Environmental Protection Review Report: Rabbit Lake Operation

Executive summary

The Canadian Nuclear Safety Commission (CNSC) conducts environmental protection reviews (EPRs) for all nuclear facilities with potential interactions with the environment, in accordance with its mandate under the *Nuclear Safety and Control Act* to ensure the protection of the environment and the health and safety of persons. An EPR is a science-based environmental technical assessment conducted by CNSC staff. The fulfillment of other aspects of the CNSC's mandate is met through other oversight activities.

This EPR report was written by CNSC staff as a stand-alone document, describing the scientific and evidence-based findings from their review of Cameco Corporation's (Cameco's) environmental protection measures. Under its current uranium mine licence, UML-MINEMILL-RABBIT.01/2023, Cameco is permitted to mine and mill uranium at the Rabbit Lake Operation in northern Saskatchewan. The Rabbit Lake Operation is situated within Treaty 10 territory, the Homeland of the Métis, and is within the traditional territories of the Denesųłiné, Cree, and Métis peoples.

CNSC staff's EPR report focuses on items that are of Indigenous, public, and regulatory interest, such as potential environmental releases from normal operations, as well as on the risk of radiological and hazardous (non-radiological) substances to the receiving environment, valued components, and species at risk.

This EPR report includes CNSC staff's assessment of documents submitted by the licensee from 2013 to 2022 and the results of CNSC staff's compliance activities, including the following:

- the results of Cameco's environmental monitoring, as reported in annual reports
- Cameco's 2015 human health and ecological risk assessment for the Rabbit Lake Operation
- Cameco's 2020 environmental risk assessment for the Rabbit Lake Operation
- Cameco's 2020 preliminary decommissioning plan for the Rabbit Lake Operation
- the plans for the CNSC's Independent Environmental Monitoring Program
- the results from other environmental monitoring programs (such as the Eastern Athabasca Regional Monitoring Program) and/or health studies (including studies completed by other levels of government) in proximity to Cameco's Rabbit Lake Operation

Based on their assessment and evaluation of Cameco's documentation and data, CNSC staff have found that the potential risks from the Rabbit Lake Operation's radiological and hazardous releases to the atmospheric, terrestrial, aquatic, and human environments are low to negligible, and that these releases are at levels similar to natural background. Furthermore, human health is not impacted by operations at the Rabbit Lake Operation and the health outcomes are indistinguishable from health outcomes found in similar northern Saskatchewan communities. CNSC staff have also found that Cameco continues to implement and maintain effective environmental protection

measures that meet regulatory requirements and adequately protect the environment and the health and safety of persons. CNSC staff will continue to verify Cameco's environmental protection programs through ongoing licensing and compliance activities.

CNSC staff's findings from this report may inform recommendations to the Commission in future licensing and regulatory decisions, as well as inform CNSC staff's ongoing and future compliance verification activities. CNSC staff's findings do not represent the Commission's conclusions. The Commission's decisions will be informed by submissions from CNSC staff, the licensee, Indigenous Nations and communities, and the public, as well as through any interventions made during public hearings on licensing matters.

For more information on the Rabbit Lake Operation, visit the CNSC's web page and Cameco's web page. References used throughout this document are available upon request, subject to confidentiality considerations, and requests can be sent to ea-ee@cnsc-ccsn.gc.ca.

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1.0 Introduction

1.1 Purpose

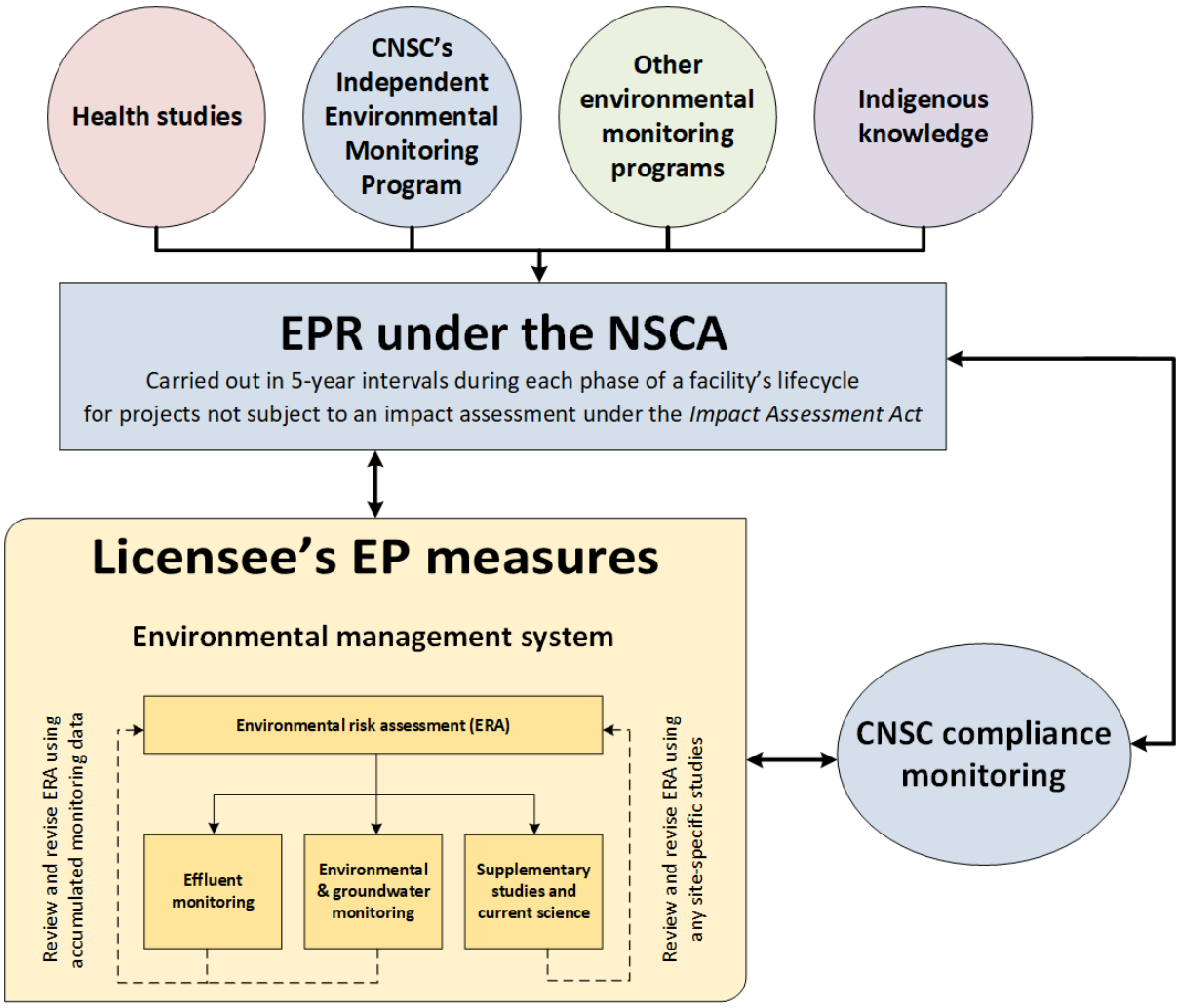
The Canadian Nuclear Safety Commission (CNSC) conducts environmental protection reviews (EPRs) for all nuclear facilities with potential interactions with the environment, in accordance with its mandate under the *Nuclear Safety and Control Act* (NSCA) [1]. CNSC staff assess the environmental and health effects of nuclear facilities and/or activities during every phase of a

facility's lifecycle. As shown in figure 1.1, an EPR is a science-based environmental technical assessment conducted by CNSC staff to support the CNSC's mandate for the protection of the environment and human health and safety, as set out in the NSCA. The fulfillment of other aspects of the CNSC's mandate is met through other regulatory oversight activities and is outside the scope of this report. Each EPR is typically conducted every 5 years and is informed by the licensee's environmental protection (EP) program and documentation submitted by the licensee as per regulatory reporting requirements.

As per the CNSC's **Indigenous Knowledge Policy Framework** [2], the CNSC recognizes the importance of considering and including Indigenous knowledge in all aspects of its regulatory processes, including EPRs. CNSC staff are committed to working directly with Indigenous Nations and communities and knowledge holders on integrating their knowledge, values, land use information, and perspectives in the CNSC EPR reports, where appropriate and when shared with the licensee and the CNSC.

The purpose of this EPR is to document the outcome of CNSC staff's assessment of Cameco Corporation's (Cameco's) EP measures and CNSC staff's health science and environmental compliance activities for the Rabbit Lake Operation. This review serves to assess whether Cameco's environmental protection measures at the Rabbit Lake Operation meet requirements and adequately protect the environment and the health and safety of persons.

Figure 1.1: EPR framework



CNSC staff's findings may inform recommendations to the Commission in future licensing and regulatory decision making, as well as inform CNSC staff's ongoing and future compliance verification activities.

CNSC staff's findings do not represent the Commission's conclusions. The Commission is an independent, quasi-judicial administrative tribunal and court of record. The Commission's conclusions and decisions are informed by information submitted by CNSC staff, the licensee, Indigenous Nations and communities, and the public, as well as through any interventions made during public hearings on licensing matters. The information in this EPR report is also intended to inform Indigenous Nations and communities, members of the public, and interested stakeholders.

EPR reports are prepared to thoroughly document CNSC staff's assessment relating to a licensee's EP measures and are posted online for information and transparency. Posting EPR reports online, separately from the documents drafted during the licensing process, allows interested Indigenous Nations and communities and members of the public additional time to review information related to EP prior to any licensing hearings or Commission decisions. CNSC staff may use the EPR

reports as reference material when engaging with interested Indigenous Nations and communities, members of the public, and interested stakeholders.

This EPR report is informed by documentation and information submitted by Cameco, compliance activities completed by CNSC staff from 2013 to 2022, as well as the following:

- regulatory oversight activities (section 2.0)
- CNSC staff's review of Cameco's 2020 Rabbit Lake Operation preliminary decommissioning plan [3] (section 2.2)
- CNSC staff's review of Cameco's annual compliance monitoring reports [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20]
- CNSC staff's review of Cameco's 2015 Rabbit Lake Operation human health and ecological risk assessment [21] (section 3.2)
- CNSC staff's review of Cameco's 2020 Rabbit Lake Operation environmental risk assessment [22] (section 3.2)
- the CNSC's Independent Environmental Monitoring Program (IEMP) plans, including discussions with Indigenous Nations and communities (section 4.0)
- health studies with relevance to the Rabbit Lake Operation (section 5.0)
- data from other environmental monitoring programs (EMPs) in proximity to the Rabbit Lake Operation site (section 6.0)

This EPR report focuses on topics related to the environmental performance of the facility, including atmospheric (emission) and liquid (effluent) releases to the environment, and the potential transfer of constituents of potential concern (COPCs) through key environmental pathways and associated potential exposures and/or effects on valued components (VCs), including human and non-human biota. VCs refer to environmental, biophysical, or human features that may be impacted by a project. The value of a component relates not only to its role in the ecosystem, but also to the value people place on it (for example, it may have scientific, social, cultural, economic, historical, archaeological, or aesthetic importance). The focus of this report is on radiological and hazardous substances associated with licensed activities undertaken at the Rabbit Lake Operation, with additional information provided on other topics of Indigenous, public, and regulatory interest, such as greenhouse gas (GHG) emissions. CNSC staff also present information on relevant regional environmental and health monitoring, including studies conducted by the CNSC or other governmental organizations.

1.2 Facility overview

This section of the report provides general information on the Rabbit Lake Operation site, including a description of the site location and a basic history of site activities and licensing. This information is intended to provide context for later sections of this report, which discuss completed and ongoing environmental and associated regulatory oversight activities.

1.2.1 Site description

The Rabbit Lake Operation is a uranium mine and mill facility located within the Athabasca Basin of northern Saskatchewan, approximately 750 kilometers (km) north of Saskatoon (figure 1.2). The

facility is located within Treaty 10 territory, the Homeland of the Métis, and is within the traditional territories of the Denesųłiné, Cree, and Métis peoples. Owned and operated by Cameco, the Rabbit Lake Operation includes an underground mine (Eagle Point ore body), a mill, the Rabbit Lake In-Pit Tailings Management Facility (RLITMF), the Above-Ground Tailings Management Facility (AGTMF), overburden stockpiles, lined ore pads, waste rock stockpiles, effluent treatment facilities, former open-pit mines, camp infrastructure, and an airstrip (figure 1.3).

The Rabbit Lake Operation is comprised of two surface leases (the Rabbit Lake lease and the Parks Lake lease) totalling approximately 2,500 hectares (ha) of land, and the surrounding area predominantly consists of boreal woodland with low floristic diversity interspersed with lakes, rivers, and streams. The site is located on the west side of Wollaston Lake and is accessible year-round. The site has potential to influence five watershed areas, namely Horseshoe Creek, Parks Lake, Link Lakes, Ivison Bay, and Collins Bay [22].

The Rabbit Lake Operation is situated in a sparsely populated and largely underdeveloped region of Saskatchewan. The communities of Hatchet Lake Denesųłiné First Nation and the adjoining Northern Hamlet of Wollaston Lake are the closest permanent communities and are located on the southeast shore of Wollaston Lake, approximately 32 km southeast of the site. La Ronge is the largest town in northern Saskatchewan (with a population of approximately 2,500 people, based on the 2021 Census) and is located 350 km south of the site [23]. Other active uranium mine and mill facilities are located in the region, including Cameco's Cigar Lake Operation, Key Lake Operation, and McArthur River operation, as well as Orano Canada Inc.'s McClean Lake facility.

Figure 1.2: Location of the Rabbit Lake Operation [22]

Figure 1.3: Aerial view of the Rabbit Lake Operation [24]

1.2.2 Facility operations

Cameco's Rabbit Lake Operation first began commercial operation of the open pit mine in 1975. Production of 5 million pounds per year was first achieved in 1977 and was maintained until the early 1980s, when lower ore grades resulted in lower production rates. The initial life of the mine was proposed to be 10 years; however, the identification of a series of smaller ore bodies, including the Collins Bay A-Zone, B-Zone, D-Zone, and Eagle Point deposits, led to further exploration. Mining of the Rabbit Lake Operation ore body was completed in May 1984, at which time the open pit was converted to a tailings management facility, otherwise known as the RLITMF, and use of the AGTMF for tailings deposition was discontinued. Additional preparations were made to the Rabbit Lake Operation site, and licensing approvals were obtained to begin extracting from the smaller ore bodies.

Open-pit mining of the Collins Bay B-Zone deposit began in 1985 and Eagle Point underground test mining commenced in 1991. Production mining of the Eagle Point deposit began in 1994, while production of the Collins Bay A-Zone and D-Zone deposits began in 1995. All tailings generated by the mining of these ore bodies were managed within the RLITMF. Production from the D-Zone was completed in 1996, followed by the A-Zone in 1997. Both pits were backfilled with waste material and a sand/till cap, and then flooded with water from Collins Bay. A transitional monitoring period followed, and reclamation activities were completed in 2006 for the A-Zone and in 2010 for the D-Zone.

Production from the Eagle Point underground mine continued, with a pause from 1999 until 2002 due to market conditions. Following the licensing approvals in 2008, the RLITMF pit crest was expanded in 2009 [24].

Current licence activities

The Rabbit Lake Operation's licence, UMOL-MINEMILL-RABBIT.00/2023, was issued by the CNSC in October 2013. The licence was amended in March 2021 (UML-MINEMILL-RABBIT.01/2023) to reflect the revised Rabbit Lake Operation financial guarantee.

Cameco is currently permitted to extract uranium from ore and produce up to 4.25 million kilograms (kg) of uranium (U) (equivalent to 11 million pounds (lbs) of uranium ore concentrate) per year from the mill for shipment off site. Additional authorized activities include:

- operation of the Eagle Point underground mine
- processing of uranium ore
- operation of the water treatment plant
- storage of clean and mineralized waste rock
- handling and storage of hazardous materials and disposal of hazardous wastes
- possession, storage, transfer, importation, use, and disposal of nuclear substances
- possession, transfer, importation, and use of radiation devices

Additionally, within the licence conditions handbook (LCH) [25], there is a provision for an increase in production at the Rabbit Lake Operation from 4.25 million kg of U to 6.5 million kg of U, provided Cameco notify the CNSC before implementing the increase. CNSC staff would

then ensure that the proposed production increase meets CNSC requirements and remains within the licensing basis for the Rabbit Lake Operation before Cameco would be permitted to proceed with the production increase at the facility.

In 2016, the Rabbit Lake Operation was placed in a state of safe care and maintenance, which has continued to date (2022). As such, key facilities are being preserved and contained, waste waters are being collected and treated, compliance activities are continued, and progressive decommissioning and reclamation projects are ongoing. The Eagle Point mine has an estimated remaining resource of 14.8 million kg U (indicated) and 13.0 million kg U (inferred). To date, Cameco has not informed CNSC staff of any plans to restart production at the Rabbit Lake Operation.

2.0 Regulatory oversight

The CNSC regulates nuclear facilities and activities in Canada to protect the environment and the health and safety of persons in a manner that is consistent with applicable legislation and regulations, environmental policies, and Canada's international obligations. The CNSC assesses the effects of nuclear facilities and activities on human health and the environment during every phase of a facility's lifecycle. This section of the EPR report discusses the CNSC's regulatory oversight of Cameco's EP measures for the Rabbit Lake Operation.

To meet the CNSC's regulatory requirements and according to the licensing basis for the Rabbit Lake Operation, Cameco is responsible for implementing and maintaining EP measures that identify, control, and (where necessary) monitor releases of radiological and hazardous substances and their effects on human health and the environment. These EP measures must comply with, or have implementation plans in place to comply with, the regulatory requirements found in Cameco's licence and LCH. The relevant regulatory requirements for Cameco's Rabbit Lake Operation are outlined in this section of the report.

2.1 Environmental protection reviews and assessments

To date, 3 federal environmental assessments (EAs) have been carried out for the Rabbit Lake Operation, as indicated in table 2.1. Subsection 2.1.1 provides a description of the EAs conducted under the Federal Environmental Assessment and Review Process (EARP) [26] and the *Canadian Environmental Assessment Act* (CEAA 1992) [27], predecessor to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) [28]. In 2019, the *Impact Assessment Act of Canada* (IAA) [29] came into force, replacing CEAA 2012. Cameco's current activities at the Rabbit Lake Operation do not require an impact assessment under the IAA's *Physical Activities Regulations* [30]. The purpose of any one of these assessments is to identify the possible impacts of a proposed project or activity and to determine whether those effects can be adequately mitigated to protect the environment and the health and safety of persons.

This stand alone EPR report is the first developed for the Rabbit Lake Operation. CNSC staff have previously publicly documented evaluations and assessments of Cameco's EP performance for the Rabbit Lake Operation through the EP sections found in the licensing Commission member documents (CMDs) and as part of the uranium mines and mills regulatory oversight reports (RORs).

Table 2.1: Federal EAs completed for the Rabbit Lake Operation

Project	Applicable EA process and/or legislation	EA start date	EA decision date
Rabbit Lake Uranium Mining A-Zone, D-Zone, Eagle Point (1)	Federal Environmental Assessment and Review Process (EARP)	1986	1988
Rabbit Lake Uranium Mining A-Zone, D-Zone, Eagle Point (2)	Federal Environmental Assessment and Review Process (EARP)	1991	1994
Rabbit Lake Solution Processing Project	*Canadian Environmental Assessment Act* (CEAA 1992)	2005	2008

2.1.1 Environmental assessments completed under the EARP and CEAA 1992

The original proposal to develop the Rabbit Lake Operation open-pit mine was initiated in 1975, prior to Canada having consistent federal environmental legislation in place. The same applies to the 1982 proposal to mine the B-Zone and transform the Rabbit Lake Operation pit into a tailings management facility.

