Canada's Nuclear Regulator

Environmental Protection Review Report:
Key Lake Operation

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Environmental Protection Review Report: Key Lake Operation

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Revision history

The following table identifies the revision history of this document.

Revision number	Change	Summary of changes	Date
000	Initial release	N/A	January 2023
001	Revision 1	Formatting revised to meet new accessibility requirements.	September 2023

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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) environmental protection measures. Under its current uranium mill operating licence, UML-MILL-KEY.01/2023 (previously licensed as UMLOL-MILL-KEY.00/2023), Cameco is licenced to produce uranium oxide at the Key Lake Operation in northern Saskatchewan. Key Lake Operation is situated within historic Treaty 10 territory, in 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 2021 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 2013 Key Lake Operation Extension Project ecological and human health risk assessment
- Cameco's 2020 Key Lake Operation environmental risk assessment
- Cameco's 2019 Key Lake Operation preliminary decommissioning plan
- the results of 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 Key Lake Operation

Based on their assessment and evaluation of Cameco's documentation and data, CNSC staff have found that the potential risks from the Key Lake Operation's radiological and hazardous releases to the atmospheric, terrestrial, aquatic and human environments are low to negligible, and that these releases are similar to natural background. Furthermore, human health is not impacted by operations at the Key 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 Key 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.

1.0 Introduction

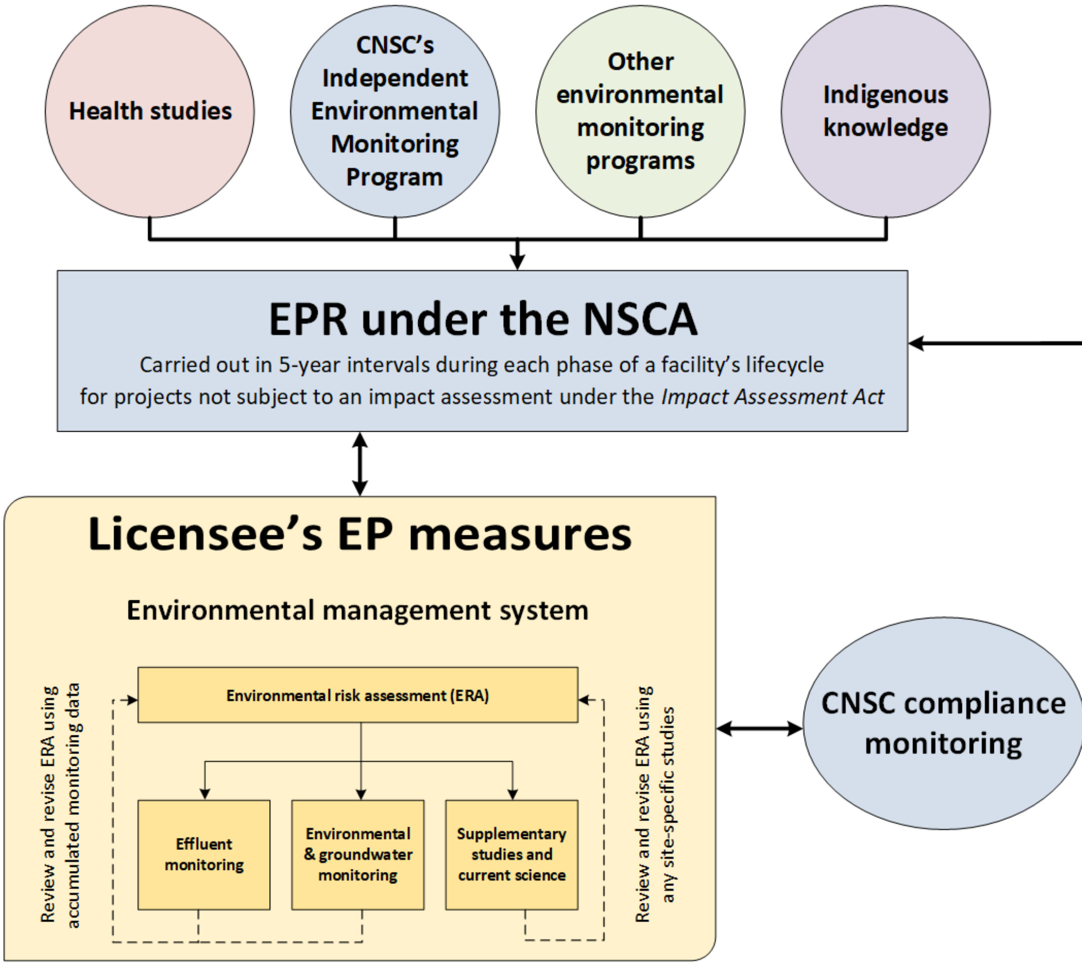
1.1 Purpose

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 at 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 it's 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 report 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 Key Lake Operation. This review serves to assess whether Cameco's EP measures at Key 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 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 EP related information 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 2021, as well as the following:

- regulatory oversight activities (section 2.0)
- CNSC staff's review of Cameco's 2019 Key Lake Operation preliminary decommissioning plan [3] (section 2.2)
- CNSC staff's review of Cameco's annual compliance reports [4, 5, 6, 7, 8, 9, 10, 11, 12]
- CNSC staff's review of Cameco's 2013 Key Lake Operation Extension Project ecological and human health risk assessment [13] (section 3.2)
- CNSC staff's review of Cameco's 2020 Key Lake Operation environmental risk assessment [14] (section 3.2)
- the CNSC's Independent Environmental Monitoring Program (IEMP) results, including discussions with Indigenous Nations and communities (section 4.0)
- health studies with relevance to Key Lake Operation (section 5.0)
- data from other environmental monitoring programs (EMPs) in proximity to Key Lake Operation (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 Key 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 Key Lake Operation, 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

Key Lake Operation is a uranium mill located within the Athabasca basin in the north of Saskatchewan, approximately 570 kilometres (km) north of Saskatoon (figure 1.2). The facility is located within historic Treaty 10 territory and the Homeland of the Métis, and is within the traditional territories of the Denesųłiné, Cree, and Métis peoples. The Key Lake Operation is owned by Key Lake Joint Venture, where the partners are approximately 83% Cameco and 17% Orano Canada Inc. (Orano). Cameco is the operator and licensee.

The Key Lake Operation consists of milling and tailings operations, water treatment facilities and monitoring ponds, contaminated water reservoir ponds, a domestic landfill, waste rock piles, special waste rock stockpiles, and mineralized waste/ore pads. There are also administration offices, camp infrastructure, miscellaneous operational facilities and infrastructure located on the licensed site (figure 1.3).

Key Lake Operation is situated in a sparsely populated and largely undeveloped region of Saskatchewan. The nearest community is the northern village of Pinehouse, located 220 km away by highway 914. Other active uranium mines and mill facilities are located in the region, including Cameco's Cigar Lake Operation, Rabbit Lake Operation, and McArthur River Operation, as well as Orano's McClean Lake facility.

Key Lake Operation borders the Athabasca Plain and Churchill River upland ecoregions. Releases from the Key Lake Operation are received by David Creek, McDonald Creek and Outlet Creek drainages, which join the Wheeler River drainage to flow into Russell Lake [14].

Figure 1.2: Location of the Key Lake Operation [3]

Figure 1.3: Aerial view of the Key Lake Operation [15]

1.2.2 Facility operations

Open-pit mining was conducted at Key Lake Operation from 1982 to 1997. Cameco began milling in 1983 and continued with milling of stockpiled ore after 1997 when mining ceased. In 2000, Cameco began producing uranium ore concentrate at Key Lake from ore transported from Cameco's McArthur River Operation. Tailings were originally deposited in the above-ground tailings management facility (AGTMF) and treated effluent discharged to Wolf Lake. In 1995, tailing deposition was shifted from the AGTMF to the converted Deilmann in-pit Tailings Management Facility (DTMF) [14].

Current licence activities

The Key Lake Operation's current licence, UML-MILL-KEY.01/2023 [16], (previously licensed as UMLOL-MILL-KEY.00/2023), was issued by the CNSC in November 2013. The licence was amended in July 2020 to reflect the revised Key Lake Operation financial guarantee. Cameco is currently permitted to extract uranium from ore and produce up to 9.6 million kilograms (kg) of uranium (equivalent to 25 million pounds of triuaranium octoxide) per year from the mill for shipment off-site. Additional authorized activities include:

- Receipt, storage and processing of ore slurry and mineralized rock
- Receipt, storage and processing of recycle products from the Blind River and Port Hope Conversion Facilities
- Disposal of tailings in the Deilmann Tailings Management Facility and disposal of contaminated wastes in approved facilities
- Operation of the Above Ground Tailings Management Facility, the dewatering and water management systems and the Water Treatment Plants
- Authorized decommissioning and reclamation
- Handling and storage of hazardous materials and disposal of hazardous wastes and storage of clean and special waste rock
- Possession, storage, transfer, importation, use and disposal of nuclear substances and radiation devices

In November 2017, Cameco announced that the Key Lake Operation would transition to a state of care and maintenance by end of January 2018. Operations such as the wastewater treatment plant continue to operate. On February 9, 2022, Cameco announced their intent to begin the process of transitioning the Key Lake Operation from care and maintenance to production [17].

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 Key Lake Operation.

To meet the CNSC's regulatory requirements and according to the licensing basis for the Key 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 the 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 licence conditions handbook (LCH). The relevant regulatory requirements for Cameco's Key Lake Operation are outlined in this section of the report.

2.1 Environmental protection reviews and assessments

To date, 4 federal environmental assessments (EAs) have been carried out for the Key Lake Operation, as indicated in table 2.1. Subsection 2.1.1 provides a description of the first EA conducted for this facility, and section 2.1.2 describes the subsequent EAs are described in section 2.1.2 conducted under the *Canadian Environmental Assessment Act* (CEAA 1992) [18], predecessor to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) [19]. In 2019, the *Impact Assessment Act* [20] came into force, replacing CEAA 2012. Cameco's current activities do not require an impact assessment under the IAA's *Physical Activities Regulations* [21]. The purpose of any 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 Key Lake Operation. CNSC staff have previously publicly documented evaluations and assessments of Cameco's EP performance for the Key Lake Operation through the EP sections found in 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 Key Lake

Project	Applicable EA process and/or legislation	EA start date	EA decision date
Key Lake Project	Key Lake Board of Inquiry appointed by the Province of Saskatchewan	1976	1981
Construction of a New Tailings Management Facility (Deilmann TMF)	*Canadian Environmental Assessment Act* (CEAA 1992) [19]	1994	1995
Key Lake Mill Services Project (CEAR: 08-01-40614)	*Canadian Environmental Assessment Act* (CEAA 1992) [19]	2008	2013
Key Lake Extension Project (CEAR: 55518)	*Canadian Environmental Assessment Act* (CEAA 1992) [19]	2009	2014

2.1.1 First environmental assessment completed prior to CEAA 1992

Key Lake Project (1976 - 1981)

Key Lake Mining Corporation (KLMC) began the EA process in 1976 and filed an Environmental Impact Statement (EIS) with the Saskatchewan Ministry of Environment (SMoE) in 1979. The Project comprised of the construction and operation of separate open pit mining of two uranium orebodies and milling of extracted ores into yellowcake [22].

In December 1979, the provincial government appointed the Key Lake Board of Inquiry to examine the Key Lake Project in a public hearing process. The Board of Inquiry recommended that the project proceed in 1981. The provincial government of Saskatchewan accepted the Board's recommendation and signed a surface lease agreement with KLMC on August 27, 1981, for a 21-year period [22].

