signage

- Attached to the exterior of the area, a clearly visible and legible radiation hazard warning sign, with contact details of personnel to contact in case of emergency. Refer to WRE-RP-256-01 posting of radiation warning signs work instruction.

Transfer and disposal of nuclear substances:

- No transfer or disposal of nuclear substance is currently expected. Should this situation change, a procedure will be established, ensuring full compliance with CNSC regulations.

Monitoring and Exposure control

- All workers **must** wear personal dosimeters when there is a need to enter the secured area.
- Reassignment to non-radiation area will be considered for workers when monitoring shows that exposure reaches 75% of their annual dose limit.

Incident Reporting and Response:

- In the event of a spill involving liquid radioactive materials, workers should immediately evacuate the area, secure the spill site, inform the RSO for further containment and clean up, and follow the Incident Investigation and reporting procedure, DMC-HS-150.

Training and Awareness:

- Nuclear substances and radiation devices management training will be included in the Advance Radiation protection program.
- Training will include identifying risks associated with handling radioactive liquids or powders and responding to spills effectively.

Records Keeping

- The following inventory log of nuclear substances will be maintained
    1. Details of the type of the substance.
    2. Quantity.
    3. Location.

Records:

Record Name	Retention Time

References:

- Radiation Protection program.
- CNSC Nuclear Substances and Radiation Devices Regulations
- Posting of radiation warning signs work instruction WRE-RP-256-01.
- Radiation Work permit work instruction.

Author:

Radiation Safety Lead	**Sanmi Davids.**
Title	**Name**

Approver:

VP Operations & Regulatory Affairs	**Kevin Himbeault**
Title	**Name**

35 Denison Mines Corp. Wheeler River Operation, Threat and Risk Assessment Procedure, Version #1,

Purpose:

The purpose of this *Security Threat and Risk Assessment* procedure (Procedure) is to provide guidance, ensure consistency, and follow the guidelines set out by the *Canadian Nuclear Safety Commission* (CNSC), *Uranium Mines and Mills Regulations & General Nuclear Safety and Control Regulations* and the *International Atomic Energy Agency* (IAEA), *Nuclear Security in the Uranium Extraction Industry* for security threat and security risk assessment.

Applicable To:

- Vice President, Operations

Background:

A threat is defined as a person or group of persons with the motivation, capability, and intention of unauthorized removal of uranium ore concentrate. The target is uranium in process, in storage, and in transit. The risk is the unauthorized removal of uranium ore concentrate in one of its three forms: solution, precipitate, or powder. Denison, as the operator and shipper shall carry out vulnerability assessments based on the current threat assessment and regulatory requirements.

The attractiveness of the product is dependent on the amount involved and its removability if unauthorized access was gained.

A vulnerability assessment provides a means of evaluating the effectiveness of security measures against the defined threat. Denison will carry out vulnerability assessments based on the current threat assessment and regulatory requirements.

Denison plans to complete inventory tracking and monitoring of its product, as per the regulations set out in the *Nuclear Security in the Uranium Extraction Industry*.

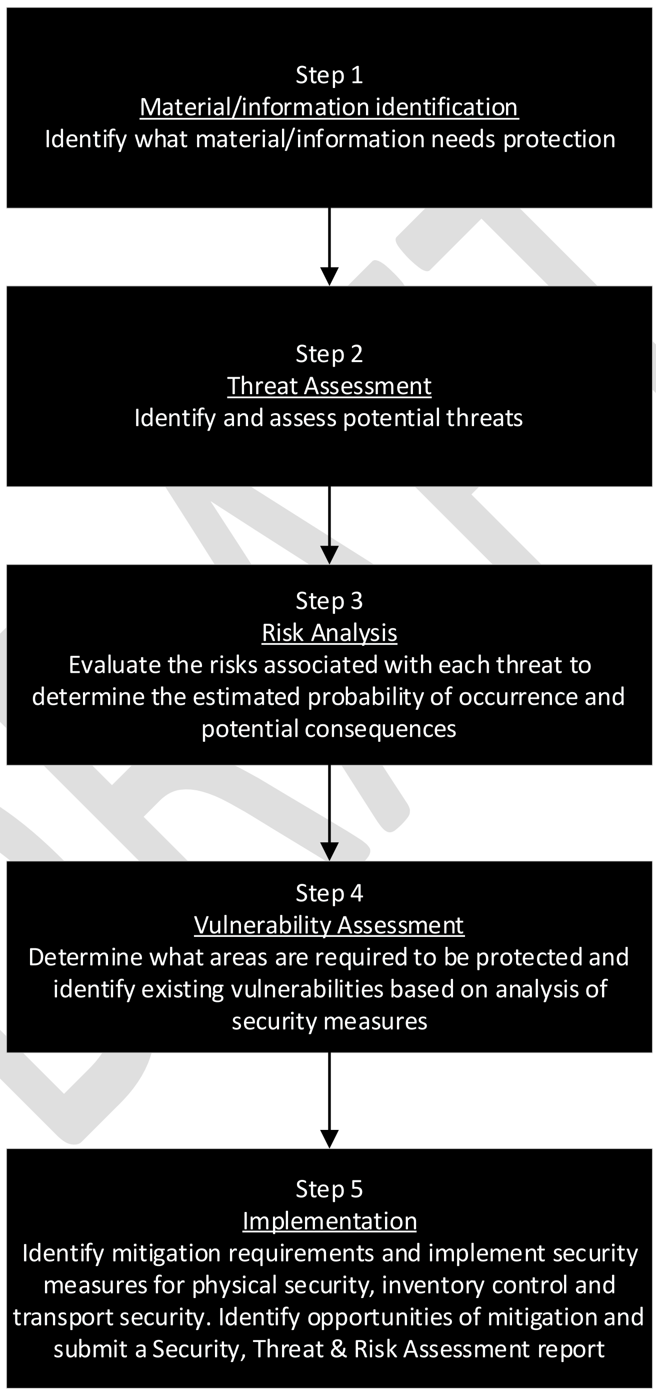
Procedure:

Senior Management will complete a Security Threat and Risk Assessment every three years.

Figure 1 depicts the process will be followed:

Figure 1 Security Threat and Risk Assessment Process

Process for Developing a Risk Based Approach



Asset Identification

1. Identify assets and loss impacts:
   a. Determine critical assets requiring protection.
   b. Identify undesirable events and expected impacts.
   c. Value and prioritize assets based on consequence of loss.

Threat Identification and Assessment

2. Identify and characterize threats.
   a. Identify threat categories and adversaries.
   b. Assess intent and motivation of adversaries.
   c. Assess capability of adversary or threat.
   d. Determine frequency of threat related incidents based on historical data.
   e. Estimate degree of threat relative to each critical asset.
3. Conduct site-specific threat assessment.

Risk Analysis

4. Conduct a risk assessment.
   a. Estimate the degree of impact of undesirable events relative to each critical asset.
   b. Estimate the likelihood of an attack from potential threats.
   c. Estimate the likelihood that a specific vulnerability will be exploited by a particular threat/adversary.

Vulnerability Assessment

5. Once a risk assessment has been completed, identify potential countermeasures to reduce vulnerabilities. Some typical countermeasures include, but are not limited to:
    - Procedures:
        - Security policies
        - Security procedures
        - Training
        - Awareness programs
        - Security investigations
        - Disclosure statements
        - Emergency procedures
    - Equipment:
        - Locking mechanisms
        - Doors
        - Fences
        - Alarms/sensors
        - Paper shredder
        - Closed circuit TV
    - Workforce:
        - Contractor security force
        - Vehicle checks
6. Identify the benefit of each option.
    - How does this option mitigate the risk?
    - Does this option detect, deter or destroy the risk?
    - To what degree does this option mitigate the risk?
7. Countermeasures should:
    - Reduce the risk to an acceptable level.
    - Protect against more than one vulnerability.
    - Satisfy the requirement for protection of the asset.

Implementation

8. Implement the countermeasures identified as a group in 'Step 5', then complete an effectiveness review after a set amount of time to determine if the countermeasures have been effective.

Records:

Record Name	Retention Time
WRE-SEC-401-00-00, Security Threat and Risk Assessment Form	Indefinite
WRE-QUA-115-05, Verification of Effectiveness Solutions	Indefinite

References:

Canadian Nuclear Safety Commission (CNSC). 2015a. General Nuclear Safety and Control Regulations. SOR/2000-202. Minister of Justice.

Canadian Nuclear Safety Commission (CNSC). 2017. Uranium Mines and Mills Regulations. SOR/2000-206. Minister of Justice.

International Atomic Energy Agency (IAEA). 2016. Nuclear Security in the Uranium Extraction Industry.

Author:

Senior Coordinator, Environment & QMS	**Tracy Gaudry**
Title	**Name**

Approver:

Vice President, Operations	**Kevin Himbeault**
Title	**Name**

36 Denison Mines Corp. Wheeler River Operation, Wheeler River Preliminary Decommissioning Cost Estimate and Financial Guarantee Memo, June 2025

The information in this reference document is subject to a request for confidentiality under rule 12 of the *Canadian Nuclear Safety Commission Rules of Procedure*. Contact the Commission Registry (interventions@cnsc-ccsn.gc.ca) for more information concerning confidentiality.