Rabbit Lake Uranium Mining A-Zone, D-Zone, Eagle Point (1)

In 1986, Eldorado Resources Limited (Eldorado), the original owner of the Rabbit Lake Operation, sought approval from the Atomic Energy Control Board (AECB) to produce uranium from the Collins Bay A-Zone and D-Zone deposits, as well as develop an underground mine at nearby Eagle Point [31]. In January 1988, the Government of Saskatchewan issued an approval. This was followed by a conditional licence approval from the AECB in April 1988 for the Eagle Point underground test mine and the open-pit mining of A-Zone and D-Zone orebodies, subject to the submission of construction drawings. The AECB determined that the environmental effects of the proposed project were mitigable with known technology [32]. Eagle Point test mining commenced in 1991 [24]. No additional follow-up program requirements were identified as part of the EA process.

Rabbit Lake Uranium Mining A-Zone, D-Zone, Eagle Point (2)

In 1991, the AECB re-examined the approvals granted to Cameco in 1988. AECB referred the proposal for 2 open-pit operations in the Collins Bay A-Zone and D-Zone, and full production underground mining at Eagle Point, to the Minister of Environment for a review under the federal EARP to examine the environmental, health, safety, and socioeconomic impacts of the proposed project. The proposal was referred to the Minister of the Environment in accordance with section 14 of the EARP due to public concern regarding the proposal. A revised environmental impact statement was completed and submitted to regulatory agencies in 1992, followed by Cameco's participation in public hearings. The panel recommended that full-production underground mining at Eagle Point be allowed to proceed under conditions described in the panel report, and that mining of the A-Zone and D-Zone orebodies not proceed until

additional information be provided by Cameco on waste rock management and decommissioning and mitigation measures. In 1994, approval was granted to develop all three deposits [24]. No additional follow-up program requirements were identified as part of the EA process; however, recommendations were made for the creation of an environmental management committee to verify monitoring results and project activities related to waste-rock management, the tailings pit, water treatment, and cumulative effects [32]. This recommendation was considered in the formation of the Athabasca Working Group, which formed from an agreement-in-principle signed in 1994 between Saskatchewan uranium mining companies and communities of the Athabasca region.

Rabbit Lake Solution Processing Project

In 2005, a joint proposal that involved sending uranium-rich solution (URS) from Cogema Resources Inc.'s McClean Lake operation to Cameco Corporation's Rabbit Lake Operation for processing was submitted to the CNSC. The proposed project also included a request for modifications to the Rabbit Lake Operation mill (to receive the URS), modifications to the RLITMF pit crest to accommodate for managing of processing-related waste materials, and the construction of a dedicated haul road between the 2 operations.

CNSC staff determined that pursuant to subsection 18(1) of CEAA 1992, a screening EA of the project was required before a decision from the Commission could be made pursuant to the NSCA, and a screening report was prepared in accordance with the requirements of CEAA 1992.

Following the Commission's consideration of the screening report in 2008, the Commission rendered its decision on the EA stating that, upon considering implementation of mitigation measures identified in the EA screening report, the project was not likely to cause significant adverse environmental effects [33].

Follow-up program requirements were identified as part of the EA and accepted in the Commission decision. These requirements included ongoing compliance monitoring for socio-economic benefits, monitoring of the effluent discharge quality from the Rabbit Lake Operation effluent treatment system, research and monitoring of the long-term behaviour of arsenic in the RLITMF, model calibration to incorporate aquatic plant constituent concentrations, and monitoring to collect site-specific data in the area to verify assumptions related to presence of muskrat and waterfowl and constituent levels. The CNSC licensing and compliance program was used as the mechanism for ensuring implementation of follow-up activities and reporting results, with a planned endpoint of 2015 for the follow-up program [33].

2.2 Planned end state

The following section provides high-level information on the currently planned end-state of the Rabbit Lake Operation site following decommissioning activities. This section is informed by Cameco's preliminary decommissioning plan (PDP) for the Rabbit Lake Operation. The PDP is important to consider as part of CNSC staff's ongoing oversight for the assessment of environmental and health effects of nuclear facilities and activities during every phase of a facility's lifecycle.

A PDP is required to be developed by the licensee and submitted to the CNSC for review and acceptance as early as possible in the lifecycle of the facility or the conduct of the licensed activities. The PDP is progressively updated, where needed, to reflect the appropriate level of

detail required for the respective licensed activities. The PDP is developed for planning purposes only and the associated cost estimate is used to set aside dedicated decommissioning funding in the form of a financial guarantee. The PDP does not authorize decommissioning and does not provide sufficient details for the assessment of environmental impacts during decommissioning. Prior to the commencement of any decommissioning activities and to support an application for a licence to decommission, a detailed decommissioning plan is required to be developed by the licensee and submitted to the CNSC for review and acceptance.

The PDPs for nuclear facilities are updated at least every 5 years, or considering notable changes relevant to decommissioning, by the licensee and reviewed by CNSC staff. The decommissioning strategy and end-state objectives for the Rabbit Lake Operation are documented in the 2020 Rabbit Lake Operation Preliminary Decommissioning Plan [3].

Cameco has prepared the PDP based on a 'decommission tomorrow' scenario. The preliminary decommissioning activities for the Rabbit Lake Operation site include active thawing of historic frozen layers of the RLITMF, the removal of underground infrastructure at the Eagle Point mine, and flooding of the Eagle Point mine. Additionally, waste rock from mining activities would be placed within the RLITMF following completion of thawing; subsequently, a 2-m thick drainage layer and a 1-m till layer would be placed on top of the RLITMF. Water would be actively pumped and treated until completion of the cover, at which time water levels are expected to return to near pre-mining conditions.

This plan includes that all surface infrastructure would be dismantled on site, non-contaminated and non-hazardous waste would be removed and disposed of in the domestic landfill on site, and both radiological and hazardous waste would be placed in the AGTMF or the RLITMF. Environmental monitoring would be conducted during all stages of active decommissioning, followed by a 10-year transitional monitoring period. The Rabbit Lake Operation site, which encompasses approximately 435 ha of disturbed land (including the Parks Lake surface lease), would be graded, contoured, scarified, and vegetated to reintegrate the site with the surrounding environment. The airstrip may remain to serve as an emergency landing strip and administrative controls would be put in place in appropriate areas to prevent future development [3].

Cameco intends for the decommissioned Rabbit Lake Operation site to be transferred into the Province of Saskatchewan's Institutional Control Program once it has been confirmed that decommissioning objectives and criteria have been met and that the site is in a stable or improving condition. Cameco expects that the site will be suitable for certain traditional land uses following acceptance into the provincial Institutional Control Program. The site would meet unconditional clearance levels for all remaining material.

Cameco submitted a revised update of the Rabbit Lake Operation PDP in June 2020 (following an initial submission in May 2018). The revised PDP was reviewed and accepted by the CNSC in November 2020 [34]. An updated revised PDP was submitted in December 2022 and is currently under review by CNSC staff.

2.3 Environmental regulatory framework and protection measures

The CNSC has a comprehensive EP regulatory framework which includes the protection of people and the environment and considers both radiological and hazardous substances, as well as physical stressors (such as noise). Public dose is considered under the EP framework. The focus of this section of the EPR report is on the EP regulatory framework and the status of Cameco's

environmental protection program (EPP) for the Rabbit Lake Operation. The results derived from Cameco's EPP are detailed in section 3.0 of this report.

Cameco's EPP for the Rabbit Lake Operation was designed and implemented in accordance with REGDOC-2.9.1, Environmental Protection: Environmental Principles, Assessments and Protection Measures (2017) [35], as well as the CSA Group's environmental protection standards listed below. The implementation status for these items is shown in table 2.2.

Table 2.2: Status of EP measures to implement regulatory documents and standards

Regulatory document or standard	Status
CSA N288.4-10, Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills [36]	Implemented
CSA N288.5-11, Effluent Monitoring Program at Class I Nuclear Facilities and Uranium Mines and Mills [37]	Implemented
CSA N288.6-12, Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills [38]	Implemented
CSA N288.7-15, Groundwater Protection Programs at Class 1 Nuclear Facilities and Uranium Mines and Mills [39]	Implemented
CSA N288.8-17, Establishing and Implementing Action Levels to Control Releases to the Environment from Nuclear Facilities [40]	Implemented
CNSC REGDOC-2.9.1, Environmental Protection: Environmental Principles, Assessments and Protection Measures, version 1.1 (2017) [35]	Implemented

CNSC staff confirm that Cameco has implemented programs that are in compliance with the relevant EP regulatory documents and standards.

Licensees are also required to regularly report on the results of their EPPs. Reporting requirements are specified in REGDOC-3.1.2, Reporting Requirements, Volume I: Non-Power Reactor Class I Nuclear Facilities and Uranium Mines and Mills [41], the *Radiation Protection Regulations* [42] (for example, for action levels (ALs) or dose limit exceedances), and the LCH [25].

Cameco is required to submit annual reports as per REGDOC-3.1.2 [41]. These reports are reviewed by CNSC staff for compliance verification, as well as trending. Summaries of the effluent monitoring results contained in Cameco's annual reports are available on Cameco's Rabbit Lake Operation web page [43].

CNSC staff regularly report on licensee performance to the Commission for activities conducted at the Rabbit Lake Operation. For example, CNSC staff RORs are a standard mechanism for updating the Commission, Indigenous Nations and communities, and the public on the operation and the regulatory performance of licensed facilities. Previous RORs are available on the CNSC regulatory oversight reports web page [44]. CNSC staff may also report to the Commission on events, such as unplanned releases to the environment, through an initial event report.

2.3.1 Environmental protection measures

To meet the CNSC's regulatory requirements under REGDOC-2.9.1 (2017) [35], Cameco is responsible for implementing and maintaining EP measures that identify, control, and monitor releases of radioactive and hazardous substances from the Rabbit Lake Operation, as well as the effects of these substances on human health and the environment. EP measures are an important component of the overall requirement for licensees to make adequate provisions to protect the environment and the health of persons.

This subsection and the following ones under section 2.3 summarize Cameco's EPP for the Rabbit Lake Operation and the status of each specific EP measure, relative to the requirements or guidance outlined in the latest regulatory document or CSA Group standard. Section 3.0 of this EPR report summarizes the results of these programs or measures against relevant regulatory limits and environmental quality objectives or guidelines, and discusses, where applicable, any notable trends.

Cameco is required to implement an environmental management system (EMS) that conforms to REGDOC-2.9.1 (2017) [35] and to submit an EPP for the Rabbit Lake Operation. Cameco's EPP includes the following components to meet the requirements and guidance as outlined in REGDOC-2.9.1 (2017):

- EMS
- environmental risk assessment (ERA)
- effluent and emissions control and monitoring
    - air emissions and liquid effluent monitoring
- environmental monitoring program (EMP)
    - ambient air monitoring
    - terrestrial monitoring
    - surface water monitoring
    - groundwater monitoring

2.3.2 Environmental management system

An EMS refers to the management of an organization's environmental policies, programs, and procedures in a comprehensive, systematic, planned, and documented manner. It includes the organizational structure as well as the planning and resources to develop, implement, and maintain an EP policy. An EMS requires a facility to continuously improve its EPP; this includes periodic updates to the ERA. The results from the ERA updates determine whether the facility's effluent monitoring and EMP are effective. The EMS serves as a management tool to integrate all of a licensee's EP measures in a documented, managed, and auditable process, in order to:

- identify and manage non-compliances and corrective actions within the activities, through internal and external inspections and audits
- summarize and report on the performance of these activities both internally (licensee management) and externally (Indigenous Nations and communities, the public, interested stakeholders, and the Commission)
- train personnel involved in these activities

- ensure the availability of resources (that is, qualified personnel, organizational infrastructure, technology, and financial resources)
- define and delegate roles, responsibilities, and authorities essential to effective management

Cameco established and implemented an EMS for the Rabbit Lake Operation in accordance with REGDOC-2.9.1 (2017) [35] and is also registered and certified under the International Organization for Standardization (ISO) standard 14001:2015 (a standard that helps an organization achieve the intended outcomes of its EMS). CNSC staff review Cameco's annual internal audits, management reviews, and environmental goals, targets, and objectives to ensure compliance with REGDOC-2.9.1 (2017).

While the CNSC does not consider ISO 14001 certification as part of the criteria for meeting the requirements of REGDOC-2.9.1, the results of these third-party audits are reviewed by CNSC staff as part of the compliance program. As part of their review of the annual reports on EP, CNSC staff also review the status of Cameco's annual goals, targets, and objectives and implementation of the EMS.

The results of these reviews demonstrate that Cameco's EMS for the Rabbit Lake Operation meets CNSC requirements as outlined in REGDOC-2.9.1 (2017) [35]. The implementation of the EMS ensures that Cameco continues to improve environmental performance at the Rabbit Lake Operation.

2.3.3 Environmental risk assessment

An ERA of nuclear facilities is a systematic process used by licensees to identify, quantify, and characterize the risk posed by contaminants and physical stressors in the environment on human and other biological receptors, including the magnitude and extent of the potential effects associated with a facility. The ERA serves as the basis for the development of site-specific EP control measures and EMPs. The results of these programs, in turn, inform and refine future revisions of the ERA.

In 2020, Cameco submitted an updated Rabbit Lake Operation ERA [22] in accordance with the requirements set out in CSA N288.6-12 [38]. The ERA included updated assessments for the Collins Bay and Horseshoe Creek watersheds and reviews of the most recent ERAs for the Link Lakes (2015) and Parks Lake (2016) watersheds, along with an updated Rabbit Lake Operation air quality modelling assessment. CNSC staff found the Rabbit Lake Operation ERA to be compliant with CSA N288.6-12 [38] and found that human health and the environment in the vicinity of Rabbit Lake Operation remain protected.

Cameco's findings from the 2020 ERA are summarized in table 2.3. CNSC staff reviewed the ERA and found that potential effects on ecological and human health due to releases of COPCs to the air and water from the Rabbit Lake Operation are low to negligible. The next ERA for the Rabbit Lake Operation is expected in 2025.

Table 2.3: Summary of ERA findings for the Rabbit Lake Operation [22]

Type	Humans	Aquatic and terrestrial biota

Radiological	There are no adverse impacts expected from radiological COPCs released from the Rabbit Lake Operation.	There are no adverse impacts expected from radiological COPCs released from the Rabbit Lake Operation.
Hazardous	There are no adverse impacts expected from hazardous COPCs released from the Rabbit Lake Operation.	There are no adverse impacts expected from hazardous COPCs released from the Rabbit Lake Operation.
Physical stressors	No physical stressors associated with the operation of the Rabbit Lake Operation were found to be relevant for assessment.	No physical stressors associated with the operation of the Rabbit Lake Operation were found to be relevant for assessment.

2.3.4 Effluent and emissions control and monitoring

Controls on environmental releases are established to provide protection to the environment and to respect the principles of sustainable development and pollution prevention. The effluent and emissions prevention and control measures are established based on industry best practice, the application of optimization (such as in design) and of as low as reasonably achievable (ALARA) principles, the Canadian Council of Ministers of the Environment (CCME) guidelines, and results of the licensee's ERAs.

The Rabbit Lake Operation's current EPP [45] was reviewed and accepted by CNSC staff. This program contains licence limits and site-specific ALs to control radiological and hazardous effluent. Limits in the CNSC's licences for uranium mines and mills are adopted from schedule 4 of the *Metal and Diamond Mining Effluent Regulations* (MDMER) [46].

Under section 4 of the CNSC's *Uranium Mines and Mills Regulations* [47], Cameco is required to implement an environmental code of practice (ECOP) as part of their effluent monitoring program. The objectives of an ECOP are to ensure that releases to the environment are kept ALARA, and that any events which could indicate a potential loss-of-control are identified to ensure that corrective actions can be taken, if warranted. The ECOP contains ALs that serve as an early warning of a potential loss of control, to prevent a licence limit exceedance. ALs are derived from actual performance data from the mine and mill water treatment plant. This follows the methodology outlined in CSA N288.8-17 [40]. The ECOP also must contain actions that would be taken if an AL were to be exceeded, such as reporting the incident to the CNSC within 24 hours, immediately performing an investigation to determine whether a loss of control has occurred, taking immediate action to restore the effectiveness of the EPP, and submitting a report to the CNSC explaining the actions taken to correct the situation and prevent recurrence. In addition, Cameco has internal administrative levels that are set lower than the ALs.

The Rabbit Lake Operation effluent monitoring program was reviewed and accepted by CNSC staff in March 2022 and is compliant with REGDOC-2.9.1 (2017) [35] and the relevant standards, including CSA N288.5-11 [37].

Based on compliance activities, CNSC staff have found that the effluent monitoring program currently in place for the Rabbit Lake Operation continues to protect human health and the environment.

2.3.5 Environmental monitoring program

The CNSC requires each licensee to design and implement an EMP that is specific to the monitoring and assessment requirements of the licensed facility and its surrounding environment. The program is required to:

- measure contaminants in the environmental media surrounding the facility or site
- determine the effects, if any, of the facility or site operations on people and the environment
- serve as a secondary support to emission monitoring programs to demonstrate the effectiveness of emission controls

More specifically, the program must gather the necessary environmental data to calculate public dose and demonstrate compliance with the public dose limit found in the *Radiation Protection Regulations* [42] of 1 millisievert (mSv) per year. The program design must also address the potential environmental interactions identified at the facility or site. Hazardous substances are the major focus at the Rabbit Lake Operation, though radionuclides are included within monitoring activities associated with liquid discharges and air emissions. Cameco's EMP for the Rabbit Lake Operation consists of the following components:

- ambient air monitoring (radon and particulates)
- lichen monitoring
- aquatic biota monitoring (fish and benthic invertebrates)
- sediment monitoring
- surface water monitoring
- groundwater monitoring

Monitoring frequency is specified in the EMP. Ambient air, surface water, and groundwater monitoring is conducted regularly throughout each year, while lichen, aquatic biota, and sediment monitoring are conducted every 3, 6, or 10 years depending on the sampling media and location. Cameco's EMP also contains a requirement to perform annual inspections of synthetic liners and annual geotechnical inspections of retention ponds, ore pads, and other retaining structures within the Rabbit Lake Operation site.

Cameco is required to maintain its EMP to comply with REGDOC-2.9.1 (2017) [35] and relevant standards, including CSA N288.4-10 [36].

Based on compliance activities, CNSC staff have found that Cameco is compliant with REGDOC-2.9.1 (2017) [35] and continues to implement and maintain an effective EMP for the Rabbit Lake Operation that adequately protects the environment and the health and safety of persons.

2.4 Reporting of environmental releases under other federal or provincial legislation

A core element of the CNSC's requirement for an EMS is the identification of all regulatory requirements applicable to the facility, whether pursuant to the NSCA or other federal or provincial legislation. The EMS must ensure that programs are in place to respect these requirements.

2.4.1 Greenhouse gas emissions

While there are a range of broadly applicable federal environmental regulations (for example, petroleum products storage tanks, environmental emergency regulations), the management of GHG emissions has been identified as a national priority.