2.1.2 Environmental assessments completed under CEAA 1992

Construction of a New Tailings Management Facility

In 1994, partway through the initial project licence period, Cameco applied to the Atomic Energy and Control Board (AECB), the CNSC's predecessor, for the renewal of licence AECB-MFOL-164-2.1 and approval to convert the mined out Deilmann pit into a tailings management facility.

As the Responsible Authority, AECB determined that a screening level EA under CEAA 1992 [18] was required. An EA screening report was prepared in accordance with the requirements of CEAA 1992 [23].

The AECB concluded that the conversion of the Deilmann pit into a tailings management facility and related activities were not likely to cause significant adverse environmental effects, and that health, safety and radiation hazards would be adequately controlled [23].

Key Lake Operation Mill Services Project

In 2008, Cameco applied to the CNSC to seek approval to replace certain mill services at Key Lake Operation, including steam, acid and oxygen plants, which required approval by the Commission.

CNSC staff reviewed the application and determined that a screening level EA under CEAA 1992 [18] was required. An EA screening report was prepared in accordance with the requirements of CEAA 1992 [24].

The Commission determined that the project was not likely to cause significant adverse environmental effects and approved the construction of the mill services at Key Lake Operation, pending implementation of a follow-up and monitoring program (FUMP), as identified in the EA screening report [25]. Cameco received approval by the Commission to operate the new facilities in 2013 on the condition that a summary of results of the follow-up monitoring components be submitted two years following the start up of the new acid plant [24].

Key Lake Operation Extension Project

In 2010, Cameco applied to the CNSC to seek approval for an amendment of the LCH, in accordance with licence condition 1.2 of the former licence. The Project consisted of increasing capacity of the DTMF, increasing mill production capacity and adapting facilities to sustain milling of ores from other deposits [26].

CNSC staff reviewed the application and determined that pursuant to section 5 of CEAA 1992 [18], a screening EA was required. An EA screening report was prepared in accordance with the requirements of CEAA 1992 [27].

The Commission considered the EA Screening Report in 2014, along with public concerns expressed about the project and CNSC staff recommendations [28]. The Commission determined that the project, considering implementation of mitigation measures identified in the EA Report [29], was not likely to cause significant adverse environmental effects. The application for a licence amendment was approved by the Commission, according to the provisions of the NSCA [30].

EA FUMPs were optional for CEAA 1992 screening EAs, thus the Commission determined that a FUMP was not necessary because the Key Lake Operation Extension Project was occurring on currently licensed facilities with adequate existing monitoring programs in place [31]. FUMP commitments required under previous environmental assessment approvals have been completed [4].

2.2 Planned end-state

The following section provides high-level information on the end-state of the Key Lake Operation following decommissioning activities. This section is informed by Cameco's Preliminary Decommissioning Plan (PDP) for the Key Lake Operation [3]. 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/or activities at 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 develop 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 (DDP) is required to be developed by the licensee and submitted to the CNSC for review and acceptance.

The PDPs for nuclear facilities are updated 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 Key Lake Operation are documented in the Key Lake Operation preliminary decommissioning plan [3].

Cameco has prepared the PDP based on a 'decommission tomorrow' scenario. The PDP describes a plan to reclaim all structures and disturbed areas to pre-mining ecological and radiological conditions, as close as is reasonably achievable, and the land suitable for certain traditional land uses. Other end-state objectives include releases to surface water that comply with Saskatchewan Environmental Quality Guidelines (SEQG) or site-specific water quality objectives, radioactive releases from decommissioned components that comply with as low as reasonably achievable (ALARA) principles, and maximum receptor doses that do not exceed criteria in applicable regulations.

Cameco intends for the decommissioned Key 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 submitted an update of the Key Lake Operation PDP in October 2019 after addressing regulatory review comments from CNSC and SMOE on the initial August 2018 submission. The revised PDP was reviewed and accepted by the CNSC, and the revised financial guarantee was accepted by the Commission on July 29, 2020. 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 Key Lake Operation. The results derived from Cameco's EPP are detailed in section 3.0 of this report.

Cameco's Key Lake EPP for the Key Lake Operation was designed and implemented in accordance with REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures* (2017) [32], as well as the CSA group's environmental protection standards 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 Standard N288.4-10, Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills [33]	Implemented
CSA Standard N288.5-11, Effluent Monitoring Program at Class I Nuclear Facilities and Uranium Mines and Mills [34]	Implemented
CSA Standard N288.6-12, Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills [35]	Implemented
CSA Standard N288.7-15, Groundwater Protection Programs at Class 1 Nuclear Facilities and Uranium Mines and Mills [36]	Implemented
CSA Standard N288.8-17, Establishing and Implementing Action Levels to Control Releases to the Environment from Nuclear Facilities [37]	Implemented
CNSC Regulatory Document REGDOC-2.9.1, Environmental Protection: Environmental Principles, Assessments and Protection Measures, version 1.1 (2017) [32]	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* [38], the *Radiation Protection Regulations* [39] (for example, for action levels (ALs) or dose limit exceedances), and the LCH.

Cameco is required to submit annual reports as per REGDOC-3.1.2. 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 Key Lake Operation webpage [17].

CNSC staff regularly report on the licensee performance to the Commission for activities conducted at the Key Lake Operation. For example, CNSC staff's regulatory oversight reports RORs are a standard mechanism for updating the Commission, Indigenous Nations and communities, and the public on the operation and regulatory performance of licensed facilities. Previous RORs are available on the CNSC regulatory oversight report web page [40]. 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 CNSC's regulatory requirements under REGDOC-2.9.1 (2017) [32], Cameco is responsible for implementing and maintaining EP measures that identify, control, and monitor releases of radioactive and hazardous substances from the Key Lake Operation, and 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 health and safety of persons.

This subsection and the following ones under section 2.3 summarize Cameco's EPP for the Key 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) [41] and to submit an EPP for Key Lake. Cameco's EPP includes the following components to meet the requirements and guidance as outlined in REGDOC-2.9.1 (2017) [41]:

- EMS
- environmental risk assessment (ERA)
- effluent emissions control and monitoring
    - air emissions and liquid effluent monitoring
- environmental monitoring program
    - 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 planning and resources to develop, implement and maintain a policy for EP. 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, 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 Key Lake Operation in accordance with REGDOC-2.9.1 (2017) [32], and is also registered and certified under the International Organization for Standardization (ISO)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 Key Lake Operation meets CNSC requirements as outlined in REGDOC-2.9.1(2017) [32]. The implementation of the EMS ensures that Cameco continues to improve environmental performance at Key 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 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 2013, Cameco submitted an ERA to the CNSC for the Key Lake Operation. A review to the 2013 ERA was submitted in 2020 to address CNSC staff's comments [13, 14]. The 2020 ERA included an Ecological Risk Assessment and a Human Health Risk Assessment (HHRA) for radiological and hazardous contaminants. CNSC staff reviewed Cameco's 2020 ERA and found it to be compliant with CSA N288.6-12 *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills* [35] and found that human health and the environment in the vicinity of the Key Lake Operation remain protected.

In 2020, Cameco submitted an updated ERA [28] in accordance with the requirements set out in CSA standard N288.6-12, [35] to review and revise their ERA every five years. CNSC staff agree with Cameco's findings that the results of the 2020 ERA are consistent with previous ERAs and that human health in the vicinity of the operation remain protected. The 2020 ERA identified some potential local effects to the aquatic community from operation, but the wider Wheeler River Drainage remains protected [28].

CNSC staff found the 2020 ERA to be acceptable and that the update addressed staff's technical comments and recommendations.

The findings of the 2013 and 2020 ERA are summarized in table 2.3. Effects to ecological and human health due to releases of COPCs to the air and water from Key Lake Operation were found to be negligible, with the exception of some potential localized effects to the most sensitive species of aquatic invertebrate, fish, and aquatic plant/algae, such as changes in density, diversity, and condition in Wolf Lake. These effects were identified through modelling within the ERA but have not been found in current environmental monitoring. CNSC will receive the next update to the ERA in 2025.

Table 2.3: Summary of ERA findings for Key Lake Operation [28]

Type	Humans	Aquatic and terrestrial biota
Radiological	No adverse impacts expected from radiological COPCs released from Key Lake Operation.	Potential effects to aquatic biota in the nearfield exposure area within David Creek drainage.
Hazardous	No adverse impacts expected from hazardous COPCs released from Key Lake Operation.	Potential effects to aquatic biota and terrestrial biota with a primarily aquatic diet within David Creek drainage.
Physical stressors	No adverse impacts expected from physical stressors resulting from the Key Lake Operation.	No adverse impacts expected from physical stressors resulting from the Key Lake Operation.

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 (for example, such as in design) and of ALARA principles, the Canadian Council of Ministers of the Environment (CCME) guidelines, and results of the licensee's ERAs.

The Key Lake Operation's current EPP [42] was reviewed and accepted by CNSC staff. This program contains licence limits and site-specific ALs to control radiological and hazardous effluent. Limits in CNSC's licences for uranium mines and mills are adopted from schedule 4 of the *Metal and Diamond Mining Effluent Regulations* (MDMER) [43].

Under section 4 of CNSC's *Uranium Mines and Mills Regulations* [44], Cameco is required to implement an Environmental Code of Practice (ECOP) as part of its 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 mill water treatment plant. This follows the methodology outlined in CSA standard N288.8-17 [37]. 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 Key Lake Operation's effluent monitoring program [42] was reviewed and accepted by CNSC staff in December 2021, and is in compliance with REGDOC-2.9.1(2017) [32] and the relevant standards, including CSA Standard N288.5-11 [34].

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

2.3.5 Environmental monitoring program

The CNSC requires licensees to design and implement an environmental monitoring program 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* [45] 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 of the EMP at Key Lake Operation as monitoring has indicated they are more abundant in effluent, though radionuclides are included within monitoring activities associated with liquid discharges and air emissions. Cameco's EMP for the Key Lake Operation consists of the following components:

- ambient air monitoring (radon and particulates)
- soil and 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 soil and lichen, aquatic biota and sediment monitoring are conducted every 3, 5 or 6 years depending on the sampling media and location. Cameco's EMP also contains a requirement to perform annual inspections of synthetic and/or concrete liners and annual geotechnical inspections of retention ponds, ore pads and other retaining structures.

Cameco is required to maintain its EMP to comply with REGDOC-2.9.1 (2017) [32] and relevant standards, including CSA Standard N288.4-10 [33].

Based on compliance activities, CNSC staff have found that the Cameco is compliant with REGDOC-2.9. 1 (2017) [32] and continues to implement and maintain an effective EMP for the Key Lake Operation that adequately protects the environment and the health and safety of persons.

2.4 Reporting of airborne emissions under other federal or provincial legislation

A core element of 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) [46], Cameco is required to monitor GHG emissions [47]. Nuclear facilities that emit more than the emission reporting threshold (that is, 10,000 tonnes of CO_2 equivalent) on an annual basis must report its 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, Key Lake Operation reported GHG emissions to ECCC in 2017, 2018, 2019, and 2020. The emissions data can be found on ECCC's Greenhouse Gas Reporting Program webpage [48].https://climate-change.canada.ca/facility-emissions/ As of July 2022, the 2021 results are not yet available.

The CNSC maintains a collaborative working relationship with ECCC through a formal Memorandum of Understanding (MOU) [49], which includes a notification protocol. An exceedance of the GHG emissions threshold would be included under this notification protocol. This ensures 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* [50], Cameco is required to provide a semi-annual halocarbon release report to ECCC containing the release of halocarbons of an amount greater than 10 kg but less than 100 kg from any system, container, or equipment at the Key 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 1 halocarbon release of 20.41 kg of the R-22 refrigerant in 2015. The release was in accordance with ECCC's *Federal Halocarbon Regulations* [50], and therefore, CNSC staff found that there was little environmental impact from the R-22 releases.

2.4.3 National pollutant release inventory

Under the authority of CEPA 1999 [46], Cameco is required to report emissions of pollutants from the Key Lake Operation to the National Pollutant Release Inventory (NPRI) [51] if they are above the reporting threshold . 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 Key Lake Operation [52]. 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 Key Lake Operation throughout the current licensing period have been in compliance with the facility's approval to operate pollutant control facilities and 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 Key Lake Operation. It first includes a description of the radiological and hazardous releases to the environment (section 3.1), followed by a description of the environment surrounding Key Lake Operation and an assessment of any potential effects to the different components of the environment, due to 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 section on EP in licensing CMDs and annual RORs. Summaries of annual reports submitted by Cameco for the Key Lake Operation are made publicly available and can be viewed on the Key Lake Operation website [53].

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 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 Key Lake site 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 Key Lake Operation, and thus, should not be interpreted as a complete depiction of Key Lake Operation and its surrounding environment. The specific releases and COPCs associated with Key Lake Operation are explained in detail in the following subsections.

Figure 3.1: Conceptual model of the environment around the Key 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 the Environment issues an Approval to Operate a Pollutant Control Facility licence, which sets out release limits adopted from Saskatchewan's *The Mineral Industry Environmental Protection Regulations* [54]. At the federal level, under the *Fisheries Act* [55], metal and diamond mines must adhere to the requirements of the MDMER [43], 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 Key Lake Operation.

Table 3.1: Authorized licence limits for waterborne effluent at Key Lake Operation, adopted from the MDMER [43]

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) Based on the MDMER [50], "Monthly Mean Concentration" means the average value of the concentrations in composite or grab samples collected over a calendar month.

(b) Based on the LCH **[32]**, a "composite sample" means (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 not 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 not more than 24 hours.

(c) Based on the LCH **[32]**, a "grab sample" means a quantity of undiluted effluent collected at any given time.

(d) N/A stands for "not available".

(e) "Acutely lethal" (Source MDMER), 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, and thus, there are no limits for these parameters in the CNSC licence issued for the Key Lake Operation. The limits for selenium and uranium provided in section 3.1.3 (table 3.3) 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. REGDOC 2.9.1 (2017) [32] 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 3.1.3.3 of this report.

The CNSC has an interim objective for uranium releases of 0.1 mg/L, which is 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 [56], which was prepared under contract for the CNSC.

No provincial or federal licence limits currently exist for molybdenum. In the 2000s, the CNSC required that uranium mines and mills with high molybdenum releases upgrade their effluent management and water treatment processes to treat 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 and ALs to effectively manage and control molybdenum. Prior to May 2020, the Key Lake Operation had a molybdenum administrative loading target of 600 kg/yr in their EPP. This was removed in May 2020 with CNSC staff's approval because the Key Lake Operation demonstrated strong controls for molybdenum in the treated effluent.

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 Key Lake Operation, selenium is controlled using a target that is equal to the site specific ERA upper bound concentration of 0.03 mg/L. This value is derived from the site's ERA modelling. Prior to May 2020, the Key Lake Operation had a selenium administrative loading target of 40 kg/yr in their EPP. This was removed in May 2020 with CNSC staff's approval because the Key Lake Operation demonstrated strong controls for selenium in the treated effluent. The CNSC also requires the uranium mines and mills to 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 is available in draft REGDOC-2.9.2, *Controlling Releases to the Environment* [57]. The selenium site specific ERA upper bound concentration is currently being met for the Key Lake Operation as shown in Tables 3.4-3.6.

Draft REGDOC-2.9.2 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 Key Lake Operation to the environment under its EPP. This program is based on CSA N288.5-11 [34] and includes monitoring of both radiological and hazardous emissions.

The sources of possible airborne releases at Key Lake Operation include:

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

The emission sources have the potential to emit:

- particulate matter (PM) from wind erosion and material handling of tailings and the stockpiles, unpaved road dust, etc. (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), sulphur dioxide (SO_2) and carbon monoxide (CO))
- metals from from wind erosion of tailings and the stockpiles, mill stack emissions, etc. (that is, arsenic, cobalt, copper, lead, molybdenum, nickel, selenium, uranium and zinc)
- radon gas from tailings and ore and waste rock stockpiles

There are mitigation systems in place at Key Lake Operation to reduce airborne releases to the environment. For example, emissions from Key Lake Operation acid plant are passed through a scrubber to remove sulphur dioxide before it is released to the environment. Exhaust gas from Key Lake Operation mill calciner is passed through a scrubbing system to remove particulates before it is released to the environment. Emissions from the mill crystallization process, crushing room and packaging room are passed through scrubbers to remove particulates before it is released to the environment. Exhaust air from the mill building calciner room and yellowcake temprite is filtered before it is released to the environment. Another mitigation system is that dust emissions from unpaved roads are controlled through applying water to the road surfaces.

Since January 2018, Key Lake Operation has been in care and maintenance. Therefore, the sulphuric acid plant has been shut down and there have been no releases of sulphur dioxide to the environment. The annual total airborne releases from Key Lake Operation are shown in table 3.2.

Air emissions sources identified for the Key Lake Operation were modelled in Key Lake Operation Air Quality Modelling Assessment [58]. The results showed that there were no significant risks to the environment and persons from the identified emission sources.

Table 3.2: Annual total estimated airborne emissions from Key Lake Operation in tonnes (2013–2020) [4, 5, 6, 7, 8, 9, 10, 11, 12]

Parameter (tonnes)	2013	2014	2015	2016	2017	2018	2019	2020
Sulphur Dioxide	224.1	208.1	85.3	325.1	159.9	-	-	-
Oxides of Nitrogen (NO_2)	106.0	137.1	148.0	70.7	35.0	39.0	20.6	24.2
Ammonia (total)	43.0	39.6	34.0	32.1	30.2	7.5	-	-
Volatile Organic Compounds	171.1	132.1	163.7	115.0	111.1	-	-	-
Carbon Monoxide	348.0	347.9	344.9	358.0	109.6	-	-	-
PM	63.5	71.2	157.6	102.7	101.4	46.1	55.0	34.4
PM_{10}	17.9	16.9	45.2	32.6	30.2	16.7	18.5	12.8
$PM_{2.5}$	4.8	4.6	7.7	6.0	5.2	3.7	3.9	2.4

A dash indicates that the emission was below the reporting threshold.

Table 3.3 shows the sulphur dioxide ambient levels from the Key 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 Key Lake Operation (2013 to 2021) [4, 5, 6, 7, 8, 9, 10, 11, 12]

Parameter	Standard	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maximum hour (ppm)	0.170	0.461	0.459	0.476	0.200	0.170	0.035	0.129	0	0
Maximum 24 hour (ppm)	0.060	0.105	0.096	0.092	0.027	0.024	0.003	0.009	0	0
Annual average (ppm)	0.010	0.007	0.007	0.009	0.0006	0.0005	0.0004	0.0015	0	0

There are no limits for airborne emissions in the CNSC licence and in the Province of Saskatchewan's Approval to Operate permit. Instead, the uranium mines and mills conduct ambient air quality monitoring and compare the results to the ambient air quality standards in Schedule 2 of their provincial Approve to Operate permit. Please refer to section 3.2.1.2 for more information about ambient air quality monitoring and tables 3.8 and 3.9 for the ambient air quality data.

3.1.2.1 Findings

Based on CNSC staff's review of the results of the Key Lake Operation EPP and Key Lake Operation Air Quality Modelling Assessment [58] , CNSC staff found that Cameco's air emissions to the environment from the Key Lake Operation are very low. CNSC staff 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 Key Lake Operation to the environment under its implementation of the EPP. This program is based on CSA N288.5-11 [35], and includes monitoring of radiological and hazardous releases.

The Key Lake Operation has two water treatment plants: the bulk neutralization circuit within the mill and the reverse osmosis (RO) treatment plant. These two water treatment plants are summarized in the Facility Licensing Manual [59]. At both of the water treatment plants, Cameco monitors temperature, conductivity, pH, metals (for example,, arsenic, copper, lead, molybdenum, nickel, selenium, uranium, un-ionized ammonia and zinc) and radionuclides (for example,, radium-226, thorium-230, polonium-210, and lead-210) in effluent released. Also, Cameco records the flow rate and total volume of each release from the Key Lake Operation. With this information, Cameco calculates and reports the total mass loadings of COPCs to the environment.

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 [43] These are are recognized standard aquatic toxicity tests used in concert with effluent limits to assess compliance with 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 Key Lake Operation met the MDMER acute lethality requirements.

3.1.3.1 Effluent from the bulk neutralization circuit

The bulk neutralization circuit at Key Lake Operation mill receives contaminated water feeds from various sources and removes dissolved metals and suspended solids. The treatment process consists of multiple pH controlled chemical precipitation and final polishing stages that include:

- the solution neutralization and the low pH molybdenum/selenium thickener stage is used to precipitate arsenic, molybdenum, and selenium. The low pH effluent enters the Molybdenum/Selenium Thickener to precipitate these elements with the assistance of a flocculant (substance that is added to help solid particles clump together). The effluent is sent to a couple of pachuca tanks (common industry name for effluent storage tanks) to increase the pH. The effluent enters the Bulk Neutralization Thickener to precipitate heavy metals and uranium. Then the effluent is fed to the Radium Removal Circuit.
- the Radium Removal Circuit is used to react and precipitate radium-226. Barium chloride and dilute sulphuric acid are added to reduce the final pH of the effluent stream. The effluent is sent to a Radium Removal Thickener for final fine particle solids removal and effluent polishing.
- at monitoring ponds, where treated water is pumped, a composite sample is taken as the pond fills up, and treated water is batch discharged to Wolf Lake in the David Creek drainage, provided that lab results indicate that COPCs in the sample are within licence limits and internal targets, otherwise the treated water is recycled back for further treatment. A composite sample is a quantity of effluent consisting of three equal volumes of effluent, or three volumes proportional to flow, that has been collected at approximately equal time intervals over a period of between 7 to 24 hours.
- during a pond release, a composite pond discharge sample is collected and analyzed. These results are reported as the final analysis of the monitoring pond's quality. In-line pH and total suspended solids probes will also stop the discharge of a monitoring pond if water quality deviates above or below the acceptable range for release.

If the sample results are outside of release criteria, the release is immediately stopped and the water is pumped back to a collection pond to be returned to the bulk neutralization circuit for further treatment.

Table 3.4 summarizes the annual monthly mean concentrations of liquid effluent discharged to Wolf Lake from 2013 to 2021, before dilution at the end of pipe. In addition to licence limits, Cameco has established liquid effluent ALs for important COPCs, such as uranium, molybdenum, and selenium, and internal control levels (also known as administrative levels). Exceedances of licence limits and ALs are required to be reported to the CNSC, documented, investigated, and appropriate corrective actions are taken where warranted. With the exception of the total suspended solids (TSS) event in November 2022, all of the COPCs in the effluent discharged from the bulk neutralization circuit remain below regulatory limits. With the exception of the uranium event in October 2022, no AL at the bulk neutralization circuit has been exceeded over the current reporting period. More information about these events are discussed in the following paragraphs.