Under the federal *Canadian Environmental Protection Act, 1999* (CEPA 1999) [48], Cameco is required to monitor GHG emissions [49]. Nuclear facilities that emit more than the emission reporting threshold (that is, 10,000 tons of CO_2 equivalent) on an annual basis must report their GHG emissions to Environment and Climate Change Canada (ECCC).

In 2017, the reporting threshold was lowered from 50,000 tonnes CO_2 equivalent to 10,000 tonnes CO_2 equivalent. As a result, Rabbit Lake Operation reported GHG emissions to ECCC in 2017 and 2018. The Rabbit Lake Operation was below the reporting threshold in 2019 and 2020. The emissions data can be found on ECCC's Greenhouse Gas Reporting Program web page [50]. At the time of this EPR report's publication, the 2021 results were not yet available.

The CNSC maintains a collaborative working relationship with ECCC through a formal memorandum of understanding (MOU) [51], which includes a notification protocol. An exceedance of the GHG emissions threshold would be included under this notification protocol. This ensures that a coordinated regulatory approach is achieved to meet all federal requirements associated with EP, including GHGs.

2.4.2 Halocarbons

In accordance with the *Federal Halocarbon Regulations, 2022* [52], Cameco is required to provide a semi-annual halocarbon release report to ECCC on the release of halocarbons of an amount greater than 10 kg but less than 100 kg from any system, container, or equipment at the Rabbit Lake Operation. In the event of a release that surpasses 100 kg, Cameco would be required to report the releases to ECCC within 24 hours and ECCC would inform the CNSC through the notification protocol of the MOU. Cameco would then be required to submit a follow-up report within 30 days of the release detailing the circumstances leading to the release and the corrective and preventative actions taken to prevent a reoccurrence.

Between 2013 and 2021, Cameco reported 9 halocarbon releases. In 2013, there were 2 releases of 29.5 kg and 34.0 kg of R-22. In 2014, there were 2 releases of 11.4 kg and of 26.8 kg of R-22. In 2018, there was a release of 10.3 kg of R-410A. In 2020, there were 4 releases of R-22, in the amounts of 12.4 kg, 26.9 kg, 20.8 kg, and 14.1 kg. The releases were in accordance with ECCC's *Federal Halocarbon Regulations* [52]; therefore, CNSC staff found that there was little environmental impact from the R-22 and R-410A releases.

2.4.3 National Pollutant Release Inventory

Under the authority of CEPA 1999 [48], Cameco is required to report emissions of pollutants from the Rabbit Lake Operation to the National Pollutant Release Inventory (NPRI) [53] if they are above the reporting threshold [54]. Additional information about the NPRI can be found in section 6.3 of this report.

2.4.4 Other environmental compliance approvals

Cameco holds an approval to operate pollutant control facilities issued by the Saskatchewan Ministry of the Environment for the Rabbit Lake Operation [55]. The approval contains requirements for air emission monitoring, air quality monitoring, effluent monitoring, surface water monitoring, waste management, inspections, event and compliance reporting, decommissioning, and reclamation. The approval also contains effluent quality limits and authorized concentrations of contaminants in ambient air quality standards.

Emissions from the Rabbit Lake Operation throughout the current licensing period have complied with the facility's approval to operate pollutant control facilities and the CNSC's regulatory requirements. More information on these emissions can be found in sections 3.1.1, 3.1.2, and 3.1.3 of this report.

3.0 Status of the environment

This section provides a summary of the status of the environment around the Rabbit Lake Operation. It starts with a description of the radiological and hazardous releases to the environment (section 3.1), followed by a description of the environment surrounding the Rabbit Lake Operation and an assessment of any potential effects on the different components of the environment as a result of exposure to these contaminants (section 3.2).

CNSC staff regularly review the potential effects to environmental components through annual reporting requirements and compliance verification activities, as detailed in other areas of this report. This information is reported to the Commission in the sections on EP in licensing CMDs and annual RORs.

3.1 Releases to the environment

Radioactive and hazardous substances that have the potential to cause an adverse effect to ecological or human receptors are identified as COPCs. Once COPCs are emitted from a facility or a licensed site, they are considered a release to the environment. The ways in which COPCs could find their way to the different receptors considered by the ERA are called ‘exposure pathways’.

Figure 3.1 illustrates a conceptual model of the environment around the Rabbit Lake Operation uranium mine and mill to show the relationship between releases (airborne emissions or waterborne effluent) and human and ecological receptors. This graphic is meant to provide an overall conceptual model of the releases, exposure pathways, and receptors for the Rabbit Lake Operation, and thus, should not be interpreted as a complete depiction of the Rabbit Lake Operation site and its surrounding environment. The specific releases and COPCs associated with the Rabbit Lake Operation are explained in detail in the following subsections.

Figure 3.1. Conceptual model of the environment around the Rabbit Lake Operation

3.1.1 Licensed release limits

All operating uranium mines and mills in Canada are in northern Saskatchewan and are regulated at both the provincial and federal level. At the provincial level, the Saskatchewan Ministry of Environment issues an Approval to Operate a Pollutant Control Facility licence, which sets out release limits adopted from Saskatchewan's *Mineral Industry Environmental Protection Regulations* [56]. At the federal level, under the *Fisheries Act* [57], metal and diamond mines must adhere to the requirements of the MDMER [46], which contain release limits that are enforced by ECCC. In addition, under the NSCA, uranium mines and mills are issued a CNSC licence, which includes licence limits from the MDMER.

Table 3.1 shows the current MDMER-based licence limits for waterborne effluent applicable to the Rabbit Lake Operation

Table 3.1: Authorized licence limits for waterborne effluent at the Rabbit Lake Operation, adopted from the MDMER [46]

Deleterious substance	Maximum authorized monthly mean concentration [(a)]	Maximum authorized concentration in a composite sample [(b)]	Maximum authorized concentration in a grab sample [(c)]
Arsenic (mg/L)	0.30	0.45	0.60
Copper (mg/L)	0.30	0.45	0.60
Lead (mg/L)	0.10	0.15	0.20
Nickel (mg/L)	0.50	0.75	1.00
Zinc (mg/L)	0.50	0.75	1.00
Un-ionized ammonia (mg/L)	0.50	N/A[(d)]	1.00
Total suspended solids (mg/L)	15.00	22.50	30.00
Radium-226 (Bq/L)	0.37	0.74	1.11
Acid balance (H_3O^+) reported as pH	In a range of 6.0 to 9.5	In a range of 6.0 to 9.5	In a range of 6.0 to 9.5
Acutely lethal effluent [(e)]	0%	0%	0%

(a) "Monthly mean concentration" refers to the average value of the concentrations in composite or grab samples collected over a calendar month, in accordance with the MDMER [46].
(b) Based on the LCH [58], a "composite sample" refers to (i) a quantity of undiluted effluent consisting of a minimum of three equal volumes of effluent, or three volumes proportionate to flow, that has been collected at approximately equal time intervals over a sampling period of not less than 7 hours and no more than 24 hours, or (ii) a quantity of undiluted effluent collected continually at an equal rate, or at a rate proportionate to flow, over a sampling period of not less than 7 hours and no more than 24 hours.
(c) Based on the LCH [58], a "grab sample" refers to a quantity of undiluted effluent collected at any given time.
(d) N/A stands for "not available".
(e) "Acutely lethal" [46], in respect of an effluent, means that the effluent at 100 percent concentration kills

> a) more than 50 percent of the rainbow trout subjected to it for a period of 96 hours, when tested in accordance with the acute lethality test set out in section 14.1;
> b) more than 50 percent of the threespine stickleback subjected to it for a period of 96 hours, when tested in accordance with the acute lethality test set out in section 14.2; or
> c) more than 50 percent of the Daphnia magna subjected to it for a period of 48 hours, when tested in accordance with the acute lethality test set out in section 14.3.

There are currently no MDMER limits for selenium, uranium, and molybdenum; therefore, there are no limits for these parameters in the CNSC licence issued for the Rabbit Lake Operation. The limits for selenium and uranium provided in section 3.1.3 (table 3.4) come from the Province of Saskatchewan and are presented here to put the CNSC's regulatory expectations into perspective. While licensees must meet other federal and provincial regulatory requirements, the CNSC reserves the right to place more stringent expectations when deemed necessary. As such, the CNSC has required uranium mine and mill licensees to implement additional treatment technologies and process optimization techniques, where necessary. REDGOC-2.9.1 (2017) [35] requires licensees to demonstrate the application of the principles of ALARA and best available technology economically available (BATEA), and to ensure site-specific environmental protection related to selenium, uranium, and molybdenum. As a result, releases have been substantially lower than those authorized by the Province of Saskatchewan. Further information on controls of selenium and molybdenum can be found in section 3.1.3 of this report.

The CNSC has an interim objective for uranium releases of 0.1 mg/L used as a benchmark to demonstrate the current application of ALARA and BATEA. This value is based on a 2006 review of uranium treatment within the uranium mine and mill sector [59], which was prepared under contract for the CNSC.

No provincial or federal licence limits currently exist for molybdenum. In the 2000s, the CNSC required uranium mines and mills with high molybdenum releases to upgrade their effluent management and water treatment processes for treating molybdenum. This resulted in a significant reduction of molybdenum loadings to the environment. In the absence of a licence limit, uranium mine and mill licensees have implemented administrative limits and ALs to effectively manage and control molybdenum.

In the absence of a CNSC limit for selenium, the CNSC requires all uranium mines and mills to manage selenium releases to the environment. For the Rabbit Lake Operation, selenium is controlled using a target that is equal to the site-specific ERA upper bound concentration of 0.006 mg/L. This value is derived from the site's ERA modelling. The CNSC also requires that uranium mines and mills demonstrate continuous improvement by applying process optimization techniques that reduce the concentrations of molybdenum, selenium, and uranium in effluent. If a uranium mine or mill facility cannot achieve the selenium site specific targets, the CNSC will require the facility to go into adaptive management. This ensures that the licensee takes corrective actions to mitigate an identified unreasonable risk or a potential unreasonable risk to the environment to a level accepted by the CNSC. More information about adaptive management can be found in the draft of REGDOC-2.9.2, *Controlling releases to the environment* [60]. The selenium site-specific ERA upper bound concentration is currently being met for the Rabbit Lake Operation.

Draft REGDOC-2.9.2 [60] was recently developed by CNSC staff and was presented to the Commission in September 2022. Should REGDOC-2.9.2 be approved by the Commission as

drafted and become part of the licensing basis, formal licence release limits will be required for selenium, uranium, and molybdenum, as applicable.

3.1.2 Airborne emissions

Cameco controls and monitors airborne emissions from the Rabbit Lake Operation to the environment under its EPP. This program is based on CSA N288.5-11 [37] and includes monitoring of both radiological and hazardous emissions.

The sources of possible airborne releases at the Rabbit Lake Operation include:

- material handling of ore, waste rock, and overburden stockpiles and tailings
- grading of unpaved roads
- handling of sediment from sedimentation ponds
- wind erosion of ore, waste rock, and overburden stockpiles and tailings
- vehicle travel on unpaved areas, site roads, and haul roads
- diesel and propane fuel combustion
- ventilation exhaust from the mill building and uranium ore mill infrastructure
- underground mine ventilation exhaust
- emissions from ore, waste rock, and overburden stockpiles and tailings (radon)
- fugitive sources of radon

The emission sources have the potential to emit:

- particulate matter (PM) from the underground ventilation exhaust (that is, total suspended particulate (TSP), PM less than 10 microns in diameter (PM_{10}) and PM less than 2.5 microns in diameter ($PM_{2.5}$))
- gaseous COPCs from fuel combustion (that is, nitrogen oxides (NO_X) and sulphur dioxide (SO_2))
- metals from the underground mine ventilation exhaust and the ore and waste rock stockpiles (that is, arsenic, cobalt, copper, lead, molybdenum, selenium, nickel, and uranium)
- radon gas from the mill and mine ventilation exhaust, tailings, and waste rock stockpiles

Air emission sources identified for the Rabbit Lake Operation were modelled in the Rabbit Lake Operation air quality modelling assessment [61]. The results showed that there were no significant risks to the environment and persons from the identified emission sources. The total annual estimated airbirne emissions from the Rabbit Lake Operation are reported to the NPRI.

There are mitigation systems in place at the Rabbit Lake Operation to reduce the amount of airborne emissions released to the environment. For example, at the sulphuric acid plant, emissions from the acid plant are passed through a scrubber to remove sulphur trioxide (SO_3) before discharge to the environment. Further, emissions from the Rabbit Lake Operation mill uranium packaging process, the drying process, and packaging and drying rooms are passed through scrubbers to remove particulates before discharge to the environment.

Since April 2016, the Rabbit Lake Operation has been in a state of care and maintenance. Hence, the sulphuric acid plant has been shut down and there have been no releases to the environment.

Table 3.2 shows the total amount of sulphur dioxide released from the Rabbit Lake Operation from 2013 to 2021.

Table 3.2: Annual total airborne releases of sulphur dioxide from the Rabbit Lake Operation (2013 to 2021) [12] [13] [14] [15] [16] [17] [18] [19] [20]

Parameter	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sulphur dioxide (kg)	37,336	58,229	41,308	16,232	0	0	0	0	0

Table 3.3 shows the sulphur dioxide ambient levels from the Rabbit Lake Operation from 2013 to 2021 compared against the ambient air quality standards in the provincial approval to operate.

Table 3.3: Sulphur dioxide ambient levels from the Rabbit Lake Operation (2013 to 2021) [12] [13] [14] [15] [16] [17] [18] [19] [20]

Parameter	Standard	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maximum hour (ppm)	0.170	0.027	0.404	0.381	0.015	0	0	0	0	0
Maximum 24 hour (ppm)	0.060	0.013	0.047	0.029	0.006	0	0	0	0	0
Annual average (ppm)	0.010	0.0005	0.001	0.001	0.001	0	0	0	0	0

3.1.2.1 Findings

Based on their review of the results of the EPP and the Rabbit Lake Operation air quality modelling assessment, CNSC staff found that Cameco's air emissions to the environment from the Rabbit Lake Operation were very low to negligible during the period from 2013 to 2016. Since 2016, the Rabbit Lake Operation has been in care and maintenance and there have been no airborne emissions to the environment from the Rabbit Lake Operation mine and mill. CNSC staff have also found that Cameco continues to provide adequate protection of people and the environment from air emissions.

3.1.3 Waterborne effluent

Cameco controls and monitors liquid (waterborne) effluent from the Rabbit Lake Operation to the environment under its implementation of the EPP. This program is based on CSA N288.5-11 [37] and includes monitoring of radiological and hazardous releases.

The Rabbit Lake Operation mill process and effluent treatment systems receive contaminated water feeds from various sources, remove dissolved metals and suspended solids, and subsequently discharge to the final effluent polishing system adjacent to the Rabbit Lake Operation AGTMF for final treatment and discharge to Horseshoe Creek. The process is summarized in the facility's licensing manual [62] and the mill operations program [63].

The treatment process consists of multiple pH-controlled chemical precipitation and final polishing stages, which encompass the following:

- The solution neutralization and the low pH clarifier stage is used to precipitate arsenic, molybdenum, selenium, and radium and other metals that will precipitate at a low pH. Lime slurry, sulphuric acid, ferric sulphate, and barium chloride are added to the effluent in pachuca tanks. The effluent is fed to a low pH clarifier and then to the to the high pH neutralization circuit.
- The high pH neutralization circuit is used to react and precipitate heavy metals, radium, uranium, and other metals that will precipitate at a high pH. Barium chloride, ferric sulphate, and lime slurry are added to reaction tanks. The effluent is fed to the mine water treatment circuit.
- The mine water treatment circuit adds sulphuric acid to neutralize the high-pH solution down and additional barium chloride and ferric sulphate for further polishing of the effluent in the settling ponds.
- The effluent polishing stage is used to precipitate further barium-radium sulphate and other metal sulphates. Additional ferric sulphate is added in the first settling pond. The effluent is fed into a second settling pond where barium chloride is added.

The treated effluent from the precipitation ponds is discharged to a channel which feeds into an overflow weir called Weir #2. This weir can be controlled to prevent the discharge of effluent, if required. Then, the effluent reaches Weir #3, which is the final point of control. During normal operations, the effluent is continuously discharged over Weir #3. The compliance monitoring consists of the collection of weekly composite (24-hour) samples. A composite sample of the final effluent is taken by an automatic interval sampling system.

There is instrumentation located throughout the water treatment plant that monitors the pH of the effluent throughout the water treatment process and the flow rates of the reagents and flocculants added to the water treatment process. There is also instrumentation on the pipes to and from the water treatment plant that monitor pressure. A significant change in pressure would indicate that there is a potential leak in the pipe. These readings are monitored in real-time by the water treatment plant operators. There are different alarms associated with these readings. These alarms will alert the operators if a parameter is outside of normal operating conditions. If an alarm is received, the operators will investigate and take corrective actions as necessary. If there is a major process upset, the operators will immediately shut down the water treatment plant and take actions to correct the situation. Furthermore, Cameco has the ability to manually stop discharge at Weir #3 at the Rabbit Lake Operation, if needed.

Cameco is required to monitor temperature, conductivity, pH, metals (arsenic, copper, lead, molybdenum, nickel, selenium, uranium, unionized ammonia, and zinc), and radionuclides (radium-226, thorium-230, polonium-210, and lead-210) in effluent released from the Rabbit Lake Operation.

Table 3.3 summarizes the annual monthly mean concentrations of liquid effluent discharged to Horseshoe Creek from 2013 to 2021, before dilution at the end of pipe. In addition to licence limits, Cameco has established liquid effluent ALs at the Rabbit Lake Operation for important COPCs, such as uranium, molybdenum, selenium, and internal control levels (also known as administrative levels). Exceedances of licence limits and ALs are required to be reported to the CNSC, and are subsequently documented, investigated, and appropriate corrective actions are taken where warranted. As shown in table 3.4, all of the COPCs in the effluent discharged from the Rabbit Lake Operation remain at a very small fraction of regulatory limits and no AL at the water treatment plant has been exceeded over the current reporting period.

Table 3.4: Annual waterborne releases from the Rabbit Lake Operation compared with applicable release limits (2013 to 2021) [12] [13] [14] [15] [16] [17] [18] [19] [20]

Parameter [(a)]	Licence limit	2013	2014	2015	2016	2017	2018	2019	2020	2021
Arsenic (mg/L)	0.3	0.0055	0.0056	0.0040	0.0025	0.0010	0.0009	0.0009	0.0009	0.0012
Copper (mg/L)	0.3	0.0045	0.0040	0.0030	0.0013	0.0002	0.0003	0.0002	0.0002	0.0002

Lead (mg/L)	0.1	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Nickel (mg/L)	0.5	0.0144	0.0184	0.0057	0.0038	0.0017	0.0015	0.0013	0.0013	0.0014
Zinc (mg/L)	0.5	0.0010	0.0010	0.0010	0.0010	0.0006	0.0006	0.0007	0.0005	0.0009
pH [(b)]	6.0 to 9.5	7.2	7.3	7.4	7.3	7.5	7.5	7.1	7.2	7.3
Radium-226 (Bq/L)	0.37	0.008	0.010	0.007	0.007	0.007	0.006	0.006	0.006	0.006
Total suspended solids (TSS) (mg/L)	15	2	2	2	2	1	1	1	1	1
Un-ionized ammonia [(g)] (mg/L)	0.5	0.01 [(f)]	0.01 [(f)]	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Selenium (mg/L)	0.6 [(c)]	0.0052	0.0042	0.0042	0.0035	0.0024	0.0026	0.0023	0.0026	0.0025
Uranium (mg/L)	2.5 [(d)]	0.063	0.046	0.052	0.073	0.070	0.032	0.027	0.021	0.018
Molybdenum (mg/L)	N/A [(e)]	0.324	0.282	0.268	0.273	0.139	0.180	0.159	0.184	0.213

(a) Results show the mean of the concentrations for each month in 1 year.
(b) pH is taken from every discharge samples. It is not measured in monthly composite samples.
(c) This is the provincial limit that is not in the CNSC licence.
(d) This is the provincial limit that is not in the CNSC licence. As discussed in subsection 3.1.1, in the absence of a CNSC licence limit for uranium, the CNSC uses the interim objective for uranium of 0.1 mg/L as a benchmark to demonstrate the application of ALARA and BATEA.
(e) Refer to subsection 3.1.1 for an explanation of why no provincial or federal licence limits currently exist for molybdenum.
(f) The 2013 and 2014 un-ionized ammonia values are calculated using the measured temperature, field pH, and ammonia values.
(g) Un-ionized ammonia was added to the MDMER in 2021.