Table 3.4: Annual average waterborne releases from Key Lake treated mill effluent compared with applicable release limits (2013 – 2021) [4, 5, 6, 7, 8, 9, 10, 11, 12]

Parameter	Licence limit	2013	2014	2015	2016	2017	2018	2019	2020	2021
Arsenic (mg/L)	0.3	0.008	0.008	0.006	0.007	0.008	0.0076	0.0075	0.0113	0.0109
Copper (mg/L)	0.3	0.013	0.014	0.030	0.029	0.023	0.005	0.001	0.001	0.002
Lead (mg/L)	0.1	<0.01	<0.01	0.01	0.01	0.01	0.01	0.0003	0.0002	0.0004
Nickel (mg/L)	0.5	0.067	0.049	0.071	0.144	0.167	0.257	0.142	0.153	0.094
Zinc (mg/L)	0.5	0.009	0.012	0.009	0.010	0.009	0.009	0.007	0.006	0.005
pH [(a)]	6.0 to 9.5	6.3	6.3	6.4	6.4	6.5	6.7	6.6	6.6	7.0
Radium-226 (Bq/L)	0.37	0.05	0.05	0.07	0.05	0.07	0.07	0.09	0.036	0.017
Total suspended solids (mg/L)	15	1.8	1.8	2.8	2.1	3.1	2.0	2.0	2.3	1.7
Un-ionized Ammonia (mg/L)	0.5[(b)(c)]	0.012	0.019	0.016	0.015	0.015	0.004	0.003	0.003	0.02
Selenium (mg/L)	0.6 [(d)]	0.017	0.018	0.018	0.017	0.015	0.010	0.010	0.011	0.010
Uranium (mg/L)	2.5 [(e)]	0.008	0.006	0.008	0.006	0.011	0.013	0.0243	0.0259	0.0239
Molybdenum (mg/L)	N/A [(f)]	0.15	0.16	0.10	0.08	0.12	0.07	0.05	0.056	0.038

(a) pH is taken from every discharge sample. It is not measured in monthly composite samples.
(b) The un-ionized ammonia data from 2013 to 2020 were calculated using the pH, temperature, and ammonia concentrations.
(c) Un-ionized ammonia was added to the MDMER in 2021.
(d) This is the provincial limit that is not in the CNSC licence.
(e) This is the provincial limit that is not in the CNSC licence. As discussed in section 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 bencmark to demonstrate the application of ALARA and BATEA.
(f) Refer to section 3.1.1 for an explanation of why no provincial or federal licence limits currently exist for molybdenum.

On October 28, 2022, the pond discharge composite sample of the treated effluent discharged to the environment from the bulk neutralization circuit had an uranium concentration of 81 µg/L, which is above the action level of 80 µg/L. Cameco investigated the incident and determined that there were fluctuations in uranium concentrations in feedwater from reservoir #1 and the final effluent at the time of the incident. Cameco removed the solids and sediment in reservoir #1 in summer 2022 through agitation, resulting in an increase in the concentrations of solids, including uranium, entering the bulk neutralization circuit. Immediately after the incident, water feed to the bulk neutralization circuit was switched to reservoir #2 to allow the water quality in reservoir #1 to improve and stabilize. As a result, the subsequent uranium concentrations were below the action level. On October 31, Cameco collected a water sample with a uranium concentration of 2.2 µg/L from the monitoring station in Wolf Lake, which is within historical ranges at this station. Cameco completed the investigation and took corrective actions in response to the event, as a result, CNSC staff conclude there is no potential impact on the environment.

On November 24, 2022, there was an action level exceedance of TSS at the bulk neutralization circuit. The pond fill composite sample met the discharge criteria and was authorized for discharge to the environment. As the pond was being discharged to the environment, the turbidity interlock system activated. The discharge was immediately stopped and grab samples were collected. The interlock indicated high turbidity values and the effluent was recycled back to the bulk neutralization circuit for further treatment. The grab sample had a TSS value of 37 mg/L, which is above the action level of 18 mg/L and also above the limit of 30 mg/L as contained in Schedule 1 in the provincial Approval to Operate. Approximately 1307 m3, or 32% of the pond, was released to the environment. On November 25, Cameco collected a water sample at the monitoring station in Wolf Lake. The TSS concentration was 1.9 mg/L and CNSC staff confirmed that this is within historical ranges at this station. As of December 1st, 2022, Cameco’s investigation is still underway.

As seen in table 3.4, the concentrations of some parameters increased after the Key Lake Operation was placed in care and maintenance. Some fluctuations in parameters were expected because of activities during the care and maintenance period and because of a change in operational states. For example, once the mill shuts down, some of the uranium that would have been removed as a product ends up in the effluent. The increase in uranium is also due to a reduction in solids in the bulk neutralization thickener during care and maintenance. The increase in nickel is due to the focused treatment of RO reject water, which is high in nickel, and the removal after raffinate from the treatment mix, which provided both additional iron and solids to enhance precipitation in the treatment circuit.

Table 3.5 summarizes the annual waterborne loadings to Wolf Lake before dilution for the period of 2013 to 2021 [14]. The data shows that the loadings remained stable during the operational period from 2013 to 2017. The loadings of some parameters (molybdenum and selenium) slightly decreased after the Key Lake Operation was placed in care and maintenance in 2018. The loadings of some parameters, such as nickel and uranium, increased during care and maintenance as a result of higher concentrations and higher volumes released.

Table 3.5: Annual waterborne loadings discharged to Wolf Lake from the treated mill effluent (2013–2021) [4, 5, 6, 7, 8, 9, 10, 11, 12]

Parameter	2013	2014	2015	2016	2017	2018	2019(a)	2020	2021
Arsenic (kg)	10.5	8.9	5.5	5.0	6.6	9.2	9.2	16.7	12.9
Copper (kg)	15.8	17.1	30.7	21.7	20.6	6.8	1.5	1.6	1.8
Lead (kg)	12.2	11.3	9.2	8.1	8.2	13.3	0.4	0.3	0.5
Nickel (kg)	81.9	52.8	63.2	107.0	129.3	327.0	173.8	226.0	111.1
Zinc (kg)	10.6	13.9	8.5	7.3	6.6	12.8	8.0	8.6	5.6

Radium-226 (MBq)	56.6	53.0	64.4	41.7	61.8	95.6	110.1	53.3	20.1
Total suspended solids (kg)	2,227	1,949	2,548	1,729	2,227	2,698	2,448	3,407	2,014
Un-ionized Ammonia (kg) (b)	-	-	-	-	-	-	-	-	23.7
Selenium (kg)	20.2	20.1	15.7	12.9	12.2	13.6	12.5	15.7	11.7
Uranium (kg)	9.5	6.0	7.5	4.8	7.3	17.9	29.7	38.4	28.3
Molybdenum (kg)	175.6	186.4	82.0	58.4	102.0	83.4	60.0	82.7	44.8

(a) In 2019, annual reports where the average annual concentration was multiplied by the volume released to align with the methods used by ECCC, the methodology for the calculation of mass loadings was updated. Prior to 2019, individual pond concentrations were multiplied by individual pond volumes.
(b) Prior to 2021, NH_3-N loadings were reported. Following 2021, un-ionized ammonia was added to the MDMER.

3.1.3.2 Effluent from RO treatment plant

Water from the groundwater recovery wells located around the Deilmann in-pit Tailings Management Facility that contains elevated contaminants is fed to the RO treatment plant for treatment prior to discharge to the Horsefly Lake in the McDonald Lake system.

The treatment process consists of several feed water pre-treatment stages to remove critical contaminants and suspended solids that would affect the RO process. A potassium permanganate solution is injected into the raw water influent line to oxidize iron and manganese. A 50% sodium hydroxide solution is also injected into the raw water influent line to increase the pH of the raw water. The oxidized, pH adjusted raw water is fed to the manganese green sand pressure filters. The raw water is sent to the cartridge polishing filters to remove any micro-particulates that may foul the RO membrane system. Then, the raw water is sent to one of the RO membrane treatment modules, which has membrane arrays for maximum filtering. Each array contains thin film composite membranes. The membranes remove ions and dissolved substances with a diameter in the single to double-digit angstrom range.

Cameco collects a daily sample of the treated water from the RO plant at the Key Lake Operation. The samples are analyzed in the Key Lake Operation laboratory. In addition, samples are collected from the final point of discharge, Horsefly Lake Dewatering Discharge, on a weekly basis. If the lab results show that there is a licence limit exceedance, the discharge is immediately stopped.

Table 3.6 summarizes the annual mean concentrations of liquid effluent discharged to Horsefly Lake from 2013 to 2021. In addition to licence limits, Cameco has established internal control levels (also known as administrative levels). As shown in table 3.6, with the exception of one event that is described in the next paragraph, all of the COPCs in the effluent discharged from the RO plant remain below regulatory limits.

Table 3.6: Annual average waterborne releases from Key Lake Operation RO plant compared with applicable release limits (2013–2021) [4, 5, 6, 7, 8, 9, 10, 11, 12]

Parameter (a)	Licence limit	2013	2014	2015	2016	2017	2018	2019	2020	2021
Arsenic (mg/L)	0.3	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper (mg/L)	0.3	<0.0002	0.0002	<0.0002	<0.0002	0.0002	0.0002	<0.0002	<0.0002	<0.0002
Lead (mg/L)	0.1	<0.0001	0.0001	0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Nickel (mg/L)	0.5	0.0287	0.0245	0.0217	0.0323	0.0112	0.0160	0.0310	0.0414	0.0487

Zinc (mg/L)	0.5	0.0022	0.0014	0.0007	0.0012	0.0006	0.0011	0.0025	0.0026	0.0037
pH	6.0 to 9.5	6.8	6.4	6.4	6.6	6.5	6.6	6.8	6.8	6.8
Radium-226 (Bq/L)	0.37	0.007	0.006	0.005	0.006	0.006	0.005	0.006	0.005	0.005
Total suspended solids (mg/L)	15	0.3	0.2	0.2	0.2	<0.2	0.2	0.2	1.1	1.1
Un-ionized ammonia (mg/L)	0.5 (b)	-	-	-	-	-	-	-	-	<0.01
Selenium (mg/L)	0.6 (c)	<0.0009	<0.0009	<0.0001	0.0001	<0.0001	<0.0001	0.0001	0.0001	0.0001
Uranium (mg/L)	2.5 (d)	0.0034	0.0027	0.0039	0.0040	0.0017	0.0035	0.0035	0.0055	0.0048
Molybdenum (mg/L)	N/A (e)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	0.0001	0.0001	<0.0001

(a) Units are in milligrams per litre (mg/L) or becquerels per litre (Bq/L). Results show the mean of the concentrations for each month in one year.
(b) Un-ionized ammonia was added to the MDMER in 2021.
(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 section 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 section 3.1.1 for an explanation of why no provincial or federal licence limits currently exist for molybdenum.

In December, 2013, approximately 200m^3 of treated effluent with a pH of approximately 10.8 was released from the RO plant to Horsefly Lake following an upset condition in the RO plant. Again, in October 2018, approximately 10 m^3 of high pH (10.16) effluent was released from the RO plant to Horsefly Lake. Although only a relatively small volume of discharge was released in each event, the pH was above the upper pH limit specified in the MDMER (9.5) [43] and was also above the maximum grab sample limit within the provincial operating approval (9.5) [60]. Supplemental monitoring was initiated and indicated that pH met all regulatory requirements downstream. As a comparison to the volume of elevated pH effluent discharged during the events, the average daily discharge of treated effluent to the environment in December 2013 and October 2018 was approximately 11,645 m^3 and 14,860 m^3, respectively. Furthermore, a total of 4,326,661 m^3 and 4,999,381 m^3 of water was discharged to Horsefly Lake in 2013 and 2018, respectively. Cameco completed investigations and developed corrective actions to improve pH control. CNSC staff reviewed the status of Cameco's follow-up actions during compliance inspections, and found that they were acceptable.

Table 3.7 summarizes the annual waterborne loadings to Horsefly Lake before dilution for the period of 2013 to 2021 [14]. The data shows that the loadings remained stable during the operational period from 2013 to 2017. The loadings of some parameters, such as nickel and uranium, increased during care and maintenance as a result of higher concentrations and higher volumes released.

Table 3.7: Annual waterborne loadings discharged to Horsefly Lake from the RO plant (2013 – 2021) [4, 5, 6, 7, 8, 9, 10, 11, 12]

Parameter	2013	2014	2015	2016	2017	2018	2019	2020	2021
Arsenic (kg)	0.43	0.35	0.34	0.38	0.38	0.50	0.40	0.50	0.43
Copper (kg)	0.86	0.77	0.67	0.76	0.76	1.00	0.81	0.99	0.87
Lead (kg)	0.43	0.35	0.34	0.38	0.38	0.50	0.40	0.50	0.43
Nickel (kg)	124.17	85.26	72.81	123.49	42.71	79.99	125.10	205.53	211.06
Zinc (kg)	9.52	4.87	2.35	4.59	2.29	5.50	10.09	12.91	16.04
Radium-226 (MBq)	30	20	17	23	23	25	24	24	22
Total suspended solids (kg)	1298.0	696.0	671.0	764.6	762.7	999.9	807.1	5461.0	4767.2
Un-ionized Ammonia (kg)	-	-	-	-	-	-	-	-	43.34
Uranium (kg)	14.70	9.39	13.10	15.29	6.48	8.50	14.12	27.31	20.80

3.1.3.3 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 had the potential to cause adverse environmental effects. As a result of this finding and upon request by the Commission [61, 62], 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 mill water treatment plant at the Key Lake Operation to more effectively control selenium and molybdenum in effluent. This resulted in more stable loadings to the environment.

3.1.3.4 Findings

CNSC staff found that liquid effluent discharged from the Key Lake Operation to Wolf Lake and to Horsefly Lake remained below CNSC's licence limits throughout the reporting period (2013 to 2021), with the exception of the high-pH release events in December 2013 and October 2018. CNSC staff also found that the treated effluent met the requirements for acute lethality testing to aquatic organisms in the receiving environment.

CNSC staff are satisfied that Key Lake Operation is taking the appropriate above-mentioned measures 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 2020 ERA (see section 2.3.3). The ERA was performed in a stepwise manner as follows:

- quantify the releases (of COPCs) to the environment from current (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 [14] along with Cameco's 2015–2019 Environmental Performance Report [63], and the Key Lake Operation annual compliance monitoring and operational performance reports submitted between 2013 and 2021, inclusively [4, 5, 6, 7, 8, 9, 10, 11, 12].

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, as well as those that 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 Key Lake Operation.

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.

Key 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.

Key Lake Operation features an on-site meteorological station, which until 2018 has been used by ECCC to report meteorological data for the area. In 2018, weather information was obtained from three sources located at Key Lake Operation. This meteorological equipment was decommissioned as part of cost saving measures during the care and maintenance shutdown. Use of the automated weather station on the Deilmann North Waste Rock Pile (DNWRP) at Key Lake Operation has been used from October 2018 onwards.

3.2.1.2 Ambient air quality

ERA predictions

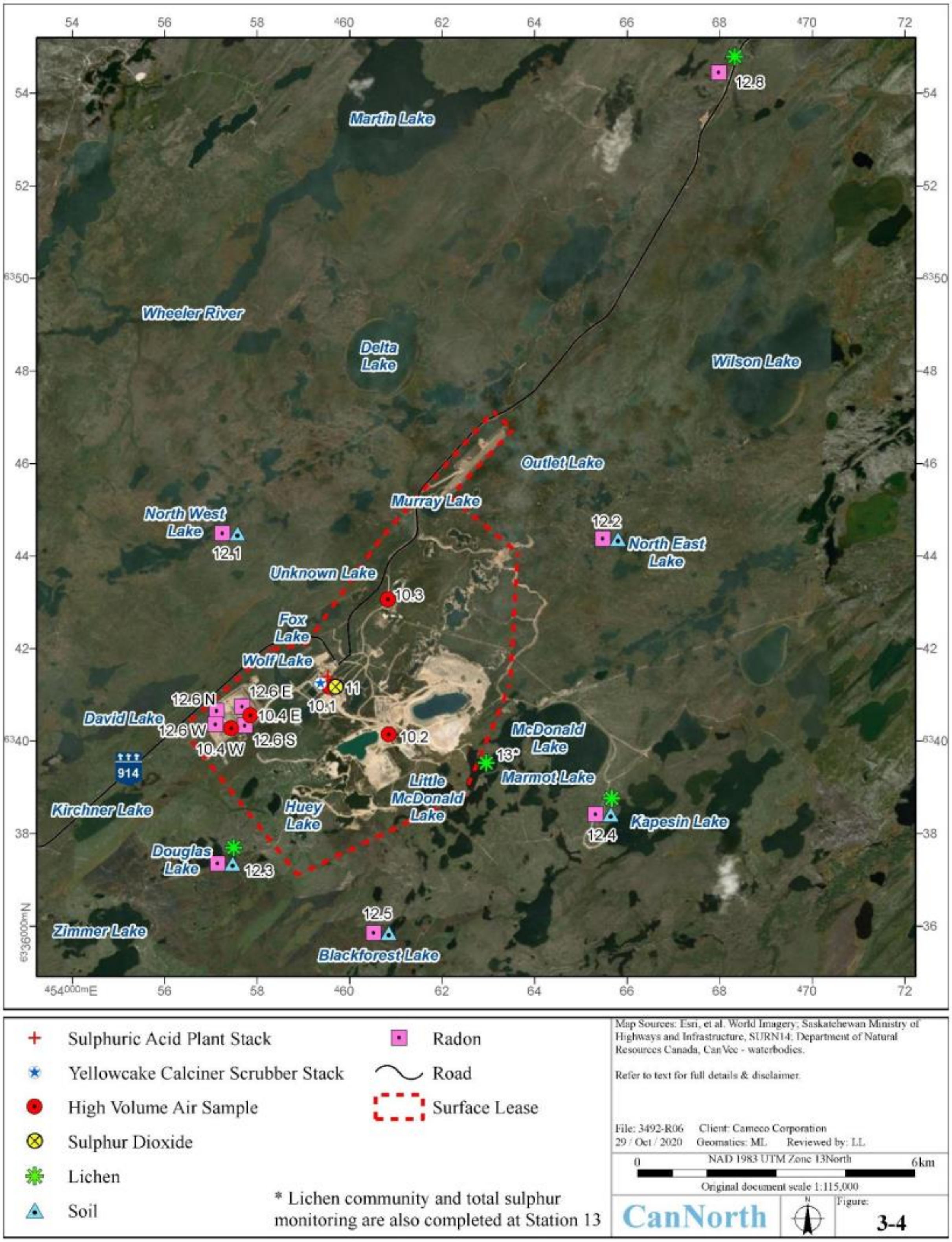
In the 2020 ERA, Cameco predicted and assessed the potential impacts to ambient air quality at Key Lake Operation by using the CALMET/CALPUFF modelling software to predict concentrations of COPCs generated by Key Lake Operation [14].

Overall, the predicted potential air quality effects from Key Lake Operation were limited and were related to short-term exceedances of TSP, particulate matter smaller than 10 and 2.5 micrometres, nitrogen dioxide air quality standards and exceedances of annual guideline values for uranium and radon. However, the model showed poor calibration against measured uranium concentrations at locations around Key Lake Operation, which is likely attributable to overestimates of key parameters in the emissions inventory. In addition, due to the conservative assumptions that have been built into this assessment, it is likely that the predicted concentrations and exceedances noted for the other COPCs will be less than what was predicted by the model.

Ambient air monitoring

Cameco monitors emissions and ambient air through multiple programs, including high volume air sampling, ambient sulphur dioxide monitoring, stack sampling, and radon monitoring. Refer to figure 3.2.

Figure 3.2: Air and terrestrial monitoring locations at Key Lake Operation [14]



The Key Lake Operation ambient air monitoring consists of 5 high-volume air samplers to measure particulate matter and associated levels of metals and radionuclides that may originate from emission sources. An atmospheric SO_2 analyzer continuously measures and records ambient SO_2 levels downwind of the sulphuric acid plant and yellowcake calciner. There is no recent monitoring data for ambient SO_2, as monitoring was temporarily ceased when the acid plant was shut down for the duration of the care and maintenance period.

Yellowcake and acid plant stacks are tested for particulates and SO_2, respectively, to quantify air emissions from these sources at Key Lake Operation. During operations, stack sampling of particulate matter and select radionuclides and metals are carried out on the emissions from the yellowcake calciner scrubber.

Ambient radon (Rn-222) levels are monitored using passive radon detectors around the site boundaries and on the AGTMF.

Table 3.8 shows the average annual suspended particulate at the high-volume samplers across the site. For reference, the Saskatchewan ambient air quality standard for TSP is 60 µg/m^3, which all recorded values in Table 3.8 have remained below.

Table 3.8: High-volume air sampler total suspended particulate annual averages in µg/m^3 [4]

Year	Station 10.1	Station 10.2	Station 10.3	Station 10.4 W	Station 10.4 E	Saskatchewan Ambient Air Quality Standard
2021	7	10	8	5	5	60
2020	9	8	7	4	4	60
2019	10	9	7	5	5	60
2018	10	12	9	7	7	60
2017	19	14	16	7	8	60
2016	19	14	13	7	6	60
2015	20	11	8	9	6	60
2014	21	14	7	9	9	60
2013	16	16	9	7	7	60

Tables 3.9 and 3.10 show metal and radionuclide concentrations in air around the Key Lake Site. As federal or provincial guidelines for these parameters have not been set, the references cited are from Ontario and ICRP standards. All values in tables 3.9 and 3.10 remained below the available reference values and have either remained consistent or decreased during the care and maintenance period.