Table 3.5 summarizes the annual waterborne loadings to the environment before dilution for the period of 2013 to 2021. Following 2016, the loadings and concentrations of COPCs decreased due to the Rabbit Lake Operation being placed in care and maintenance.

Table 3.5: Annual waterborne loadings discharged to Horseshoe Pond from Weir #3 (2013 to 2021) [12] [13] [14] [15] [16] [17] [18] [19] [20]

Parameter	2013	2014	2015	2016	2017	2018	2019	2020	2021
Arsenic (kg)	23.4	24.1	16.9	11.0	3.7	3.9	3.7	3.4	4.5
Copper (kg)	19.3	17.4	12.6	6.0	0.8	1.1	1.0	0.8	0.9
Lead (kg)	0.6	0.9	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Nickel (kg)	61.1	78.9	24.1	17.0	6.8	6.4	5.2	4.8	5.4
Zinc (kg)	5.5	4.7	5.3	3.4	2.2	2.4	2.9	2.0	3.4
Radium-226 (MBq)	32.7	41.0	30.0	32.9	25.6	26.4	25.2	24.0	22.6
Total suspended solids (TSS) (kg)	8014	7635	7728	8212	4948	6004	5044	4216	5600
Selenium (kg)	22.0	18.0	17.9	15.8	9.2	10.9	9.1	9.8	9.5
Uranium (kg)	266.8	199.7	220.7	326.9	274.0	135.8	106.1	80.3	68.9
Molybdenum (kg)	1376.7	1212.7	1139.2	1226.1	542.7	757.4	623.4	696.9	815.3

Cameco is also required by the MDMER to perform quarterly acute lethality testing on the treated effluent at the final point of discharge using rainbow trout (*Oncorhynchus mykiss*) and water fleas (*Daphnia magna*) as test organisms in accordance with ECCC's procedures [46]. These are recognized standard aquatic toxicity tests used in concert with effluent limits to assess compliance with the MDMER. Acute lethality, as defined in the MDMER, means that the effluent at 100% concentration kills more than 50% of the rainbow trout over a 96-hour test period or more than 50% of the water fleas over a 48-hour test period. During the current licensing period (2013 to 2021), results showed that the treated effluent discharged from the Rabbit Lake Operation met the MDMER acute lethality requirements.

3.1.3.1 Selenium and molybdenum in effluent

As described in section 3.1.1, both selenium and molybdenum have been the focus of increased regulatory oversight by the CNSC. This is because ERAs completed in the mid-2000s indicated that releases of selenium and molybdenum have the potential to cause adverse environmental effects. As a result of this finding and upon request by the Commission [64] [65], licensees added administrative controls and upgrades to their effluent treatment systems and improved engineering controls and treatment technologies to reduce effluent releases. These actions have been successful to date for the uranium mining sector, where molybdenum and selenium releases

have substantially decreased since the mid-2000s and continue to be effectively controlled and closely monitored.

In this latter context and in response to the increase in selenium and molybdenum, Cameco implemented process optimization techniques in the mine water treatment plant to more effectively control selenium and molybdenum in effluent. This resulted in a decrease in loadings to the environment. Recent effluent data shows that loadings of selenium and molybdenum to the environment are stable.

3.1.3.2 Findings

CNSC staff found that reported liquid effluent discharged from the Rabbit Lake Operation to Horseshoe Creek remained below the CNSC's licence limits throughout the reporting period (2013 to 2021). CNSC staff also found that the treated effluent met the requirements for acute leathality testing to aquatic organisms in the receiving environment.

CNSC staff are satisfied that Cameco is taking the appropriate measures at the Rabbit Lake Operation, as mentioned above, to effectively control and reduce concentrations and loadings of molybdenum, uranium, and selenium in waterborne effluent.

3.2 Environmental effects assessment

This section presents an overview of the assessment of predicted effects from licensed activities on the environment and the health and safety of persons. CNSC staff reviewed Cameco's assessment of current and predicted effects on the environment and health and safety of persons due to licensed activities included in the ERA (see subsection 2.3.3) for the Rabbit Lake Operation. The ERA was performed in a stepwise manner, as follows:

- quantify the releases (of COPCs) to the environment from current (see section 3.1) and future activities
- identify the environmental interactions of the current and expected releases of COPCs, and COPC exposure pathways in the environment
- identify predicted COPC exposure for ecological and human receptors
- identify potential effects to receptors
- determine whether the environment and the health and safety of persons are and will continue to be protected

To inform this section of the report, CNSC staff reviewed Cameco's ERA [22], along with Cameco's 2019 comprehensive aquatic monitoring report [66], 2020 environmental performance report [66], and annual reports submitted between 2013 and 2021, inclusively [12] [13] [14] [15] [16] [17] [18] [19] [20].

While CNSC staff conducted a review for all environmental components, only a selection of components is presented in detail in the following subsections. The environmental components were selected based on regulatory requirements, facility type, and geographic context; some were also included because they have historically been of interest to the Commission, Indigenous Nations and communities, and the public.

3.2.1 Atmospheric environment

An assessment of the atmospheric environment requires Cameco to characterize both the meteorological conditions and the ambient air quality at the Rabbit Lake site.

3.2.1.1 Meteorological conditions

Meteorological conditions, such as temperature, wind speed, wind direction, and precipitation are monitored to assess the extent of the atmospheric dispersion of contaminants emitted to the atmosphere, the rates of contaminant deposition, and to determine predominant wind directions, which are used to identify critical receptor locations from the air pathway.

The Rabbit Lake Operation is in the Athabasca Plain ecoregion of the Boreal Shield ecozone of northern Saskatchewan. The climate in this region is typical of the continental sub-arctic region and is characterized by short, cool, and moist summers, and very cold, dry winters. This ecozone is classified as having a sub-humid high boreal climate. The average frost-free period is approximately 90 days.

Meteorological hourly data inputs were gathered in 2018 from the Collins Bay automated weather observing station and used to inform the air dispersion modelling assessment for the Rabbit Lake Operaiton.

3.2.1.2 Ambient air quality

ERA predictions

In the 2020 ERA, Cameco predicted and assessed the potential impacts to ambient air quality at the Rabbit Lake Operation by conducting an air dispersion modeling assessment to predict air quality concentrations and deposition rates to estimate potential risks to humans and ecological receptors [22].

Overall, the potential air quality influences from the Rabbit Lake Operation during operations, care and maintenance, and decommissioning are expected to be limited and are related to exceedances of 24-hour TSP and PM_{10} Saskatchewan Ambient Air Quality Standards (SAAQS) at off-property receptor locations.

In the decommissioning scenario, exceedances do not extend more than 500 m beyond the lease boundary and the number of predicted exceedances is within the range of historical measurements collected during operations. During care and maintenance and decommissioning, radon concentrations are expected to be elevated near some sources, but drop off quickly with distance and are indistinguishable from background levels within 2.5 km of the lease boundary.

During the post-decommissioning period, both onsite and offsite radon concentrations are predicted to return to natural background levels.

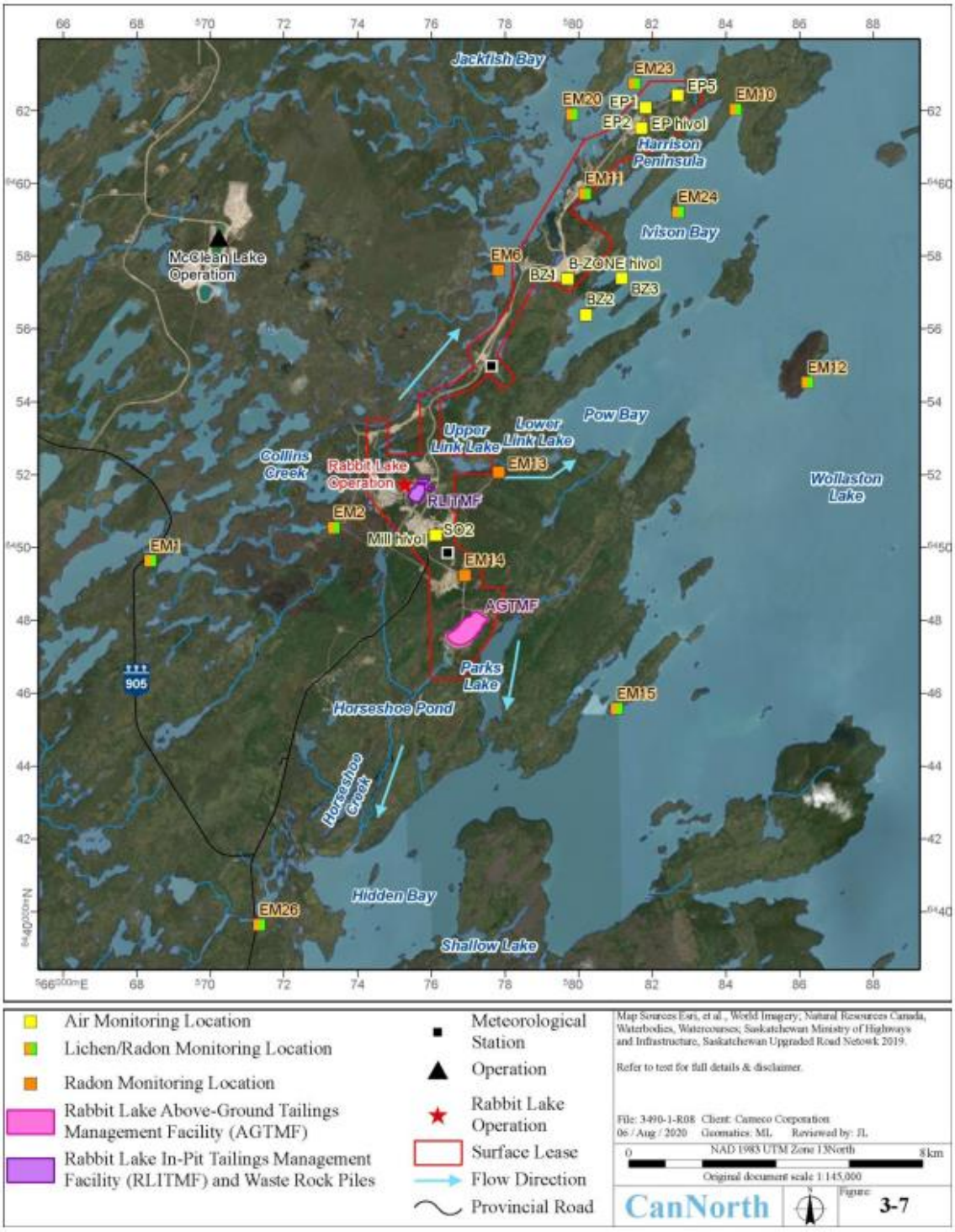
Ambient air monitoring

Ambient air quality monitoring at the Rabbit Lake Operation includes monitoring for sulphur dioxide (when the facility is in operation), radon, TSP, and select radionuclides and metals. Monitoring is completed to ensure that air quality meets applicable standards and regulations.

As part of Cameco's EPP, a suspended particulate monitoring program is implemented using high-volume air samplers (Hi-Vols) (figure 3.2). The Hi-Vols are placed at three locations

around the facility and are used to monitor TSP emissions from site operations. The TSP collected is further analyzed to determine the number of adsorbed metals (arsenic, nickel, and uranium) and radionuclides (lead-210, radium-226, and thorium-230) in dust. Radon-222 is monitored at fifteen locations around the facility using passive radon detectors (track-etch cups). Lastly, onsite meteorological stations are used to monitor site-specific weather patterns and record long-term climate trends at the facility.

Figure 3.2: Air quality, radon, and lichen monitoring locations for the Rabbit Lake Operation [67]



Between 2015 to 2019, which is the time period covered in the Rabbit Lake Operation's most recent ERA, the results from these monitoring locations show that TSP and adsorbed metals and

radionuclides were well within established standards and estimated background levels (table 3.6). The radon-222 monitoring program demonstrated that radon-222 levels were elevated near sources of radon-222 emissions, but the measured levels rapidly decreased to be consistent with background levels within a short distance [67].

Table 3.6: Metal and radionuclide concentrations adsorbed to total suspended particulate at Station #9 (B-Zone) from 2015-2019 [67]

Parameter	Minimum	Maximum	Median
Arsenic (ng/m^3)	0.0	1.9	0.3
Nickel (ng/m^3)	0.0	3.0	0.3
Uranium (ng/m^3)	0.0	1.8	0.2
Lead-210 (mBq/m^3)	0.0049	0.0220	0.0126
Radium 226 (mBq/m^3)	0.0000	0.0024	0.0004
Thorium-230 (mBq/m^3)	0.0000	0.0015	0.0006

Lichen chemistry is monitored as an indicator of air quality to measure potential spatial and temporal influences. Results measured during the current period (2015-2019) indicated that contaminant concentrations were most elevated at near-field stations in close proximity to Rabbit Lake Operation infrastructure, but that concentrations measured were lower than previous years, which could in part be due to the Rabbit Lake Operation going into care and maintenance.

3.2.1.3 Findings

Based on the review of Cameco's ERA and the results of the atmospheric monitoring program, CNSC staff found that airborne emissions from the Rabbit Lake Operation remain within the ERA predictions; therefore, ambient air quality remains at levels protective of human health and the environment.

3.2.2 Terrestrial environment

An assessment of potential effects on terrestrial biota at the Rabbit Lake Operation and the surrounding area consists of characterizing the local habitat and species (including considering federal and provincial species at risk) and assessing the possibility of their exposure to radiological and hazardous substances that may be disruptive to ecological receptors.

3.2.2.1 Soil quality

ERA predictions

Soil quality is not predicted to be a significant pathway of exposure for the Rabbit Lake Operation through either food chain transfer, incidental ingestion, groundshine, or dermal contact for human or ecological receptors.

Soil quality monitoring

Cameco collected soil samples in 2008 from 10 sites within a 5 km radius of the study area, and from 2 reference sites outside the study area (table 3.7). Samples were taken at a depth of 0 to 5 centimeters (cm). Model predicted soil contaminant concentrations were comparable to measured concentrations and were found to be well below their respective soil guidelines.

Soil is largely connected to air emissions through deposition from air, which are limited for the Rabbit Lake Operation. As such, no soil monitoring program is required at this time.

Table 3.7: Soil sampling results from the study area of the Rabbit Lake Operation from 2008 [68]

Parameter	CSQG	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10	Station 11	Station 12	Mean
Arsenic (µg/g)	-	0.9	1.7	0.7	1.2	0.5	1.9	0.8	0.4	1.5	1.9	0.6	1.1	1.10
Copper (µg/g)	63	1.3	1.1	0.9	1.2	1.8	1.3	0.6	1.2	3.3	0.9	1.7	1.2	1.38
Lead (µg/g)	140	3.7	2.9	2.9	2.8	2.5	3.6	2.2	1.8	5.7	2.5	2.9	2.5	3.00
Nickel (µg/g)	50	2.2	8.7	2.2	7.7	1	4.6	1.6	1.4	2.3	6.4	3.9	4.2	3.85
Zinc (µg/g)	200	7.4	15	3.5	5.1	5.4	6.8	5.7	2.9	6	12	32	15	9.73
Radium-226 (Bq/g)	-	0.01	0.04	0.04	<0.01	0.02	0.04	0.02	0.01	0.03	0.06	0.03	0.03	0.03
Selenium (µg/g)	1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.11
Uranium (µg/g)	23	1.1	2	0.9	1.4	0.7	1.2	0.5	0.8	1.8	1.3	0.8	1.1	0.13
Molybdenum (µg/g)	-	0.3	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.16

3.2.2.2 Terrestrial habitat and species

The terrestrial habitat in the region surrounding the Rabbit Lake Operation is within the Northern Transition Section of the Boreal Forest Region. This area is characterized by low floristic diversity, which results from the adverse climate, shallow rooting depths, thin soils of mixed sandy loam, and a high fire frequency. The terrestrial environment study area considered a 10 km radius area centered around the site.

Wildlife habitat in the area is typically boreal woodland. A young jack pine habitat dominates the immediate area and provides cover for small mammals and many bird species. An abundance of nearby lakes and connecting drainages ensures the availability of riparian areas potentially important for moose. Wildlife populations and diversity can vary significantly within the boreal woodlands area. Greater than 40 mammal species are typically present in the ecozone. The bird density is moderately low with 218 species reported to appear in the region.

Habitat mapping was completed around 2 of the site drainage systems in 2006 to document the presence/absence of muskrat and other aquatic mammals in these areas. This habitat study found that although key potential summer habitat areas for muskrat are present in Horseshoe Creek and Link Lakes watershed, the lack of suitable winter habitat is a limiting factor for their abundance. Overall, habitat quality is poor and habitat supply is limited. Muskrat is present in the area, but the population density remains low. Signs of beaver, otter, and mink activity have also been observed. Moose were seen during an aerial survey and waterfowl nests were found in low numbers [22].

Terrestrial species at risk

In Saskatchewan, the following legislation applies to species at risk; the *Wild Species at Risk Regulations* [69], which is integrated with the federal *Species at Risk Act* (SARA) [70] and applies to species at risk. Biological surveys were conducted to identify the species at risk potentially present on or around the Rabbit Lake Operation. Table 3.8 lists the 5 terrestrial species at risk that were identified as potentially present around the Rabbit Lake Operation and that were assessed in the 2020 ERA.

Table 3.8: Status of terrestrial species at risk present around the Rabbit Lake Operation

Category	Species	SARA status [70]	Assessment Notes
Birds	Bank swallow	Threatened	Observed in study area; assessed via surrogate (Canada warbler)
Birds	Canada warbler	Threatened	Observed in study area; assessed
Birds	Horned grebe	Special Concern	Observed in study area; assessed via surrogate (scaup)
Birds	Olive-sided flycatcher	Threatened	Observed in study area; assessed via surrogate (Canada warbler)
Mammals	Woodland caribou	Threatened	Sign of observed in study area; assessed

ERA predictions

The most recent assessment of potential effects on terrestrial biota near the Rabbit Lake Operation was provided in the 2020 ERA [22]. As discussed in subsection 2.3.3, the ERA fully complied with the requirements of CSA N288.6-12 [38] and incorporated recent environmental monitoring data.