Table 3.9: Metal and radionuclide concentrations in ambient air at Key Lake Operation (2013-2021) [4]

Station	Parameter	Reference[(a)]	2013	2014	2015	2016	2017	2018	2019	2020	2021
Station 10.1	Radium-226 (Bq/m^3)	0.013	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Station 10.1	Lead-210 (Bq/m^3)	0.021	0.0003	0.0004	0.0003	0.0004	0.0002	0.0003	0.0003	0.0003	0.0001
Station 10.1	Thorium-230 (Bq/m^3)	0.0085	0.0001	<0.0001	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Station 10.1	Uranium (µg/m^3)	0.06	0.0268	0.0342	0.0334	0.0325	0.0342	0.0013	0.0005	0.0003	0.0004
Station 10.1	Arsenic (µg/m^3)	0.06	0.001	0.0011	0.0007	0.0005	0.0006	0.0007	0.0002	0.0001	0.0003
Station 10.1	Nickel (µg/m^3)	0.04	0.001	0.0013	0.001	0.0003	0.0004	0.0005	0.0001	0.0002	0.0004
Station 10.2	Radium-226 (Bq/m^3)	0.013	0.0001	0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Station 10.2	Lead-210 (Bq/m^3)	0.021	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004
Station 10.2	Thorium-230 (Bq/m^3)	0.0085	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Station 10.2	Uranium (µg/m^3)	0.06	0.0029	0.0034	0.0037	0.0027	0.0035	0.0011	0.0005	0.0002	0.0004
Station 10.2	Arsenic (µg/m^3)	0.06	0.0016	0.0028	0.0025	0.0011	0.0051	0.0014	0.0005	0.0003	0.0005
Station 10.2	Nickel (µg/m^3)	0.04	0.0015	0.0018	0.0019	0.0010	0.0056	0.0006	0.0002	0.0003	0.0006
Station 10.3	Radium-226 (Bq/m^3)	0.013	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Station 10.3	Lead-210 (Bq/m^3)	0.021	0.0001	0.0001	0.0001	0.0002	0.0002	0.0001	0.0001	0.0001	0.0002
Station 10.3	Thorium-230 (Bq/m^3)	0.0085	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Station 10.3	Uranium (µg/m^3)	0.06	0.0005	0.0002	0.0007	0.0005	0.0004	0.0004	0.0001	<0.0001	0.0002
Station 10.3	Arsenic (µg/m^3)	0.06	0.0005	0.0012	0.0011	0.0005	0.0002	0.0004	0.0001	0.0001	0.0002
Station 10.3	Nickel (µg/m^3)	0.04	0.0003	0.0004	0.0005	0.0004	0.0003	0.0002	0.0001	0.0001	0.0003

Table 3.10: Metal and radionuclide concentrations in ambient air at Key Lake (2013-2021) Continued [4]

Station	Parameter	Reference(a)	2013	2014	2015	2016	2017	2018	2019	2020	2021
Station 10.4 W	**Radium-226 (Bq/m^3)**	0.013	0.0001	0.0001	0.0001	<0.0001	0.0008	0.0002	0.0001	<0.0001	<0.0001
Station 10.4 W	**Lead-210 (Bq/m^3)**	0.021	0.0004	0.0004	0.0004	0.0002	0.0007	0.0003	0.0002	0.0001	0.0002
Station 10.4 W	**Thorium-230 (Bq/m^3)**	0.0085	0.00001	0.0001	0.0001	<0.0001	0.0007	0.0002	0.0002	<0.0001	<0.0001
Station 10.4 W	**Uranium ($\mu g/m^3$)**	0.06	0.0011	0.0008	0.0015	0.0008	0.0032	0.0004	0.0006	0.0001	0.0002
Station 10.4 W	**Arsenic ($\mu g/m^3$)**	0.06	0.0026	0.0027	0.0022	0.0011	0.019	0.0024	0.0043	0.0005	0.0003
Station 10.4 W	**Nickel ($\mu g/m^3$)**	0.04	0.0015	0.0012	0.001	0.0007	0.0055	0.0014	0.0028	0.0004	0.0004
Station 10.4 E	**Radium-226 (Bq/m^3)**	0.013	0.0001	0.0007	0.0001	<0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
Station 10.4 E	**Lead-210 (Bq/m^3)**	0.021	0.0004	0.0009	0.0003	0.0001	0.0004	0.0003	0.0004	0.0002	0.0003
Station 10.4 E	**Thorium-230 (Bq/m^3)**	0.0085	0.0001	0.0007	0.0001	<0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
Station 10.4 E	**Uranium ($\mu g/m^3$)**	0.06	0.0010	0.0011	0.001	0.0014	0.001	0.0021	0.0022	0.0003	0.0003
Station 10.4 E	**Arsenic ($\mu g/m^3$)**	0.06	0.0029	0.0175	0.0026	0.0010	0.0036	0.0057	0.0055	0.0026	0.0015
Station 10.4 E	**Nickel ($\mu g/m^3$)**	0.04	0.0020	0.00123	0.0019	0.0010	0.0027	0.0036	0.0050	0.0021	0.0016

(a) Reference annual air quality levels from the Province of Ontario [64] and the ICRP [65] are shown for reference only, as no limits have been established by the federal government or province of Saskatchewan

Table 3.11 shows the measurements of radon in air around the Key Lake Site. Station 12.8 is considered a reference site, the values of which are like the exposure locations, except for those around the AGTMF which are shaded grey in the table. The elevated values around the AGTMF are a result of radon exhalation from the stored tailings. As the AGTMF is open to the atmosphere, radon emissions dissipate rapidly so does not pose a significant hazard to the environment or to personnel working in the area. This is supported by the 2020 ERA, which found that workers were not at risk from radiological COPCs from working on the site.

Table 3.11: Radon monitoring (Bq/m³) track etch summary statistics 2017-2021 [4]

Station	2017	2018	2019	2020	2021
Station 12.1	9.5	8	7.5	<10.5	<15
Station 12.2	8	<7	6.5	<10.5	<15
Station 12.3	22	29	20.5	17.5	16
Station 12.4	8	7.5	14.5	<12.5	<14
Station 12.5	7	10.5	10	<11.5	<14
Station 12.6E	826.5	738	873	776.5	900
Station 12.6N	457	383	454.5	351	438
Station 12.6S	788	755	761	529	618
Station 12.6W	460.5	660.5	646	605	549
Station 12.8	8	<7	<7	<10	<14

Gray highlighted stations represent those surrounding the AGTMF

3.2.1.3 Findings

Based on CNSC staff's review of Cameco's EPP results, ERA and Key Lake Operation Air Quality Modelling Assessment, CNSC staff have found that air emissions from Key Lake Operation remain within the ERA predictions, and 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 Key Lake Operation and the surrounding area consists of characterizing the local habitat and species (including considering federal species at risk) and assessing the possibility of their exposure to radiological and hazardous substances, as well as physical stressors that may be disruptive to ecological receptors.

3.2.2.1 Soil quality

Soil deposits within Key Lake Operation area are characterized by: glaciofluvial; till; organic; and reworked glaciofluvial (eolian). Eluviated Dystric Brunisols are the dominant mineral soil in the area. The sandy soil in the area typically has low nutrient content, low cation exchange capacity, low pH, and low electrical conductivity. These materials are easily wind-blown and poor media for revegetation.

ERA predictions

The 2020 ERA determined there is a possibility of measurable changes in lichen COPC concentration due to air deposition. These changes are limited to the immediate area around the site operations, and concentrations return to background levels following decommissioning. The potential food chain impacts for animals that consume lichen were also addressed and showed that negative influences from the consumption of lichen surrounding Key Lake Operation are not expected. CNSC staff reviewed the risk assessment and agreed with the conclusions that there is negligible risk to the critical receptors from soil or lichen contamination. Further details are provided below.

Terrestial monitoring program

The terrestrial monitoring program at Key Lake Operation includes routine sampling of soils at five locations and lichen at four locations (figure 3.2) to assess the potential influence from dust and SO_2 emissions on the terrestrial environment. Since 2003, the soil and lichen survey has been completed on a five year cycle to fulfill requirements of the EMP as per the Saskatchewan Ministry of Environment issued approval to operate [52, 66]. Prior to 2003, sampling was completed on a three-year (1988 to 2003) and two-year (1982 to 1988) cycle. The most recent round of sampling was completed in 2021 with the next campaign expected in 2026.

Results from soil samples collected in 2013, 2016 and 2021 (table 3.12) shows that concentrations in soil metal parameters were below available Canadian Environmental Quality Guidelines [67] for residential/parkland land use. Radionuclide concentrations in soils were also low, near, or at background levels and analytical detection limits. CNSC staff found that the concentrations of COPCs in soil surrounding Key Lake Operation are acceptable and do not pose a risk to ecological receptors in the vicinity of the facility.

Table 3.12: Soil monitoring results from 2013 – 2021 at Key Lake Operation [63, 4]

Station	Year	Arsenic (µg/g)	Nickel (µg/g)	Sulphate (µg/g)	Uranium (µg/g)	Lead-210 (Bq/g)	Polonium-210 (Bq/g)	Radium-226 (Bq/g)	Thorium-230 (Bq/g)
Reference[(a)]	-	12	45	-	23	-	-	-	-
North West Lake 12.1	1984 (Baseline)	0.48	5.7	<50	1.1	0.24	0.04[(b)]	0.18	3.5
North West Lake 12.1	2013	0.5	0.8	17	0.2	<0.04	0.02	0.03	<0.02
North West Lake 12.1	2016	0.57	0.5	<50	0.4	0.1	0.05	0.02	<0.02
North West Lake 12.1	2021	0.5	0.2	57	0.2	<0.04	0.02	0.02	<0.02
North East Lake 12.2	1984 (Baseline)	1.4	3.6	<50	0.7	0.16	0.13[(b)]	0.06	2.2
North East Lake 12.2	2013	0.3	0.5	<10	0.2	<0.04	0.01	0.03	<0.02
North East Lake 12.2	2016	0.53	0.4	<50	0.3	0.07	0.04	0.02	<0.02
North East Lake 12.2	2021	0.4	0.1	<50	0.3	<0.04	0.02	0.02	<0.02
Douglas Lake 12.3	1984 (Baseline)	0.45	7.9	80	0.9	0.12	0.1[(b)]	0.06	<0.01
Douglas Lake 12.3	2013	0.43	0.8	30	0.2	<0.04	0.01	0.02	<0.02
Douglas Lake 12.3	2016	0.77	1	<50	0.4	0.15	0.1	0.02	<0.02
Douglas Lake 12.3	2021	0.5	0.1	<50	0.2	<0.04	0.01	0.03	<0.02
Kapesin Lake 12.4	1984 (Baseline)	0.47	7.3	50	0.7	0.13	0.02[(b)]	0.06	2.5
Kapesin Lake 12.4	2013	0.5	0.5	20	0.3	<0.04	0.01	0.03	<0.02
Kapesin Lake 12.4	2016	0.73	0.7	<50	0.5	0.06	0.04	0.03	<0.02
Kapesin Lake 12.4	2021	0.5	0.2	<50	0.2	<0.04	0.02	0.02	<0.02
Black Forest Lake 12.5	1984 (Baseline)	0.54	5.9	<50	0.7	0.17	0.07[(b)]	0.04	<0.02[(b)]
Black Forest Lake 12.5	2013	0.47	1.2	<10	0.3	<0.04	0.01	0.01	<0.02
Black Forest Lake 12.5	2016	0.33	0.3	<50	0.2	0.04	0.04	0.02	<0.02
Black Forest Lake 12.5	2021	0.5	0.6	<50	0.2	<0.04	0.03	0.02	<0.02

(a) From CCME Soil Quality Guidelines for the Protection of Environmental and Human Health (Residential/Parkland Guidelines). [67].
(b) Earliest measurements are from 1991.

As shown in table 3.13, lichen levels of arsenic, nickel, and uranium are generally declining with time and saw some of the lowest levels reported in 2021, possibly due to the recent care and maintenance status of the facility and improvements to effluent control practices over time. Levels of radionuclides have been relatively low over time and again some parameters were the lowest recorded in 2021 since the inception of the monitoring program. Results from the 2016 soil sampling program [68] illustrate that licenced parameter concentrations at all stations were comparable to, or lower than, historical results, with the exception of lead-210 and polonium-210 which increased in 2016, but returned to lower levels during the 2021 sampling period.

Table 3.13: Lichen monitoring results from 2013 – 2021 at Key Lake Operation [63, 4]

Station	Year	Arsenic (μg/g)	Nickel (μg/g)	Uranium (μg/g)	Sulphur (μg/g)	Lead-210 (Bq/g)	Polonium-210 (Bq/g)	Radium-226 (Bq/g)	Thorium-230 (Bq/g)
Kapesin Lake 12.4	2013	0.38	0.43	0.4	-	0.31	0.3	0.072	0.052
Kapesin Lake 12.4	2016	0.32	0.41	0.62	-	0.36	0.25	0.008	0.007
Kapesin Lake 12.4	2021	0.14	0.38	0.14	250	0.21	0.19	0.034	0.014
Wheeler River Reference 12.8[(a)]	2013	-	-	-	-	-	-	-	-
Wheeler River Reference 12.8[(a)]	2016	0.55	2.2	1.9	-	0.28	0.22	0.032	0.024
Wheeler River Reference 12.8[(a)]	2021	0.14	0.63	0.28	250	0.29	0.27	0.006	0.003
Marmot Lake 13	2013	1.45	1.4	2.45	322	0.41	0.36	0.029	0.019
Marmot Lake 13	2016	1.1	1.3	2.5	400	0.33	0.27	0.04	0.031
Marmot Lake 13	2021	0.58	0.76	0.74	220	0.29	0.18	0.012	0.0089

(a) The Wheeler River sample area was destroyed by fire in 2007 and subsequent sampling years did not contain sufficient lichen in 2013. A new station was established in 2016.

3.2.2.2 Terrestrial habitat and species

Key Lake Operation is located along the edges of the Athabasca Plain and Churchill River upland ecoregions, which includes part of continuous coniferous forest that extends from northwestern Ontario to Great Slave Lake in the Northwest Territories. Jack pine, shrubs, and lichens are dominant, but some paper birch, white and black spruce, balsam fir and trembling aspen occur on warmer, south facing sites. Forest fires are common in this ecoregion, and most coniferous stands tend to be young [69].

For the ERA, 16 species were selected to represent a wide range of species and potential exposure pathways and includes herbivores, omnivores, and carnivores from terrestrial and aquatic bird and mammal species.

Terrestrial species at risk

In Saskatchewan, the following legislation applies to species at risk: *The Wild Species at Risk Regulations* [70], which is integrated with the federal *Species at Risk Act* (SARA) [71]. To comply with these laws, and as part of 2020 ERA [28], in 2017 Cameco conducted a comprehensive review of wildlife species at risk that may be found in Cameco's northern operation area, including Key Lake Operation. Table 3.14 lists the 16 terrestrial species at risk that were identified as potentially present around the Key Lake Operation, of the species identified in the survey, 5 were confirmed as present onsite and were further assessed in the ERA.

Table 3.14: Status of terrestrial species at risk present around Key Lake Operation

Category	Common Name	SARA Status	Assessment Notes
Birds	Bank swallow	Threatened	Not observed in exposure area
Birds	Barn swallow	Threatened	Observed in study area; assessed via surrogate (rusty blackbird)
Birds	Canada warbler	Threatened	Not observed in exposure area
Birds	Common nighthawk	Threatened	Observed in study area; assessed via surrogate (rusty blackbird)
Birds	Evening grosbeak	Special Concern	Not observed in exposure area
Birds	Horned grebe	Special Concern	Not observed at exposure area; at reference only; assessed via surrogate (scaup)
Birds	Olive-sided flycatcher	Threatened	Not observed at study area
Birds	Peregrine falcon	Special Concern	Not observed in exposure area
Birds	Red-necked phalarope	Special Concern	Observed in study area during migration; not expected to reside in the area; assessed via surrogate (scaup)
Birds	Rusty blackbird	Special Concern	Observed in study area; assessed in ERA
Birds	Short-eared Owl	Special Concern	Not observed in exposure area
Birds	Yellow Rail	Special Concern	Not observed in exposure area
Mammals	Little brown myotis (bat)	Endangered	Not observed in exposure area
Mammals	Northern myotis (bat)	Endangered	Not observed in exposure area
Mammals	Wolverine	Special Concern	Not observed in exposure area
Mammals	Woodland caribou	Threatened	Observed assessed in study area; assessed in ERA

ERA predictions

The most recent assessment of potential effects on terrestrial biota near Key Lake Operation was provided in the 2020 ERA [28]. As discussed in section 2.3.3, the ERA fully complied with requirements of CSA N288.6-12 [10] and incorporated recent environmental monitoring data.

Cameco selected a total of 16 terrestrial receptors for the assessment based on knowledge of Key Lake Operation and its surrounding environment, and relevant field observations. They include both terrestrial and aquatic birds and mammals. 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. The 5 species at risk identified as potentially occurring in the area (that is, barn swallow, common nighthawk, red-necked phalarope, rusty blackbird, and woodland caribou) are also included as terrestrial receptors, or assessed through appropriate surrogates.

Table 3.15: Terrestrial Receptors selected for assessment in 2020 ERA

Receptor Type	Receptor	Notes
Terrestrial Bird	Bald Eagle	
Terrestrial Bird	Willow Ptarmigan	
Terrestrial Bird	Common Nighthawk	Rusty blackbird is surrogate
Terrestrial Bird	Olive-sided Flycatcher	Rusty blackbird is surrogate
Terrestrial Bird	Osprey	Bald eagle considered as surrogate as has the same diet
Terrestrial Bird	Rusty Blackbird	Surrogate for barn swallow
Aquatic Bird (Water fowl)	Mallard	
Aquatic Bird (Water fowl)	Common Merganser	
Aquatic Bird (Water fowl)	Lesser Scaup	Surrogate for Red-necked phalarope
Aquatic Bird (Water fowl)	Horned Grebe	Scaup is surrogate
Terrestrial Mammal	Masked Shrew	
Terrestrial Mammal	Snowshoe Hare	
Terrestrial Mammal	Moose	
Terrestrial Mammal	Caribou (Woodland)	
Terrestrial Mammal	Caribou (Barren-Ground)	Woodland caribou is surrogate
Terrestrial Mammal	Grey Wolf	
Terrestrial Mammal	Black Bear	
Terrestrial Mammal	Lynx	Grey wolf is surrogate
Terrestrial Mammal	Red Fox	
Semi-Aquatic Mammal	Muskrat	
Semi-Aquatic Mammal	Beaver	
Semi-Aquatic Mammal	Mink	

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, diet, 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 the radiological dose benchmarks recommended in CSA 288.6-12 [35], which is, 100 microgray 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. These results indicate negligible potential for adverse effects from radiological substances to terrestrial biota and no need for further (detailed) assessment.

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, soil, lichen, vegetation, water, sediment, and diet) to the recommended benchmark values (that is, toxicity reference values for non-human biota).

The 2020 ERA identified that, for most receptors, there are no predicted exceedances indicated. However, exceedances are indicated for arsenic and selenium to terrestrial receptors that are most connected to the aquatic environment. The potential for negative influences is indicated for some receptors, mostly aquatic-based birds and mammals and limited to the David Creek drainage. There are no potential issues identified for terrestrial receptors over the larger site area or in the Wheeler River drainage.

McDonald Creek Drainage is limited upper bound exceedances for selenium and arsenic, which are unlikley to occur under normal operation. No potential exceedances were indicated for Outlet Creek drainage in the post-decommissioning period and no potential exceedances were indicated for Russell Lake in the Key Lake Operational and post-decommissioning periods. Therefore, potential effects on terrestrial receptors are limited to near field David Creek, Delta Lake, and Farfield Pond.

Terrestrial environment monitoring

Terrestrial monitoring consists of monitoring soil and lichen. The details of their respective sampling programs are discussed above in section 3.2.2.1 for soil quality.

3.2.2.3 Findings

Based on the review of Cameco's ERA for the Key Lake Operation, some potential effects have been identified for terrestrial receptors most closely tied to the aquatic environment in the near field of Key Lake Operation; however, environmental monitoring completed during the current licensing term has indicated these effects are not currently present. CNSC staff found the results of the 2020 ERA consistent with the conclusions of the environmental impact statements and risk assessments that describe the site licensing basis for the Key Lake Operation. Potential impacts to terrestrial receptors are spatially limited, with no issues identified for receptors over the larger site area. CNSC staff agree with the findings and find the overall environment remains protected.

3.2.3 Aquatic environment

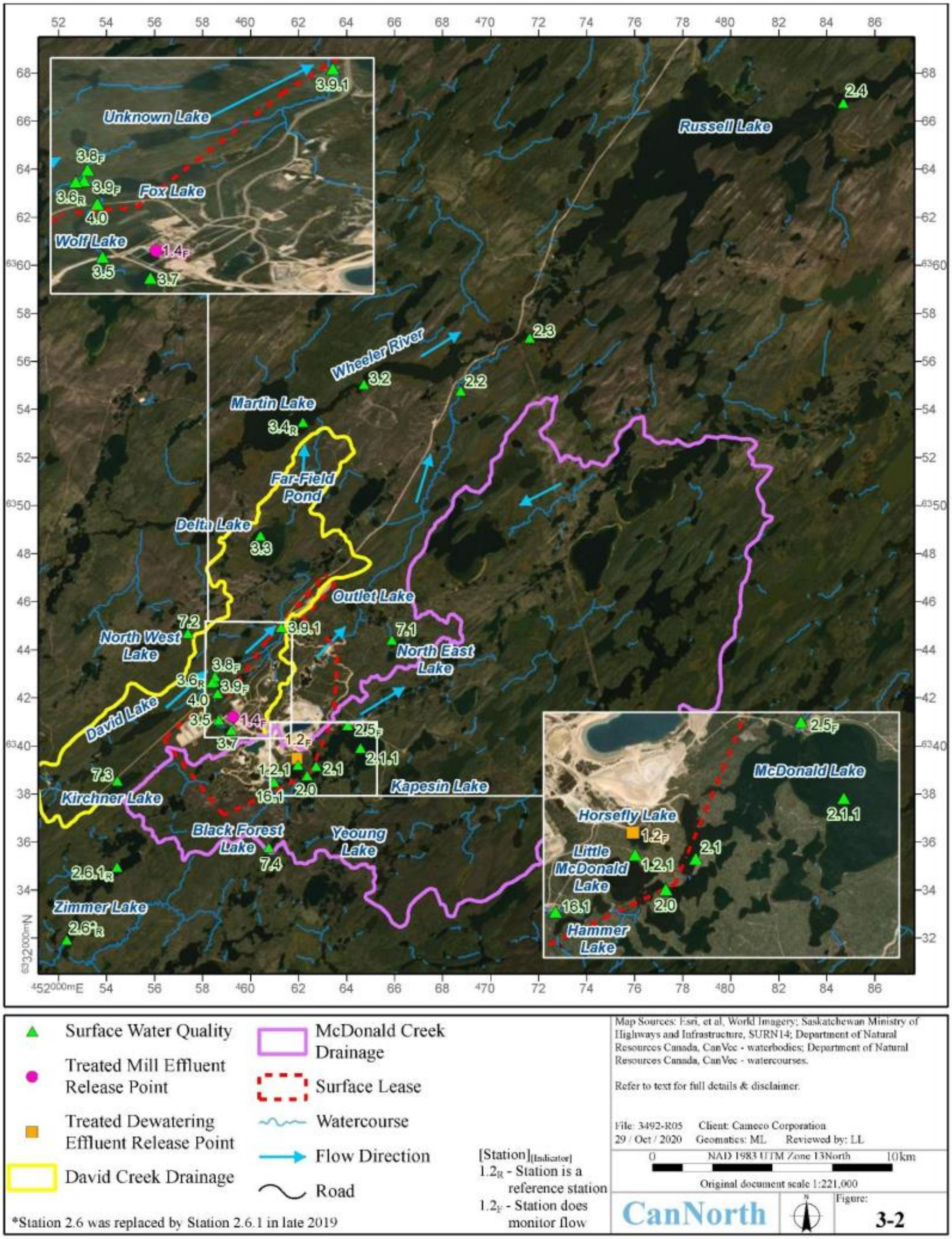
An assessment of potential effects on aquatic biota at Key Lake Operation and the surrounding area consists of characterizing the local habitat and species (including considering federal species at risk) and assessing the possibility of their exposure to radiological and hazardous substances, as well as physical stressors that may be disruptive to ecological receptors. It should be noted that no physical stressors were identified which could affect the aquatic environment.