Cameco selected terrestrial receptors for the assessment based on knowledge of the site and its surrounding environment and relevant field observations. They include terrestrial birds, aquatic birds, terrestrial mammals, and aquatic mammals (namely bald eagle, willow ptarmigan, Canada warbler, mallard, common merganser, lesser scaup, masked shrew, snowshoe hare, moose, caribou, grey wolf, black bear, red fox, muskrat, beaver, mink). The 5 species at risk identified as potentially occurring in the area (namely bank swallow, Canada warbler, horned grebe, olive-sided flycatcher, and woodland caribou) are also included as terrestrial receptors. The selected terrestrial receptors reflect a variety of diets or feeding habits, cover a variety of trophic levels, and are representative of the potential species present in the area.

Exposure to radiological substances

The potential radiological effects to ecological receptors were assessed by comparing the estimated radiation dose received by each ecological receptor from radiological COPCs through all applicable pathways (namely external and internal exposure due to radionuclides in air, soil, water, sediment, and gamma radiation) to the recommended benchmark values (that is, dose limits to non-human biota).

The overall radiation dose, which included all internal and external doses from all exposure pathways, were below their respective soil guidelines and radiological dose benchmarks recommended in CSA 288.6-12 [38] (that is, 100 micrograys per hour (µGy/h) for terrestrial receptors), as well as the more conservative benchmark of 41 µGy/h (1mGy/d) used for species at risk. This result indicates negligible potential for adverse effects and no need for further detailed assessments.

Exposure to hazardous substances

The potential hazardous effects to ecological receptors were assessed by comparing the estimated exposure concentration received by each ecological receptor from hazardous COPCs through all applicable pathways (namely exposure to hazardous contaminants in air, lichen, vegetation, water, sediment, benthic invertebrates, phytoplankton, zooplankton, and aquatic vegetation) to the recommended benchmark values (that is, toxicity reference values for non-human biota).

For the Rabbit Lake Operation ERA, potential influences were characterized both temporally and spatially within an integrated probabilistic framework to address uncertainties in the assessment of effects. This allowed the development of the mean and 95th percentile confidence intervals of predicted exposures, which incorporate conservative assumptions in areas of uncertainty to ensure there are no negative effects. As such, there are expected to be no negative effects on terrestrial plants related to the Rabbit Lake Operation. The evaluation of wildlife found that for receptors with an aquatic-based diet (namely beaver, mallard, merganser, mink, muskrat, and scaup) a potential risk was identified due to exposure of muskrat to molybdenum for the expected and upper-bound scenarios in Horseshoe Creek. Given this is not expected to result in population-level effects due to the conservative assumptions used and a small area of concern, CNSC staff are in agreement that no mitigation measures are required at this time. Special consideration was given to species at risk that could use the surrounding area, but there is a wide margin of safety for the protection of both individual aquatic receptors given that results were well below screening criteria for both the expected and upper bound scenarions. As such, it is expected that there would be no negative effects on the species at risk potentially present at the Rabbit Lake Operation.

3.2.2.3 Findings

Based on the review of Cameco's ERA and the results of the EPP for the Rabbit Lake Operation facility, CNSC staff have found that the exposure risk to muskrat is low and the probabilistic assessment confirms that the terrestrial environment remains protected from radiological and hazardous releases during potential expected and upper bound situations from the Rabbit Lake Operation.

3.2.3 Aquatic environment

An assessment of potential effects on aquatic biota at the Rabbit Lake Operation and the surrounding area consists of characterizing the local habitat and species (including considering federal and provincial species at risk) and assessing the possibility of their exposure to radiological and hazardous substances.

3.2.3.1 Surface water quality

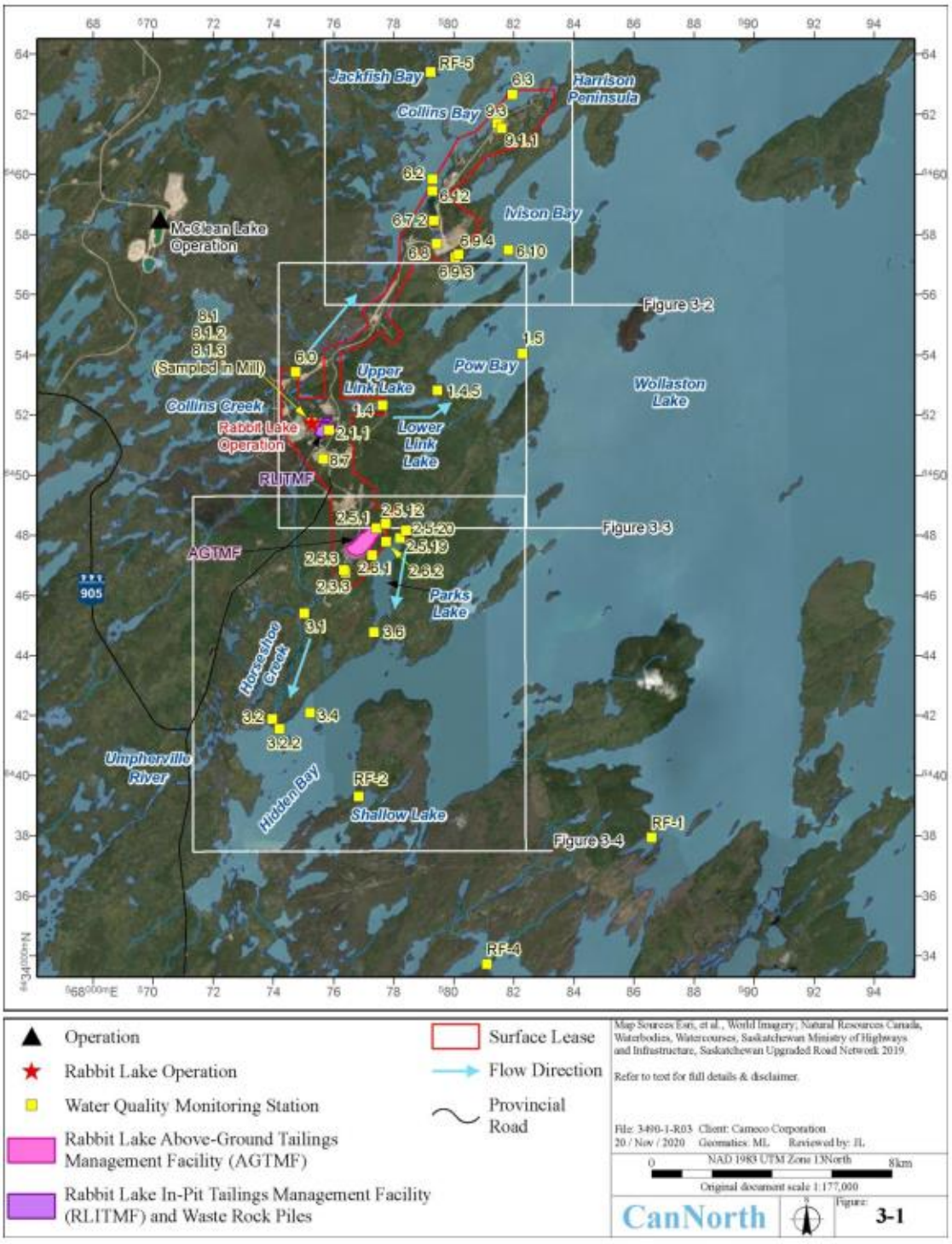
ERA predictions

Probabilistic modelling was used to confirm that the surface water quality can be expected to remain below surface water quality guidelines for most COPCs in the expected scenario, with exceedances for uranium, selenium, and fluoride in Horseshoe Pond through the decommissioning period. Shorter-term exceedances are predicted for uranium, selenium, and fluoride in Horseshoe Creek. Once the treated effluent release ends, concentrations are expected to quickly decline to levels below the applicable Saskatchewan Environmental Quality Guidelines (SEQG) [71]. There are no predicted exceedances of the surface water quality guidelines in Hidden Bay on Wollaston Lake.

Surface water monitoring

Monitoring at the Rabbit Lake Operation considers the Horseshoe Creek watershed, Parks Lake watershed, and Link Lakes watershed, which all flow into Wollaston Lake (figure 3.3). Collins Bay and Ivison Bay of Wollaston Lake are also considered. Treated effluent is discharged into Horseshoe Creek, which then flows roughly 9 km, via Horseshoe Pond, to discharge into Hidden Bay of Wollaston Lake. Seepage from the AGTMF moves in three directions; namely northward toward a wetland area (consisting of both constructed and natural wetland features) with discharge into the north end of Parks Lake, eastward through the ridge that separates the facility from Parks Lake with discharge along the west shoreline of Parks Lake, and southward toward Horseshoe Creek.

Figure 3.3: Surface water quality monitoring locations for the Rabbit Lake Operation [67]



Surface water quality was consistent at the three stations sampled in Collins Bay and COPC concentrations were also similar to those measured upstream of the Rabbit Lake Operation in

Collins Creek. No guidelines were exceeded by any COPC in these areas and trend analyses indicated there have been very few changes in COPCs over the past 10 years. On the other hand, in the flooded B-Zone pond, metal concentrations (that is, arsenic, molybdenum, nickel, and uranium) decreased significantly over the last 10 years whereas ions, nutrients, and physical parameters increased significantly. Some arsenic concentrations and all nickel concentrations continued to exceed guidelines, which is consistent with historical results and ERA predictions. In Ivison Bay, no guidelines were exceeded and COPC concentrations have remained relatively unchanged in the last 10 years, although there has been a significant decrease in molybdenum.

In the Link Lakes drainage, concentrations of COPC in surface water were highest in Upper Link Lake and lowest in Pow Bay of Wollaston Lake, illustrating a downstream gradient. Uranium and radium-226 concentrations in Upper Link Lake and uranium concentrations in Lower Link Lake continued to exceed guidelines, which is consistent with historical results and ERA predictions, and are expected to drop below guidelines within the next decade. These concentrations are due to historical practices (such as drainage of the mineralized and clean waste rock piles through open channels until the mid-1990s) and historic contributions (such as mine slimes from the 1970s) [67]. Trend analyses indicated there were significant decreases in the concentrations of numerous COPCs in the Link Lakes drainage over the past 10 years, including molybdenum concentrations at all stations. In Pow Bay, COPC concentrations measured were low and below guidelines.

Water quality monitoring in the Horseshoe Creek drainage has shown statistically significant declines in most COPC concentrations from 2010 to 2019 (table 3.9). The decreases reflect various initiatives that were implemented to reduce concentrations of molybdenum, selenium, and uranium in treated effluent. As expected, there was a decreasing gradient of COPC concentrations from upstream to downstream; in other words, water quality guidelines continued to be exceeded for many COPCs within Horseshoe Creek and Horseshoe Pond and continued to be below guidelines in Hidden Bay. In the Parks Lake drainage, concentrations of COPCs were below guidelines, other than pH, which is naturally low in the drainage gradient.

Table 3.9: Surface water quality at Station 3.1 - Horseshoe Pond [22]

Parameter [a]	Unit	Saskatchewan Environmental Quality Guidelines [b]	2010 to 2014 Median	2015 to 2019 Mean	Trend
Arsenic	µg/L	5	2.65	1.87	Decrease
Cobalt	mg/L	0.0018 [a]	0.0015	0.0008	Decrease
Copper	mg/L	0.004 [b]	0.0012	0.0007	Decrease
Lead	mg/L	0.007 [c]	<0.0001	0.0001	N/A
Molybdenum	mg/L	31	0.41	0.18	Decrease
Nickel	mg/L	0.150 [d]	0.0097	0.003	Decrease
Selenium	mg/L	0.001	0.00355	0.002	Decrease
Uranium	µg/L	15	51.5	36.1	Decrease
Lead-210	Bq/L	N/A [e]	<0.02	0.03	N/A
Polonium-210	Bq/L	N/A [e]	<0.007	0.009	N/A
Radium-226	Bq/L	0.11	0.0065	0.006	N/A
Thorium-230	Bq/L	N/A [e]	<0.01	0.01	N/A

(a) Cobalt value is from the Federal Environmental Quality Guidelines and is hardness dependant: 0.00078 mg/L when hardness is 52 mg/L; 0.0018 mg/L when hardness is 396 mg/L.
(b) Copper objective: 0.002 mg/L where hardness is 0 – 120 mg/L; 0.003 mg/L where hardness is 120 – 180 mg/L; 0.004 mg/L where hardness is > 180 mg/L.
(c) Lead objective: 0.001 mg/L where hardness is 0 – 60 mg/L; 0.002 mg/L where hardness is 60 – 120 mg/L; 0.004 mg/L where hardness is 120 – 180 mg/L; 0.007 mg/L where hardness is > 180 mg/L.
(d) Nickel objective: 0.025 mg/L where hardness is 0 – 60 mg/L; 0.065 mg/L where hardness is 60 – 120 mg/L; 0.110 mg/L where hardness is 120 – 180 mg/L; 0.150 mg/L where hardness is > 180 mg/L.
(e) There are no SEQGs for lead-210, polonium-210 and thorium-230; therefore, CNSC staff assess trends over time.

Cameco will continue to monitor water quality under their EMP to track changes over time, as well as compare and assess results relative to the ERA predictions.

3.2.3.2 Sediment quality

ERA predictions

Sediment quality is predicted to remain below sediment quality guidelines for most COPC in the expected scenario, with exceedances for molybdenum, copper, lead-210, and polonium-210. The COPC sediment exceedances are limited spatially to Horseshoe Pond and Horseshoe Creek and are expected to continue to decline with time due to upgrades to the effluent treatment system and the care and maintenance phase of the operation, which is consistent with ERA predictions.

Sediment monitoring

Cameco collects sediment samples at exposure and reference stations every 3 to 5 years (depending on the location) in accordance with the facility's EMP. Cameco submits the samples to an accredited laboratory where they are analyzed for metals, radionuclides, nutrients, and general chemistry. The results are then compared to the reference station concentrations and against the Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life (ISQG) [72], the Canadian Probable Effects Level (PEL) Sediment Quality Guidelines [73], and the Lowest Effects Levels (LEL) derived for uranium mining areas in Canada [73]. No-effects

(NE2) levels were also developed to account for local benthic invertebrate tolerance and potential chemical interactions at no-effect exposure sites [73].

Mean sediment levels exceed the NE2 benchmarks for molybdenum in Horseshoe Pond, with exceedances of the LEL benchmark indicated for arsenic, copper, nickel, selenium, and uranium (table 3.10). Mean concentrations for copper and molybdenum similarly exceed applicable benchmarks in Horseshoe Creek.

Table 3.10: Mean concentrations of COPCs in sediments in Horseshoe Pond for 2016 and 2019 [22]

Parameter	REF[(a)]	ISQG[(b)]	PEL[(c)]	LEL[(d)]	NE2[(e)]	2016	2019
Arsenic (µg/g)	20.8	5.9	17	9.8	522	84	77
Cobalt (µg/g)	-	-	-	-	-	16	17
Copper (µg/g)	-	35.7	197	22.2	-	53.8	51.8
Lead (µg/g)	-	35	91.3	36.7	-	2.8	3
Molybdenum (µg/g)	22.6	-	-	13.8	245	2224	2422
Nickel (µg/g)	21.4	-	-	23.4	326	83	95
Selenium (µg/g)	3.6	-	-	1.9	29.7	33.2	28.2
Uranium (µg/g)	96.7	-	-	104.4	2296	845	998
Lead-210 (Bq/g)	-	-	-	0.9	-	0.71	0.51
Polonium-210 (Bq/g)	-	-	-	0.8	-	0.56	0.56
Radium-226 (Bq/g)	-	-	-	0.6	-	0.28	0.33
Thorium-230 (Bq/g)	-	-	-	-	-	0.25	0.17

(a) REF refers to the 1997-2015 mean concentration at the near-field reference areas.
(b) ISQG stands for the "Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life" [73].
(c) PEL stands for "Probable Effects Level" [73].
(d) LEL stands for "Lowest Effects Levels" [73].
(e) NE2 stands for "No-Effects Levels" [73].

Horseshoe Creek drainage sediment concentrations are generally decreasing and are expected to continue to recover from historic concentrations. From 2002 to 2017, decreasing trends have been observed throughout the Horseshoe Creek drainage for arsenic, selenium, uranium, and molybdenum. Other contaminant sediment concentrations measured throughout the Horseshoe Creek drainage have remained relatively constant over time [67].

Cameco will continue to collect sediment samples at exposure and reference stations every 3 or 5 years (at the same time and locations as the benthic invertebrate samples are collected) while an additional 2 samples are collected from Collins Bay in accordance with the facility's EMP. Cameco will continue to track changes over time, as well as compare and assess results relative to the ERA predictions.

3.2.3.3 Aquatic habitat and species

Background water quality in the lakes and streams are typical of Precambrian Shield watersheds. The pH values tend to be neutral to slightly acidic, controlled by bicarbonates. Hardness and conductivity tend to be moderately low and heavy metal concentrations and radionuclide levels are generally below detection levels or guidelines [22].

Numerous fisheries investigations conducted since 1972 all reported on the presence of benthic fish in Collins Bay, Ivison Bay, Hidden Bay, and Wollaston Lake. A variety of benthic fish have been observed in the Collins Bay area and in Wollaston Lake. Fish population and large-bodied fish chemistry surveys are completed every three years in the Horseshoe Creek drainage including in 2002, 2005, 2008, 2012, 2016, and 2019. Examples of benthic fish found in study area lakes include lake whitefish, longnose sucker, slimy sculpin, and white sucker. Fish spawning habitats were observed in the Collins Bay area for lake whitefish and suckers, as well as throughout Horseshoe Creek and its associated ponds for white suckers [22]. The following fish chemistry survey in the Horseshoe Creek drainage was conducted in 2022.

Aquatic species at risk

The only aquatic species at risk identified as potentially inhabiting the Rabbit Lake Operation site is the northern leopard frog. However, site surveys have never observed nor detected signs of northern leopard frog within the Rabbit Lake Operation study area.

ERA predictions

The most recent assessment of potential effects on aquatic biota near the Rabbit Lake Operation was provided in the 2020 ERA [22]. As discussed in subsection 2.3.3, the ERA fully complied with requirements of CSA N288.6-12 [38] and incorporated recent environmental monitoring data.

OPG selected aquatic receptors for the assessment based on knowledge of the Rabbit Lake Operation site, its surrounding environment, and relevant field observations. These include amphibians, pelagic fish, zooplankton, benthic fish, benthic invertebrates, phytoplankton, and aquatic plants. The chosen ecological receptors reflect a variety of diets or feeding habits, cover a variety of trophic levels, and are representative of the potential species present in the area.

Exposure to radiological substances

The potential radiological effects to ecological receptors were assessed by comparing the estimated radiation dose received by each ecological receptor from radiological COPCs through all applicable pathways (namely external and internal exposure due to radionuclides in air, soil, water, sediment, and gamma radiation) to the recommended benchmark values (that is, dose limits to non-human biota).

The overall radiation dose, which included all internal and external doses from all exposure pathways, were below their respective water quality guidelines and radiological dose benchmarks recommended in CSA 288.6-12 [38] (that is, 400 µGy/h for aquatic receptors). This result indicates negligible potential for adverse effects and no need for further detailed assessments.

Exposure to hazardous substances

The potential hazardous effects to ecological receptors were assessed by comparing the estimated exposure concentration received by each ecological receptor from hazardous COPCs through all applicable pathways (namely exposure to hazardous contaminants in air, lichen, vegetation, water, sediment, benthic invertebrates, phytoplankton, zooplankton, and aquatic vegetation) to the recommended benchmark values (that is, toxicity reference values for non-human biota).

Aquatic biota in Horseshoe Creek may be influenced by the release of treated effluent to the system. N potential negative effects on aquatic biota are anticipated in Hidden Bay and Collins Bay of Wollaston Lake. For receptors with an aquatic-based diet (namely beaver, mallard, merganser, mink, muskrat, and scaup), a potential risk due to exposure of muskrat to molybdenum in Horseshoe Creek was identified but is not expected to result in population-level effects.

Aquatic environment monitoring

Aquatic environment monitoring is necessary for uranium mines and mills to meet the requirements of the MDMER, as well as any additional requirements from the CNSC and the Saskatchewan Ministry of Environment. Aquatic biota monitoring (namely benthic invertebrate, small-bodied fish population, and fish chemistry) was conducted on a 3-year cycle until 2012, and on either a 3-year (Horseshoe Creek drainage) or 10-year (Link Lakes drainage) cycle since 2012. There is no routine aquatic biota monitoring in Collins Bay or the Parks Lake drainage; however, special studies (that is, fish community and tissue chemistry, vegetation and soil monitoring or reclamation progress) are intermittently conducted.

Possible risks to benthic invertebrates were identified in Lower Link Lake but not in Pow Bay. Lower Link Lake benthic invertebrate community metrics have not shown any significant trends over time, although they have consistently differed from the reference community, which could be due to historical impacts, although this has not been confirmed. The benthic invertebrate community in Pow Bay continued to show no effects and endpoints have remained consistent over time [67]. Fish chemistry contaminant concentrations have decreased over time in fish from Upper and Lower Link lakes, but fish community diversity has been similar over time in both lakes.

Fish in Horseshoe Pond and Horseshoe Creek may be influenced by the exposure to selenium; however, studies have indicated that the water levels and flow volumes to Horseshoe Pond are artificially sustained (that is, treated effluent provides flow volumes that would not exist naturally). For these reasons, it is not expected that conditions in Horseshoe Pond are directly comparable to those in a natural waterbody and Horseshoe Pond has an absence of a measurable resident fish community [22].

3.2.3.4 Findings

CNSC staff reviewed the aquatic monitoring data and analysis, along with any other routine or special investigations [67], and confirmed that the impacts to the receiving aquatic environment and biota were within the predictions of the 2020 ERA [22] and that there is minimal risk to the aquatic environment.

Based on these reviews, CNSC staff have found that the aquatic environment remains protected from radiological and hazardous releases from the Rabbit Lake Operation.

3.2.4 Hydrogeological environment

The geological and hydrogeological environment of the Rabbit Lake Operation area has been characterized through a series of studies [74] [66]. Assessment on the impacts to the hydrogeological environment (in terms of groundwater flow and quality) is mainly based on the ongoing groundwater monitoring program in the Rabbit Lake Operation area.

3.2.4.1 Geological conditions

The Rabbit Lake Operation site spans several drainage basins, all of which ultimately discharge to Wollaston Lake. The site geology is comprised of 3 major lithostratigraphic units, namely (from top to bottom):

- Overburden or surficial deposits: This unit includes recent deposits, upper deglacial sediments, upper till, lower till, and lower gravel, typically ranging from 5 m to 20 m in thickness.
- Athabasca sandstone: This unit is not present in some areas (such as Eagle Point).
- Basement rock: This unit consists of Archean granites of the Pre-Wollaston Group and early Proterozoic paragneissic rocks of the Wollaston Group.

3.2.4.2 Groundwater quantity and quality

The shallow groundwater flow generally reflects topography where it is not influenced by pumping, dewatering, and/or other surface features. The primary regional groundwater discharge locations are Collins Creek and Wollaston Lake, with groundwater recharge occuring along topographic highs.

The shallow groundwater flow systems are the primary focus of the groundwater protection plan and groundwater monitoring program. Groundwater elevation data has been relatively consistent during the current assessment period. The shallow groundwater flow regime of the Harrison Peninsula (including Eagle Point, former A-Zone and D-Zone pits, and B-Zone pond) is usually flowing westward to Collins Bay or the B-Zone pond. The influence of underground mine operation at Eagle Point is demonstrated in both the shallow and deeper groundwater flow system. In the immediate vicinity of the Rabbit Lake Operation mill and RLITMF, the local groundwater flow regime is affected by the ongoing dewatering of the RLITMF.

Groundwater quality monitoring in the functional areas generally demonstrates some level of influence to the groundwater from site facilities and operations. In most cases, the COPC concentrations that are elevated above baseline have been relatively consistent (that is, with no significant increasing or decreasing trends) or decreasing. CNSC staff will pay special attention to cases where an increasing trend has been observed locally in areas as part of the annual compliance reports review.

Details of the local, shallow groundwater flow regimes and the monitored groundwater quality in each of the fucntional areas (includig Eagle Point underground mine area, A-Zone, D-Zone and B-Zone areas, RLITMF and Mill Area, and AGTMF area) are described below in more details.

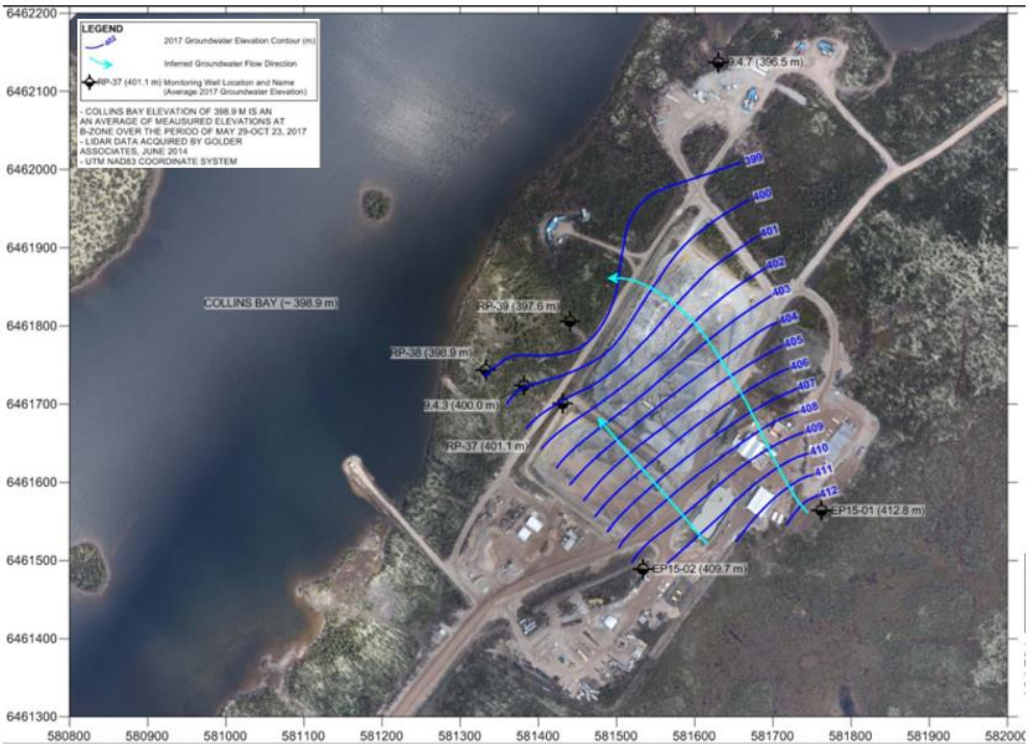
Eagle Point Underground Mine

The groundwater elevation contours developed from the recent monitoring data demonstrate groundwater flow from southeast to northwest across the Eagle Point area towards Collins Bay

(figure 3.4). The contours also show that the groundwater table is influenced by the dewatering of the underground mine operations, with localized drawdown occuring in the vicinity of the air raise shafts and/or toward the workings located near the shoreline in Collins Bay.

Groundwater quality monitoring indicates that upgradient shallow groundwater appears to have been influenced by surface development to the east of the mine portal. Downgradient shallow groundwater also demonstrates some influence from upgradient facilities (primarily Eagle Point Waste Rock Pile (EPWRP) and Eagle Point Ore Pad (EPOP)); however, solutes have not yet been detected further downgradient along the horizontal flow path within predicted time frames. The drawdown induced by the underground mine workings appears to be capturing seepage from upgradient facilities (that is, EPOP and EPWRP).

Figure 3.4: Groundwater elevation contours and inferred flow in the Eagle Point Underground Mine Area [67]



B-Zone and D-Zone areas

Based on the groundwater monitoring data around the B-Zone Waste Rock Pile (BZWRP) and B-Zone Ore Pad (BZOP), a hydraulic groundwater divide has been inferred to intersect the BZWRP and extend southwest across the BZOP (figure 3.5). Shallow groundwater from portions of these facilities flows either west/northwest (ultimately towards Collins Bay) or east/southeast (toward Ivison Bay). Around the decommissioned and reclaimed D-Zone Waste Rock Pile (DZWRP) and the B-Zone Sedimentation Pond, shallow groundwater flow is from east to west, towards Collins Bay. Overall, the groundwater flow regime in the D-Zone and B-Zone areas has remained consistent in this assessment period.

Around the immediate vicinity of the BZWRP, there has been a trend of stable to decreasing solute concentrations, except the area along the eastern edge of the pile, where some influence on

the groundwater has been observed. Cameco identified that strategic monitoring points along the southeast and northwest sides of the BZOP (immediately downgradient of the facility on either side of the inferred flow divide) should be installed and the water quality assessed [66].

Groundwater quality data indicates that COPC concentrations in groundwater beneath the DZWRP are within baseline ranges. Monitoring around the B-Zone Sedimentation Pond shows only slightly elevated COPCs above baseline ranges; however, concentrations have been generally decreasing.

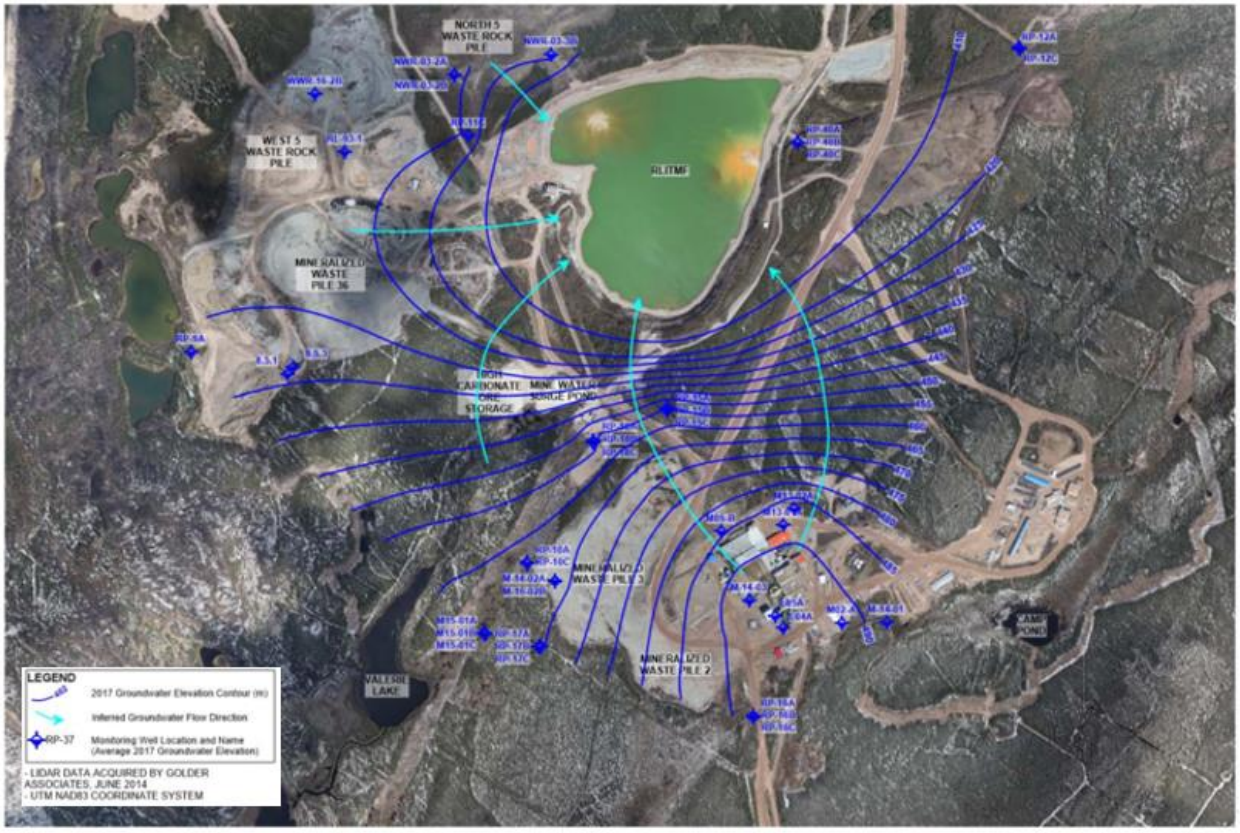
Figure 3.5: Groundwater Elevation Contours and Inferred Flow in the D-Zone and B-Zone Areas [67]

RLITMF and Mill areas

Groundwater elevations in the monitoring wells demonstrate continued drawdown towards the RLITMF over much of this area and show that the majority of sources are within the capture zone of the RLITMF (figure 3.6). Exceptions include the south/southwestern edge of Mineralized Waste Pile 2 (southwest of the Mill Complex), southeast of the Mill Complex, and along the western edge of the West 5 WRP.

Groundwater quality monitoring in these areas show some level of localized influence from site facilities and activities. The concentrations of COPCs that are elevated above baseline have been relatively consistent (although in some cases variable), with no significant increasing or decreasing trends. As indicated by the groundwater elevations, the majority of the groundwater exhibiting these operationally induced changes are within the capture zone of the RLITMF.

Figure 3.6: Groundwater Elevation Contours and Inferred Flow in the RLITMF and Mill Area [67]



AGTMF area

Groundwater monitoring data shows that shallow groundwater generally flows from northwest to southeast across the AGTMF and towards Park Lake (figure 3.7). However, some alteration of the shallow groundwater flow directions occur at the north and south dams of the facility. At the south dam and across the effluent treatment pond area, groundwater flows to the south-southwest towards Horseshoe Creek. Overall, groundwater flow regime in the AGTMF area has remained consistent.

Groundwater quality monitoring to the south of the effluent treatment pond area and south dam and to the southeast and northeast of the AGTMF demonstrates some influence from the AGTMF and effluent treatment ponds.

Figure 3.7: Groundwater Elevation Contours and Inferred Flow in the AGTMF Area [67]

3.2.4.3 Findings

Upon reviewing the groundwater conditions and monitoring results at the Rabbit Lake Operation, CNSC staff have found there are localized effects to groundwater from operations. However, based on the ERA conclusions, these effects are negligible and do not result in increased risk to people and the environment around the facility. CNSC staff have reviewed the ERA and agree with the conclusions of the ERA that the effects are negligible.

3.2.5 Human environment

An assessment of the human environment at the Rabbit Lake Operation consists of identifying representative persons located within or in proximity to the site and determining whether they could be exposed to radiological or hazardous COPCs, such as through breathing the air, being on the land, drinking and swimming in surface water, and eating plants, fish, and wildlife from the Rabbit Lake Operation area. Representative persons are those individuals who, because of their location and habits, are likely to receive the highest exposures to radiological or hazardous substances from a particular source and, therefore, potentially have their health impacted by

these exposures. In general, human receptors may be exposed to contaminants through 4 primary routes: dermal (skin), inhalation, incidental ingestion (soil), and ingestion of food and water.

Cameco's 2020 ERA [22] included a human health risk assessment (HHRA) to assess the risk to humans from both radioactive and hazardous substances released from activities at the Rabbit Lake Operation. A Wollaston Lake resident and trapper, a Hidden Bay lodge operator, a Parks Lake cabin occupant, Rabbit Lake and McClean Lake camp workers, a Points North worker, and a Collins Bay cabin occupant were determined to be the most exposed individuals for potential carcinogenic and toxic contaminant exposures. The HHRA found that human exposure to radionuclides and hazardous substances for a range of worker scenarios and families using the local area in various ways are not expected to pose a risk to human health under the assessed care and maintenance and decommissioning scenario.

3.2.5.1 Exposure to radiological substances

The CNSC's *Radiation Protection Regulations* [42] prescribes radiation dose limits to protect workers, the public, and Indigenous Nations and communities from exposure to radiation from licensed activities. Doses are either monitored by direct measurement or by estimation of the quantities and concentrations of any nuclear substance released as a result of the licensed activities. The annual effective dose limit for a member of the public is 1 mSv per year.

In the 2020 ERA [22], Cameco calculated the annual dose for the Collins Bay cabin occupants using a conservative approach. CNSC staff reviewed Cameco's assessment and found that all estimated annual doses were below the annual public effective dose limit of 1 mSv per year. The highest estimated annual dose, which was 0.39 mSv per year for the toddler staying year-round at the Collins Bay cabin, was below the annual public effective dose limit. This dose was calculated to provide context and was only predicted for the 95th percentile of the expected loading scenario. The results indicate that there are no expected risks to human health from radionuclides.

Over the licensing period (2013 to 2022), Cameco continued to ensure protection of workers and the public in accordance with the *Radiation Protection Regulations* [42].

3.2.5.2 Exposure to hazardous substances

In the Rabbit Lake Operation's HHRA, exposure to hazardous substances was evaluated for numerous human receptors (including workers and people using the site in various ways). Human exposure to hazardous substances (some hazardous substances can be carcinogens) is not expected to pose a risk to human health. While the intakes of arsenic are above the appropriate toxicity reference values (TRVs), this is almost entirely related to ingestion of store-bought foods (that is, meat, dairy, grains, vegetables). The contributions from the Rabbit Lake Operation do not add significantly to the overall arsenic exposure; therefore, no adverse effects are expected due to releases from the Rabbit Lake Operation.

Air dispersion modelling, completed using conservative emissions scenarios, indicates that particulate concentrations have the potential to exceed benchmarks at the Rabbit Lake Operation camp. However, review of literature suggests that the probability of negative influences related to exposure to these COPCs at the Rabbit Lake Operation camp is low.

Evaluation of human exposure to carcinogenic COPCs (that is, arsenic and cobalt) found that the greatest contributors to arsenic intakes are ingestion of water for the Wollaston Lake resident and

trapper, ingestion of water and duck for the Hidden Bay lodge operator, ingestion of moose for the Parks Lake lodge operator, ingestion of berries for the Rabbit Lake Operation and McClean Lake Operation camp workers, and ingestion of medicinal tea for the Points North worker. Under the assessed scenario, there is not expected to be a potential for effects on human health related to cancer risk as the predicted incremental cancer risks remain well below the Health Canada benchmark of 1 in 100,000 people for both evaluated scenarios.

3.2.5.3 Findings

Over the licensing period (2013 to 2022), the estimated radiological doses for the selected human receptors have constantly remained well below the highest predicted dose in the HHRA. Furthermore, the estimated radiological doses to the public have also remained well below the annual public dose limit of 1 mSv per year, indicating that radiological releases from the Rabbit Lake Operation pose a negligible risk to human health (that is, potential risk to humans is similar to health outcomes in similar northern Saskatchewan communities).

For hazardous substances, CNSC staff's review of the HHRA indicated that hazardous releases from the Rabbit Lake Operation pose a negligible risk to human health (that is, potential risk to humans is similar to health outcomes in similar nothern Saskatchewan communities).

Based on assessments conducted for the Rabbit Lake Operation, including the review of the 2020 ERA, annual reports, and annual environmental monitoring data, CNSC staff have found that impacts to the human environment from radiological and hazardous substances released from the Rabbit Lake Operation are negligible and that people living and working near the facility remain protected.

4.0 CNSC Independent Environmental Monitoring Program

The CNSC has implemented its IEMP as an additional verification that Indigenous Nations and communities, the public, and the environment around licensed nuclear facilities are protected. It is separate from, but complementary to, the CNSC's ongoing compliance verification program. CNSC staff's findings are supported by IEMP sampling and by the licensee EP data and ERA predictions. The IEMP involves taking samples from publicly accessible areas around the facilities and analyzing the amount of radiological and hazardous contaminant substances in those samples. For the uranium mines and mills in northern Saskatchewan, CNSC staff, with the assistance of a qualified contractor, collect the samples and send them to an accredited laboratory for testing and analysis.

4.1 IEMP at the Rabbit Lake Operation

In the summer of 2022, a qualified contractor conducted IEMP sampling around the Rabbit Lake Operation. A CNSC staff member also joined the sampling team. This is the first time that IEMP sampling has been conducted at Rabbit Lake Operation. CNSC staff developed the 2022 site-specific sampling plan with input from Indigenous Nations and communities to ensure meaningful results were obtained. The sampling plan focused on radiological and hazardous contaminants and considered Cameco's EMP and the CNSC's regulatory knowledge of the site.

The accredited contractor collected the following samples in publicly accessible areas outside the perimeter of the Rabbit Lake Operation:

- water (4 locations, 3 samples per location)
- fish (2 locations, 3 samples of a benthic fish (lake whitefish), 3 samples of a pelagic fish (northern pike), and 3 samples of lake trout per location)
- Labrador tea (4 locations, 1 sample per location)
- blueberries (4 locations, 1 sample per location)

Samples collected will be analyzed by qualified laboratory specialists in an accredited laboratory, using appropriate protocols. As requested by CNSC staff, the laboratory specialists will measure radionuclides (radium-226, thorium-230, polonium-210, and lead-210) and hazardous substances (arsenic, copper, lead, molybdenum, nickel, selenium, uranium, and zinc) in the collected samples. Water samples will be analyzed for ammonia, hardness, pH, and TSS. Labrador tea and blueberry samples will also be analyzed for moisture content to allow CNSC staff to convert the results from dry weight into wet weight to compare against the screening levels.

The IEMP results will be published on the CNSC's IEMP web page [75] once the CNSC's analysis is complete.

4.2 Indigenous participation in the IEMP

It is a priority for the CNSC that IEMP sampling reflect Indigenous traditional land use, values, and knowledge, where possible. In addition to routine IEMP sampling activities, the CNSC consulted with 2 local Indigenous Nations and communities in 2022: the Ya'thi Néné and the Métis Nation of Saskatchewan to invite suggestions for species of interest, VCs, or potential sampling locations where traditional practices and activities may take place.

In January 2022, in advance of the IEMP sampling campaign at the Rabbit Lake Operation, notification emails were sent to all Indigenous Nations and communities near the Rabbit Lake Operation inviting suggestions for species of interest, VCs, or potential sampling locations where traditional practices and activities may take place.

In 2022, the CNSC met with the Ya'thi Néné and the Métis Nation of Saskatchewan. These meetings provided CNSC staff with the opportunity to collaborate with Indigenous Nations and communities, to learn about their individual histories and cultures, and to address questions related to the operations at Cameco's Rabbit Lake Operation. The following sections summarize CNSC staff`s collaboration with each Indigenous Nation and community ahead of the 2022 sampling campaign.

4.2.1 Engagement with the Ya'thi Néné

In April 2022, CNSC staff held a virtual meeting with the Ya'thi Néné and shared the draft sampling plan for the 2022 Rabbit Lake Operation IEMP campaign ahead of the meeting. During the meeting, CNSC staff gave an overview of the IEMP and the draft sampling plan. The Ya'thi Néné indicated that they were interested in participating in the sampling plan and committed to sharing it with their community members.

In June 2022, the Ya'thi Néné submitted their comments on the draft IEMP sampling plan. The Ya'thi Néné conducted interviews in Wollaston Lake of residents and leadership and found that there was very little concern with the draft IEMP sampling plan. The respondents identified Blue Island and Snowshoe Island as potential sampling regions. CNSC staff incorporated these two locations in the final sampling plan. The respondents also identified lake trout as a species of interest. CNSC staff added lake trout to the final sampling plan.

In addition, a community land technician from the Ya'thi Néné accompanied the qualified contractor as a field assistant to help collect samples during the 2022 IEMP sampling campaign at the Rabbit Lake Operation. A CNSC staff member also participated in the sampling campaign in an effort to build trust and provide information on the CNSC's IEMP.

Once the IEMP results are available, CNSC staff will work closely with the Ya'thi Néné to disseminate and to explain the results to their communities.

4.2.2 Engagement with the Métis Nation of Saskatchewan

In March 2022, CNSC staff held a virtual meeting with the Métis Nation of Saskatchewan and shared the draft sampling plan for the 2022 Rabbit Lake Operation IEMP campaign ahead of the meeting. During the meeting, CNSC staff gave an overview of the IEMP and the draft sampling plan. The Métis Nation of Saskatchewan identified that lake trout was a species of interest to their community members. CNSC staff have incorporated the Métis Nation of Saskatchewan's suggestion into the final sampling plan.

4.3 Summary of results

Most of the parameters in the samples measured during the 2022 IEMP sampling campaign were below available guidelines/screening levels. There were some exceedances of the CNSC's conservative screening levels in arsenic and selenium in fish tissue, at both the reference (far from site) and exposure (close to site) locations. All these exceedances were within the natural

background of the region. CNSC staff performed a detailed assessment of the screening level exceedances and found that the environment is protected and that there are no anticipated health impacts. The results and CNSC staff's assessment of the screening level exceedances will be published on the CNSC's IEMP web page [75] in the spring of 2023.

The CNSC's IEMP results in 2022 are consistent with the results submitted by Cameco, supporting the CNSC's assessment that the licensee's EP program at the Rabbit Lake Operation is effective. The IEMP results and conclusions are also consistent with the results and conclusions from the EARMP. The results add to the body of evidence that people and the environment in the vicinity of the Rabbit Lake Operation are protected and that there are no anticipated health impacts.

5.0 Health studies

This section draws from the results of regional health studies, reports, and other studies to provide further independent verification on whether the health of people living near or working at the Rabbit Lake Operation, in northern Saskatchewan, is protected. Various organizations, such as the Saskatchewan Health Authority and the Northern Inter-Tribal Health Authority (NITHA), monitor the health of people living near the Rabbit Lake Operation. Disease rates of communities living near Rabbit Lake Operation are compared to similar populations to detect any potential health outcomes that may be of concern.

Cancer is the main health concern for occupational and environmental radiation exposures, and is thus the focus of health studies of workers and people living near nuclear facilities such as the Rabbit Lake Operation; however, all health outcomes were reviewed. The following subsections discuss several health studies and reports that have assessed the health of people living near the Rabbit Lake Operation, including studies conducted by the CNSC to assess the health effects of workplace radiation exposure among Saskatchewan uranium workers.

CNSC staff continue to review health studies and reports conducted by the community health authorities and conduct CNSC-based health studies, to assess the protection of human health. CNSC staff review any new publications and data related to the health of populations living near nuclear facilities. For additional information on health studies related to nuclear facilities, visit the CNSC's web page on health studies [76].

5.1 Population and community health studies and reports

5.1.1 Northern Saskatchewan Population Health Unit reports (latest to 2019)

The Northern Saskatchewan Population Health Unit (PHU) monitors the health and living circumstances of the people of northern Saskatchewan. This includes changes in population and community characteristics, determinants of health, health service use, and the health status and well-being of northern Saskatchewan residents.

The Northern Saskatchewan Health Indicators reports, developed by the PHU, provide an overview of the population of northern Saskatchewan. These reports include important community characteristics, determinants of health (that is, personal, social, economic, and environmental factors that influence health status), and health status and well-being indicators. This information is important to put the communities' health into perspective.

The PHU has published 2 Northern Saskatchewan Health Indicators reports, one in 2004 [77] and another one in 2011 [78], and updates and publishes health monitoring chapters on its Population Health Unit - Northern Saskatchewan web page [79]. In addition, older reports (from 1998) are also available on the website for the Athabasca Health Authority, Keewatin Yatthé Regional Health Authority, and Mamawetan Churchill River Health Region.

Northern Saskatchewan Health Indicators report (August 2016) [80]

Community characteristics

Northern Saskatchewan is made up of the Keewatin Yatthé Health Region (KYHR) and Mamawetan Churchill River Health Region and the Athabasca Health Authority. These are, by geographical size, the 3 largest health regions/authorities in Saskatchewan, together covering approximately 47% of the provincial surface area with over 70 communities and close to 40,000 individuals. The characteristics of the population of northern Saskatchewan are compared to the rest of the province (unless stated otherwise) to put people's health into perspective. The northern Saskatchewan geographical area encompasses all the uranium mine and mill facilities in Saskatchewan.

As of 2015, northern Saskatchewan has a much larger proportion of young people. Between 28% to 32% of its population is under 15 years of age, while only between 5% to 7% of residents are 65 years of age or older. Most people (85%) in northern Saskatchewan identify as Indigenous (approximately 68% as First Nation and 19% as Metis). Between 44% and 84% of the population in northern Saskatchewan reported having an Indigenous language as their mother tongue, and between 28% and 71% reported that an Indigenous language was the language they spoke most often at home.

Social determinants of health (SDOH)

Compared to the rest of Saskatchewan, the overall income was around 40% lower in northern Saskatchewan in 2010, and northern Saskatchewan had lower rates of people with educational qualifications (such as in high school, trades, college, and university). The long-term unemployment rates in northern Saskatchewan range between 3.3% and 15.6%, which is 3 to 5 times higher than the provincial rate. Individuals who self-identify as Indigenous tend to have lower income than the overall region.

Only between 21% and 44% of private dwellings in northern Saskatchewan are owned by the household (compared with 70% provincially). Likewise, northern Saskatchewan has between 2.5 to 4.3 times the proportion of dwellings requiring major repair and between 4.8 and 11.4 times the rates of crowding. Safe housing is a significant issue in northern Saskatchewan.

Smoking rates in northern Saskatchewan have remained high over the last number of years. The overall smoking rate in northern Saskatchewan from 2013-2014 was 41%, which was elevated in comparison to many other northern regions in Canada. In addition, non-smoking individuals in northern Saskatchewan are more likely to be exposed to second-hand smoke in vehicles, public places, or at home compared to their provincial counterparts. Northern Saskatchewan has similar rates of heavy drinking, active physical activity levels, fruit and vegetable consumption, breast feeding initiation, sense of community belonging, and life satisfaction compared to other northern regions in Canada.

Note that the SDOH vary greatly among communities in northern Saskatchewan. Some communities score as good as, or better, than the province, while other communities struggle with rates that are up to 25 times worse than the province.

Health status

Significantly fewer people in northern Saskatchewan off-reserve communities report perceiving their own health status and mental health status as very good or excellent compared to the province. However, the northern Saskatchewan off-reserve population indicate similar rates of life stress compared to the province. The percentage of northern Saskatchewan off-reserve population reporting good to full functional health has remained relatively stable from 2009 to 2010 and from 2013 to 2014, decreasing slightly from 78% to 76%. Similar rates are seen in the province and other northern regions in Canada.

Yearly total mortality rates in northern Saskatchewan have remained relatively stable over the past 10 years. Northern Saskatchewan rates have also consistently remained statistically greater than the province [81].

From 2005 to 2014, the leading causes of death in northern Saskatchewan were, in order; injuries, cancer, circulatory diseases, and respiratory diseases. However, in the KYHR, cancers were ahead of injuries as the leading cause of death. Some of the main specific causes of death in northern Saskatchewan include ischemic heart disease, intentional self-harm, lung cancer, motor vehicle collisions, cerebrovascular disease, and chronic obstructive pulmonary disease (COPD).

Injuries are the leading cause of death in most age groups in the north with intentional self-harm, motor vehicle traffic accidents, assault, and accidental poisonings being most common. In the older age groups, chronic disease becomes the leading causes of death with ischemic heart disease, lung cancer, and diabetes being most common. Of all deaths in northern Saskatchewan, 57% were deemed avoidable.

Cancer rates for all cancers combined in northern Saskatchewan are lower for males, and similar for females when compared to southern Saskatchewan. From 2010 to 2014, the leading causes of cancer incidence (that is, new cancer cases) were breast, lung, and colorectal cancer in females, and prostate, lung, and colorectal cancer in males. However, lung cancer was by far the leading cause of cancer deaths for both sexes, followed by breast and colorectal cancer for females and colorectal and prostate cancer for males (2010 to 2014). Importantly, lung cancer rates (both cases and deaths) are greater in northern Saskatchewan compared to the province.

Cigarette smoking is the leading cause of lung cancer in northern Saskatchewan. The number of daily cigarette smokers is significantly higher in northern Saskatchewan compared to the provincial average. According to the First Nation Food Nutrition and Environment Study [82], the smoking rate in some northern Saskatchewan Indigenous Nations and communities is estimated to be approximately 4 times the provincial rate, at 79%. Therefore, the impact of tobacco use on cancer in northern Saskatchewan may be even greater than in the province as a whole due to a substantially higher smoking rate. [83].

The total number of children (aged 0 to 14 years) diagnosed with cancer in Saskatchewan from 1990 to 2016 was 833. This included 23 children from northern Saskatchewan (about 1 child or fewer a year), meaning that childhood cancer rates are low [824

5.1.2 Northern Inter-Tribal Health Authority health reports (latest 2010 to 2015)

The NITHA is an Indigenous partnership organization between the Prince Albert Grand Council, Meadow Lake Tribal Council, Peter Ballantyne Cree Nation, and Lac La Ronge Indian Band. NITHA provides and maintains health services and public health programs in 33 Indigenous Nations and communities in northern Saskatchewan. NITHA's Public Health Unit provides advice and expertise for various public health programs, including population health assessment, disease surveillance, health promotion, health protection, and disease and injury prevention. NITHA's Public Health Unit also develops health-related resources, including health status reports, for its partner community members. These resources are available on the NITHA website [85]. According to the latest health status report from 2017, the leading causes of death for NITHA's partner communities from 2010 to 2015 were cancer (32%), heart diseases (16%), accidental deaths (15%), and diabetes (8%) [85]. Lung cancer was the most common cause of death from cancer, representing approximately 32% of all cancer deaths [86].

5.1.3 Saskatchewan health status reports (latest 2016)

The Province of Saskatchewan produces health status reports which describe the health of the population and offer regional and, where possible, national comparisons. The health status reports draw from a variety of sources of information, including the Saskatchewan Ministry of Health's administrative health services databases, vital statistics, census data, and survey data (such as from the Canadian Community Health Survey). According to the latest Saskatchewan Health Status Report [87], the leading causes of mortality in Saskatchewan in 2009 were circulatory diseases, cancer, injuries, and respiratory disease. While the Province of Saskatchewan's website does not indicate when the latest report was published, the data used is older than 2011 (with most data ranging from 1995 to 2009).

A fact sheet on the prevalence of asthma, COPD, diabetes, ischemic heart disease (IHD), and heart failure in Saskatchewan from 2012 and 2013 [88] noted the prevalence of asthma was lowest in northern Saskatchewan compared to the province as a whole. However, the prevalence of COPD, diabetes, IHD, and heart failure was much higher in northern Saskatchewan compared to the provincial rates.

5.1.4 Saskatchewan Cancer Agency (latest by health region 2017)

From 2014 to 2017, the Saskatchewan Cancer Agency (SCA) collaborated with the Federation of Sovereign Indigenous Nations and with Métis communities on a 3-year cancer surveillance program to gain insight into how to serve First Nation and Métis Nations and communities better [89]. In partnership with 5 Indigenous communities across the province, the SCA collected information within these communities to ensure that they had access to appropriate cancer care programs and services. Working closely with communities was essential to this project, particularly in northern Saskatchewan, where engaging community members is important for proper communication on cancer prevention; for early detection; for cancer awareness, education, and surveillance; and for finding ways to support cancer patients and their families [90]. Youth engagement was also an important focus of this work.

The SCA also conducts cancer control reports, which profile cancer for regional health authorities. The most recent Saskatchewan Cancer Control Report from 2017 [91] combines the 3 northernmost health authorities (namely Mamawetan Churchill River, Keewatin Yatthé, and Athabasca) into 1 region called "the North". This region of the province is unique because its population is small and much younger than in the rest of the province. The northern Saskatchewan Health Indicators reports use the data in the Cancer Control Reports. Cancer is most common in people over age 50. In 2014, 90% of new cancer cases diagnosed were in people aged 50 and over, with 96% of cancer deaths occuring among those aged 50 and over. This age group is growing in Saskatchewan and continues to comprise an increasing proportion of Saskatchewan's population. Thus, as the northern Saskatchewan population ages, one can expect to see more cancer cases and deaths. This has important implications for planning cancer screening, diagnostic, and treatment services.

5.1.5 Saskatchewan First Nations 2018 Health Status Report [92]

Overall, many Saskatchewan Indigenous Nations and communities continue to experience health disparities related to the SDOH [92]. These SDOH affect a community's health and wellness, and contribute to the majority of health challenges faced by Saskatchewan Indigenous Nations and communities. Specifically, poverty, inadequate and overcrowded housing conditions, and food insecurity have contributed to the persistent burden of communicable and chronic diseases. Some of the highlights of this report are as follows:

Demographics: Overall, the registered Saskatchewan Indigenous population living in Indigenous Nations and communities has increased from 61,564 to 75,165 from 2006 to 2016. The northern Saskatchewan Indigenous population had an average growth rate of about 23.3% per year between 2006 to 2016, with an increase in population from 28,884 to 35,611.

About half of the Saskatchewan Indigenous population living in Indigenous Nations and communities is younger than 25 years of age, accounting for 51.2% of the Indigenous communities' population in 2016. This is projected to grow by 34% from 75,165 in 2016 to 100,577 in 2034.

SDOH: These are the economic and social factors that influence the health of individuals and communities.

- Approximately 41% of the people living in Saskatchewan Indigenous Nations and communities speak an Indigenous language; Cree (26%) and Dene (10%) were the most common languages spoken at home. Culture and language is a SDOH for Indigenous peoples in Canada, and revitalization of Indigenous peoples' culture and language is considered a significant aspect to improve their health status.
- In 2015, 37% of Indigenous households in Saskatchewan Indigenous Nations and communities were classified as food insecure: 27% of the households were moderately insecure and 10% were severely insecure.
- The percentage of severely overcrowded households in Saskatchewan Indigenous Nations and communities remained relatively high but unchanged between 2006 and 2016 (16.2% and 16.6%, respectively). This compares to approximately 1% for people with non-Indigenous identities. In addition, households in Saskatchewan Indigenous Nations and

communities in 2016 were 7.6 times more likely to need major repairs compared to households in non-Indigenous communities (51.1% and 6.7%, respectively).
- Saskatchewan Indigenous peoples ages 25 to 54 years attained higher levels of education in 2016 compared to 2006. About 56% of people in Indigenous Nations and communities had a high school diploma or equivalency certificate or greater in 2016.
- Between 2006 and 2016, the median income for Indigenous peoples ages 25 to 54 year old in Saskatchewan Indigenous Nations and communities increased by 40.2% from $11,312 to $15,861, respectively. However, there is a large income gap between Indigenous Nations and communities and non-Indigenous populations (median income $50,253 in 2016) in Saskatchewan.
- In Saskatchewan Indigenous Nations and communities, the employment rates among Indigenous peoples ages 25 to 54 decreased between 2006 and 2016 from 45.2% to 37.7%. This compares to the decrease from 86.8% to 85.0% for non-Indigenous identity people for the same time period.

5.2 Health studies of uranium mine workers

The Saskatchewan Uranium Miners' Cohort Study (SUMC Study) is a 2-part project conducted by the CNSC, the Government of Saskatchewan, and industry stakeholders in the early 2000s.

The CNSC, Government of Saskatchewan, University of Saskatchewan, and industry stakeholders are currently working in partnership to conduct the new Canadian Uranium Workers Study (CANUWS) [93] which will follow up on the health of about 80,000 past and present uranium workers, including miners, millers, and processing workers. This new study will consider workers from previous Canadian uranium worker studies, as well as present day workers from northern Saskatchewan and Ontario.

The following subsections provide more information on the SUMC Study and the CANUWS.

5.2.1 Saskatchewan Uranium Miners' Cohort Study

Part 1 of the SUMC Study [94] [95] looked at the relationship between lung cancer (deaths and new cancer cases) and exposure to radon and its decay products in a group of Eldorado uranium workers who worked at the Beaverlodge and Port Radium uranium mine sites and Port Hope radium and uranium facility from 1932 to 1980. Workers' mortality and cancer incidence were followed until 1999. This study represents an update of the original Eldorado study group (or cohort) that looked at mortality at the Beaverlodge [96] and Port Radium [97] mine sites from 1950-1980.

Part 1 of the SUMC Study makes the following conclusions:

- Most past uranium workers were male and overall, uranium mining, milling, and processing workers were as healthy as the general Canadian male population.
- Lung cancer was the only disease that consistently showed significantly higher death and cancer incidence rates among uranium workers.
- Overall, the excess risk of lung cancer death and cancer incidence increased linearly with increasing radon exposure.

- There was no relationship between radon exposure and any disease, other than lung cancer.

Part 2 of the SUMC Study [98] determined whether it was scientifically possible to assess the number of excess lung cancers from the relatively low radon exposure in modern miners from 1975 onward. The type of risk assessed was the increased risk of lung cancer resulting from radon exposure. The study considered factors such as smoking and residential radon exposure as potential confounding factors of the relationship between lung cancer and radon.

Part 2 of the SUMC Study made the following conclusions:

- Present day Saskatchewan uranium miners have radon exposures that are significantly lower than those of past miners because of dose limits, improved mining techniques, and other radiation protection practices.
- By the year 2030, about 24,000 workers will have spent time working at a uranium mine. During the period under study, 141 miners are expected to develop lung cancer, primarily from tobacco smoking. Only 1 additional miner could expect to get lung cancer from exposure to radon in the workplace.
- It is not feasible to investigate the risk of excess lung cancer in modern miners because exposures are so low. It is also practically impossible to correct for the effects of smoking and residential radon, factors that could greatly affect the study results.

However, CNSC staff continue to monitor the occupational exposures of uranium miners to ensure they remain as low as reasonably achievable. The National Dose Registry maintains exposure records indefinitely.

5.2.2 The Canadian Uranium Workers Study [99]

The CANUWS is a multi-year project initiated by CNSC staff in 2017 to assess the health effects of occupational radiation exposure among uranium workers. The project involves researchers from the CNSC, Health Canada, and the University of Saskatchewan. This retrospective cohort study will assess the information of over 80,000 Canadian uranium mine, mill, and processing workers with occupational radiation exposures from 1932 to 2017. The study will follow up on workers' mortality (1950 to 2017) and cancer incidence (1969 to 2017).

The main objective of the CANUWS is to study the relationship between radon and lung cancer, especially the potential health effects of low cumulative radon exposures and exposure rates. This is possible due to high-quality exposure measurements and the long-term follow-up of workers' health outcomes, with the consideration of workers employed after radiation protection measures were in place. The findings of the study will help to assess the adequacy of occupational radiation safety standards and support future licensing recommendations.

The CANUWS was planned to be completed by 2022-23; however this timeline may be extended because of delays in data linkage and data access as a result of the COVID-19 pandemic. In June 2022, CNSC staff presented an update of the study's progress to the Northern Saskatchewan Environmental Quality Committee. Additionally, annual study progress reports are communicated to interested parties, such as impacted workers and Indigenous Nations and communities.

5.3 Summary of health studies

Ongoing review and conduct of health studies and reports is an important component of ensuring that the health of people living near or working in nuclear facilities is protected. Overall, many Saskatchewan Indigenous Nations and communities continue to experience health disparities related to the SDOH [92] that affect a community's health and wellness, and that contribute to the majority of health challenges faced by Saskatchewan Indigenous Nations and communities.

The population and community health studies and reports indicate that the most common causes of death among the northern Saskatchewan population are cancer and heart disease, alongside injuries, respitory diseases, and diabetes. This is similar to the rest of Canada, where heart disease and cancer are the 2 leading causes of death. The exception is Nunavut, where heart and respiratory diseases are the leading causes of death [100].

In northern Saskatchewan, cancer is predominantly seen in people aged 50 years and older, which is not atypical given that cancer rates tend to increase as a population ages. Overall, cancer rates for all cancers combined in northern Saskatchewan are lower for males, and similar for females, when compared to southern Saskatchewan. However, lung cancer rates are greater in northern Saskatchewan compared to the provincial average, and lung cancer is the most common cause of cancer death in Indigenous Nations and communities in northern Saskatchewan. To put this into perspective, lung cancer is projected to continue to be the most commonly diagnosed cancer and the leading cause of cancer death in Canada in 2020, accounting for 1 in 4 of all cancer deaths [101]. Colorectal, breast, and prostate cancer are also leading causes of cancer incidence and mortality.

According to the Canadian Cancer Society, about 72% of lung cancer cases in Canada are due to smoking tobacco [101] [102]. Other factors include second-hand smoke, radon, asbestos, occupational exposure to certain chemicals, outdoor air pollution, family history, and radiation. The number of daily smokers in northern Saskatchewan is significantly higher than the provincial average [79] [83]. Furthermore, the proportion of Saskatchewan residents who reported daily or occasional smoking was significantly higher than that of Canadian residents [103]. In Canada, exposure to indoor radon is the second leading cause of lung cancer [104]. Research from the Saskatchewan Cancer Agency has demonstrated that community work is essential to cancer control, particularly in northern Saskatchewan, where the focus should be on cancer prevention and education, and ways to support cancer patients and their families [91].

Studies of uranium workers help us assess workers' health and understand the relationship between workplace radiation and health. Part 1 of the SUMC showed that the overall health of workers employed at mines between 1932 and 1980 was similar to the general male population, except for lung cancer incidence and mortality, which were significantly greater in workers compared to the general male population. The risk of lung cancer increased linearly with increasing radon exposure. Part 2 of the SUMC demonstrated that assessing the risk of excess lung cancer resulting from radon exposure in modern miners from 1975 onward is not feasible because exposure is too low and correcting for the effects of smoking and residential radon would be practically impossible. However, strict radiation protection measures exist, including the ongoing monitoring of occupational exposure, to ensure the protection of uranium workers' health. Most recently, CNSC staff and other stakeholders started a new study of all past and

present Canadian uranium workers. This large study will add to the understanding of the relationship between radon and lung cancer, especially at the low cumulative exposure and exposure rates of today's workers.

The Rabbit Lake Operation is not likely to cause any radiation-related illness because radiation exposures are so low. However, there are a number of contributing factors in northern Saskatchewan Indigenous Nations and communities that affect the community's health and wellness, and contribute to their health challenges. CNSC staff know the importance of the environment on Indigenous health and wellness and the social/mental/spiritual effects that the Rabbit Lake Operation may have. CNSC staff will continue to work with northern Saskatchewan Indigenous Nations and communities to address these concerns.

6.0 Other environmental monitoring programs

Several monitoring programs are carried out by other levels or bodies of government, and are reviewed by CNSC staff to confirm that the environment and the health and safety of persons around the facility in question are protected. A summary of the findings of these programs is provided below.

6.1 Cumulative effects

A formal cumulative effects assessment is not a requirement within CNSC staff's assessments for EPRs as it is not a requirement under the NSCA and other regulatory documents. However, CNSC staff's assessments do consider the accumulation of COPCs within the environment because of the facility or activity through the cyclical nature of ERAs, the monitoring data in annual reports, data from the IEMP, and results from any regional monitoring programs and health studies. The CNSC has and continues to be involved in monitoring for cumulative effects and in regional monitoring outside of the potential influence of a single licensed facility or activity.

Licensees are required to meet onsite and near-field monitoring requirements associated with their provincial approvals and the federal regulations, including full life-cycle requirements. These programs focus on single operations with scheduled reports on performance submitted to the regulators. These activities are further supplemented by the CNSC's IEMP activities (see section 4.0), which focuses on local areas where Indigenous Nations and communities and members of the public could reasonably be expected to conduct recreational or traditional activities (off-site accessible areas).

Despite the robustness of site monitoring programs and community and Indigenous engagement activities associated with the IEMP, concern related to overlapping effects from multiple sites remain. In response, over the years, several industry- and government-established community-based regional programs have been developed.

The Rabbit Lake Operation has been the focus of several environmental monitoring programs due to the long history of uranium mining and milling in the region. These include the site-specific licensee programs, the CNSC's IEMP campaigns within the area, and the further afield regional cumulative effects and community-based monitoring programs such as the Eastern Athabasca Regional Monitoring Program (EARMP) and the Community Based Environmental Monitoring Programs, completed under collaboration agreements between industry and Indigenous Nations and communities in the basin. The findings from these programs demonstrate that the environment and the health and safety of persons are protected.

6.2 Eastern Athabasca Regional Monitoring Program

Due to community concerns related to cumulative impacts from multiple operations, the EARMP was launched in 2011 with funding by the Government of Saskatchewan and industry (Cameco and Orano Canada Inc.). The CNSC became a funding partner in 2017-18. The following year, the EARMP was extended with the signing of a 5-year funding agreement (from 2018-19 to 2022-23) between the CNSC, the Government of Saskatchewan, and the uranium mining and milling industry.

The EARMP is an environmental monitoring program designed to gather data on potential cumulative impacts downstream of uranium mining and milling operations. The EARMP is made up of 2 programs: the community program and the technical program. The community program monitors the safety of traditionally harvested country foods. The technical program monitors the aquatic environment at reference and far-field stations to determine if there are any cumulative impacts to aquatic communities. Both components involve a high level of community involvement and communication and have been implemented by a local Indigenous owned environmental consulting firm.

The technical program was established to monitor potential long-term changes in the aquatic environment downstream of uranium mine and mill operations where drainages from multiple discharges combined. Four cumulative assessment areas (one at each outlet of Wollaston Lake, Waterbury Lake, and Crackingstone Inlet on Lake Atahabsca) and three reference areas (Cree Lake, Pasfield Lake, and Ellis Bay on Lake Athabasca) were established. The complete suite of media and analyses were completed at these sites with additional supplemental data identified from Bobby's Lake (2009 and 2012) and Wollaston Lake Ivison Bay (at reference station #4 in 2008 and 2012). Sampling involved water, sediment, and fish tissue for chemical analyses along with collections to characterize the benthic macroinvertebrate community composition. All of these remote locations are realistically only accessible via aircraft. Sampling campaigns were completed in 2011 and 2012 to establish a current baseline with an assessment campaign completed in 2015. The assessment concluded there was little evidence of change from the baseline monitoring period and the assessment period [105].

The community program monitors the safety of traditionally harvested country foods through analysis of water, fish, berries, and wild meat (namely grouse, rabbit, caribou, and moose) from northern Saskatchewan communities. Samples are collected from areas identified by community members, who either assist in sample collection or provide samples from their own harvesting activities. The community-based program has involved consistent annual sampling of water and fish with the additional media sampled on a cyclical basis since the establishment of the initial current baseline (2011-2012).

6.2.1 Findings

The results of the program showed that concentrations of COPCs have been relatively consistent over time and generally within the regional reference range. This indicates that there is no evidence of long-range transport of contaminants associated with uranium mining and milling. Thus, the EARMP concludes that water and country foods are safe for consumption. CNSC staff reviewed the EARMP technical reports and data and agree with the EARMP's conclusions.

The history, data, and reports associated with the EARMP are available on the EARMP website [106], with the complete community-based database (2011 to 2021) now available for digital download.

6.2.2 Future of the EARMP

With the 2022/23 fiscal year being the last year of the current EARMP funding agreement, the EARMP partners have been considering its future. Uranium mining and milling activities, regional and community monitoring programs, and resident and Indigenous expectations and capabilities regarding active participation and engagement in environmental stewardship have all

substantially changed since EARMP's inception in 2011. One of the current proposals is for the 2023/24 fiscal year to serve as a year of engagement with government (provincial and federal), industry, and Indigenous representatives to discuss regional monitoring within the Athabasca Basin as a whole and the future of EARMP specifically. The goal is to optimize environmental monitoring and engagement activities to the benefit of those who work and live in the Athabasca Basin. CNSC staff are actively involved in discussions regarding the future of EARMP.

6.3 National Pollutant Release Inventory

As discussed in section 2.4 of this report, ECCC operates the NPRI [53], which is Canada's public inventory of pollutant releases, disposals, and transfers, tracking over 320 pollutants from over 7,000 facilities across the country. Reporting facilities include factories that manufacture a variety of goods; mines; oil and gas operations; power plants; and sewage treatment plants. Information that is collected includes:

- releases from facilities to air, water, or land
- disposals at facilities or other locations
- transfers to other locations for treatment and recycling
- facility activities, location, and contacts
- pollution prevention plans and activities [107]

CNSC staff conducted a search of the NPRI database and found that the uranium mines and mills (namely the Cigar Lake Operation, Key Lake Operation, McArthur River Operation, Rabbit Lake Operation, and McClean Lake Operation) are the only facilities from the Athabasca Basin that report to the NPRI. CNSC staff's review of the data did not find any trends or unusual results. Note that radionuclides are not included in the inventory of pollutants in the NPRI database. CNSC staff receive radionuclide loadings from the uranium mine and mill licensees through other means, such as annual and quarterly reports. This information has been used in this report, but the complete dataset is available for download on the CNSC's Open Government Portal [108].

7.0 Findings

This EPR report focused on items of current Indigenous, public, and regulatory interest, including airborne and waterborne releases from ongoing operations at Rabbit Lake Operation. CNSC staff have found that the potential risks from radiological and hazardous releases to the atmospheric, terrestrial, aquatic, and human environments from the Rabbit Lake Operation are low to negligible, and that people and the environment remain protected.

7.1 CNSC staff's findings

CNSC staff's findings from this EPR report may inform and support staff recommendations to the Commission in future licensing and regulatory decisions that pertain to the Rabbit Lake Operation. These findings are based on CNSC staff's technical assessments associated with Cameco's Rabbit Lake Operation, such as the submitted ERA documentation and the conduct of compliance verification activities, including the review of annual and quarterly reports and onsite inspections. CNSC staff also reviewed the results from various relevant or comparable health studies, and other EMPs conducted by other levels of government, to substantiate their findings. CNSC staff also conducted IEMP sampling around the Rabbit Lake Operation in 2022.

Based on their assessment of Cameco's documentation, CNSC staff have found that the potential risks from radiological and hazardous releases to the atmospheric, aquatic, terrestrial, and human environments from the Rabbit Lake Operation are low to negligible. The potential risks to the environment from these releases are similar to natural background, and the potential risks to human health are indistiguishable from health outcomes in similar northern Saskatchewan communities. Therefore, CNSC staff have found that Cameco has and will continue to implement and maintain effective EP measures to adequately protect the environment and the health and safety of persons. CNSC staff will continue to verify and ensure that, through ongoing licensing and compliance activities and reviews, the environment and the health and safety of persons around the Rabbit Lake Operation are protected.

8.0 Abbreviations

Units

cm	centimeter
h	hour
ha	hectar
kg	kilogram
km	kilometer
lbs	pounds
m^3	cubic meters
mGy	milligray
mSv	millisievert
µGy	microgray

Acronyms

AECB	Atomic Energy Control Board
AGTMF	Above Ground Tailings Management Facility
AL	action level
ALARA	*as low as reasonably achievable*
BATEA	*best available technology economically available*
BZOP	B-Zone Ore Pad
BZWRP	B-Zone Waste Rock Pile
Cameco	Cameco Corporation
CANUWS	Canadian Uranium Workers Study
CCME	Canadian Council of Ministers of the Environment
CEAA 1992	*Canadian Environmental Assessment Act*
CEAA 2012	*Canadian Environmental Assessment Act, 2012*
CEPA 1999	*Canadian Environmental Protection Act*
CMD	Commission member document
CNSC	Canadian Nuclear Safety Commission
COPC	constituent of potential concern
COPD	chronic obstructive pulmonary disease
DZWRP	D-Zone Waste Rock Pile

EA	environmental assessment
EARMP	Eastern Athabasca Regional Monitoring Program
EARP	Environmental Assessment and Review Process
ECCC	Environment and Climate Change Canada
ECOP	environmental code of practice
Eldorado	Eldorado Resources Limited
EMP	environmental monitoring program
EMS	environmental management system
EP	environmental protection
EPOP	Eagle Point Ore Pad
EPP	environmental protection program
EPR	environmental protection review
EPWRP	Eagle Point Waste Rock Pile
ERA	environmental risk assessment
GHG	greenhouse gas
HHRA	human health risk assessment
Hi-Vols	high volume air samplers
IAA	*Impact Assessment Act*
IEMP	Independent Environmental Monitoring Program
IHD	ischemic heart disease
ISQG	Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life
ISO	International Organization for Standardization
KYHR	Keewatin Yatthé Health Region
LCH	licence conditions handbook
LEL	Lowest Effects Levels
MDMER	Metal and Diamond Mining Effluent Regulations
MOU	memorandum of understanding
NE2	No-Effects Levels
NITHA	Northern Inter-Tribal Health Authority
NO_x	nitrogen oxides
NPRI	National Pollutant Release Inventory
NSCA	*Nuclear Safety and Control Act*

PDP	preliminary decommissioning plan
PEL	Probable Effects Level
PHU	Northern Saskatchewan Public Health Unit
PM	particulate matter
$PM_{2.5}$	PM less than 1.2 microns in diameter
PM_{10}	PM less than 10 microns in diameter
RLITMF	Rabbit Lake In-Pit Tailings Management Facility
ROR	regulatory oversight report
SAAQS	Saskatchewan Ambient Air Quality Standards
SARA	*Species at Risk Act*
SCA	Saskatchewan Cancer Agency
SDOH	social determinants of health
SEQG	Saskatchewan Environmental Quality Guidelines
SO_2	sulphur dioxide
SO_3	sulphur trioxide
SUMC Study	Saskatchewan Uranium Miners' Cohort Study
TRV	toxicity reference value
TSP	total suspended particulate
TSS	total suspended solids
U	uranium
URS	uranium-rich solution
VC	valued component

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