3.2.3.1 Surface water quality

Key Lake Operation is a part of the Geikie River drainage area, which discharges into Wollaston Lake. Operational releases from Key Lake Operation are received by the David Creek drainage and McDonald Creek drainage (figure 3.3), with post-decommissioning groundwater loads to the David Creek drainage, McDonald Creek drainage, and Outlet Creek drainage. These three drainages join the Wheeler River drainage, which flows to Russell Lake, the most downstream location considered for the assessment. Hydrology monitoring locations are indicated in figure 3.3.

Surface water quality at Key Lake Operation is influenced by two main activities: the release of treated mill effluent to the David Creek drainage and the release of treated dewatering effluent from the reverse osmosis treatment plant to the McDonald Creek drainage. Key Lake Operation conducts an extensive water quality monitoring program for physical properties, nutrients, inorganic ions, metals, and radionuclides. Surface water monitoring sampling stations have been strategically placed along near- and mid-field points within both drainage areas (figure 3.3) to capture the potential influence of these discharges on the environment and to provide the necessary data for the completion of quantitative ERAs. Monitoring stations downstream of the confluence with the Wheeler River allow for the assessment of far-field influences within the Wheeler River drainage (figure 3.3). Reference waterbodies are also monitored which includes David Creek, Wheeler River and Zimmer Lake.

Figure 3.3: Key Lake surface water quality monitoring stations [63]



Elevated mercury was reported in the second and third quarter reports in 2021 for stations in both the David and McDonald creek drainages. However, it should be noted mercury is not a COPC for the Key Lake Operation, as it is not used or produced in its operation. The reported concentrations have not been observed in the past and were not linked to specific dates. An investigation was initiated by Cameco in consultation with the external lab that provides the sample bottles and performs the analysis. The cause appears to be related to a batch of older sample bottles used for mercury analysis. The site has procured new pre-treated sample bottles and will continue to monitor the mercury results at these stations. The mercury concentrations returned to normal in the fourth quarter of 2021, supporting the conclusion the elevated mercury was caused by the older sample bottles, rather than elevated mercury in the environment.

Within the David Creek drainage, the station closest to the effluent source (station 4.0) has a gradual increase in uranium levels over the previous five years (table 3.16) while molybdenum and selenium have decreased slightly and other parameters have remained below SEQG's.

Table 3.16: Surface water quality at station 4.0 –David Creek Drainage [4]

Parameter	SEQG (a)	2017	2018	2019	2020	2021
Arsenic (mg/L)	0.005	0.0075	0.0054	0.0036	0.0041	0.0076
Cadmium (mg/L)	0.00004	0.00028	0.00005	0.00004	0.00003	0.00003
Cobalt (mg/L)	0.00078 – 0.0018(b)	0.0061	0.0212	0.0088	0.0067	0.0071
Copper (mg/L)	0.002 – 0.004(c)	0.0059	0.0014	0.0006	0.0004	0.0004
Molybdenum (mg/L)	31	0.064	0.0456	0.0306	0.0267	0.0339
Nickel (mg/L)	0.025 – 0.150(d)	0.0622	0.1183	0.0716	0.0688	0.0483
Lead (mg/L)	0.001 – 0.007(e)	0.0026	0.0001	0.0001	0.0001	0.0001
Selenium (mg/L)	0.001	0.0054	0.0054	0.0049	0.0045	0.0041
Uranium (mg/L)	0.015	0.0021	0.0029	0.0042	0.0054	0.0063
Zinc (mg/L)	0.03	0.0033	0.004	0.0044	0.0039	0.0027
Lead-210 (Bq/L)	N/A(g)	0.08	<0.07	0.02	<0.02	0.04
Polonium-210 (Bq/L)	N/A(g)	<0.02	<0.018	0.005	<0.005	0.007
Radium-226 (Bq/L)	0.11	0.023	0.023	0.039	0.034	0.025
Thorium-230 (Bq/L)	N/A(g)	0.01	<0.01	<0.01	0.01	<0.01
Hardness (mg/L)	N/A	821	1310	1195	794	724

(a) SEQG stands for Saskatchewan Environmental Quality Guidelines [72].
(b) Cobalt value is from the Federal Environmental Quality Guidelines [73]and is hardness dependant: 0.00078 mg/L when hardness is 52 mg/L to 0.0018 mg/L when hardness is 396 mg/L
(c) 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.
(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) 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.
(f) There are no SEQGs for lead-210, polonium-210 and thorium-230, and therefore, CNSC staff assess trends over time.

Within the McDonald Creek Drainage, the main parameter of concern in dewatering is nickel. The Horsefly Lake Outflow (station 1.2.1) annual average Ni concentration of 0.0431 mg/L was lower than the dewatering discharge (station 1.2) annual average Ni concentration (0.0487 mg/L) in 2021 but exceeded the SEQG of 0.025 mg/L (table 3.16). Overall, the small changes in concentrations within the McDonald Creek drainage reflect the low concentrations and changes in treated (reverse osmosis) dewatering well water discharged to Horsefly Lake over time.

The 2020 ERA identified that there is the potential that aquatic biota may be influenced from continued operation and long-term post-decommissioning loads at Key Lake Operation. Potential influences on the aquatic community, such as changes to density and diversity of benthic invertebrates and changes to condition of fish species. These changes are limited to the near-field exposure zone of Wolf Lake, Fox Lake, and Unknown Lake and the aquatic community in the Wheeler River drainage is expected to remain protected and not adversely influenced by Key Lake Operation.

Table 3.17: Surface water quality at station 1.2.1 – McDonald Creek Drainage [4]

Parameter	SEQG (a)	2017	2018	2019	2020	2021
Arsenic (mg/L)	0.005	<0.0001	0.0001	0.0001	0.0001	0.0001
Cadmium (mg/L)	0.00004	0.00009	0.00001	0.00001	0.00001	0.00002
Cobalt (mg/L)	0.00078 – 0.0018(b)	0.0006	0.0003	0.0005	0.0007	0.0011
Copper (mg/L)	0.002 – 0.004(c)	<0.0006	<0.0002	<0.0002	<0.0002	0.0002
Molybdenum (mg/L)	31	0.0005	0.0001	0.0001	0.0001	<0.0001
Nickel (mg/L)	0.025 – 0.150(d)	0.0122	0.0146	0.0243	0.0385	0.0431
Lead (mg/L)	0.001 – 0.007(e)	<0.0009	<0.0001	<0.0001	<0.0001	<0.0001
Selenium (mg/L)	0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Uranium (mg/L)	0.015	0.0018	0.0017	0.0031	0.0042	0.0046
Zinc (mg/L)	0.03	0.0012	0.0011	0.0024	0.0028	0.0036
Lead-210 (Bq/L)	N/A(f)	<0.02	<0.02	0.02	0.02	<0.02
Polonium-210 (Bq/L)	N/A(f)	<0.005	<0.005	<0.005	<0.005	<0.005
Radium-226 (Bq/L)	0.11	<0.005	0.005	0.007	0.006	0.005
Thorium-230 (Bq/L)	N/A(f)	<0.01	0.01	<0.01	<0.01	<0.01
Hardness (mg/L)	N/A	2	2	6	9	10

(a) SEQG stands for Saskatchewan Environmental Quality Guidelines [72].
(b) Cobalt value is from the Federal Environmental Quality Guidelines [73] and is hardness dependant: 0.00078 mg/L when hardness is 52 mg/L to 0.0018 mg/L when hardness is 396 mg/L
(c) 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.
(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) 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.
(f) There are no SEQGs for lead-210, polonium-210 and thorium-230, and therefore, CNSC staff assess trends over time.

3.2.3.2 Sediment quality

Cameco collects sediment samples at exposure and reference stations every three years in accordance with the facility's EMP [74], the most recent of which was completed in 2017 in the Davide Creek Drainage and 2019 in the McDonald Creek Drainage. 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) [67], the Canadian Probable Effects Level Sediment Quality Guidelines (PSQG) [67], and the Lowest Effects Levels (LEL) and Severe Effects Levels (SEL) derived for uranium mining areas in Canada [75].

ERA predictions

The 2020 ERA [14] concluded, there is the potential that aquatic biota may be influenced from continued operation and long-term post-decommissioning loads at Key Lake Operation. Potential influences on the aquatic community are limited to the near-field exposure zone of Wolf Lake, Fox Lake, and Unknown Lake. The aquatic community in the Wheeler River drainage is expected to remain protected and not adversely influenced by Key Lake Operation. CNSC staff have reviewed the ERA and accept its conclusions.

Sediment monitoring

During the previous licensing period (2013–2023), sediment monitoring data were collected in 2014 and 2017 [63] in the David Creek drainage, and in 2013, 2016, and 2019 in the McDonald Creek drainage. While the next sediment study should have taken place in 2020, the SMoE and CNSC agreed that the EMP field work in the David Creek drainage could be completed in 2021 to better align with the environmental effects monitoring (EEM) cycle. Field work was completed in the fall of 2021 to meet the SMoE and CNSC EMP requirements. This work included the collection of sediment and fish for chemical analysis along with supporting water chemistry. The report with the findings was submitted in 2022.

In 2017, three exposure waterbodies were assessed in the David Creek Drainage, including Fox (near-field), Unknown (near-field), and Delta (mid-field) lakes (figure 3.3). Fox Lake, which is not a requirement of the EEM or EMP programs but is sampled to provide additional information, is included in the program for temporal rather than spatial comparisons; thus, it has no associated reference areas. Unknown and Delta Lakes are included for both temporal and spatial comparisons. Unknown Lake, a shallow area exposure, was compared to two shallow reference areas, Black Lake and David Lake. Delta Lake, a deep area exposure, was compared to two deep reference areas, Alpha Lake and Kapesin Lake (figure 3.3).

The McDonald Creek drainage exposure sampling areas include Little McDonald Lake, McDonald Lake at the inlet from Little McDonald Lake (subsequently referred to as McDonald Lake Inlet), and McDonald Lake (figure 3.3). Associated reference areas include Yeoung and Zimmer Lakes (figure 3.3).

Tables 3.18 and 3.19 show concentrations of COPCs in Unknown Lake in the David Creek drainage and Little McDonald Lake in the McDonald Creek drainage, respectively. These were chosen as they represent the waterbodies sampled for sediments closest to the effluent source. In Unknown Lake, arsenic, copper, molybdenum, nickel, and selenium exceeded at least one available benchmark in 2017. Within Little McDonald Lake, arsenic, copper, lead, nickel, selenium, uranium, and zinc exceeded at least one available benchmark.

Table 3.18: Mean concentrations of COPCs in sediments in Unknown Lake (2014, 2017) [63]

Parameter	REF[(a)]	ISQG[(b)]	PSQG[(c)]	LEL[(d)]	SEL[(e)]	2014	2017
Arsenic (µg/g)	19	5.9	17	9.8	346.4	506	368
Cadmium (µg/g)	1.6	0.6	3.5	-	-	0.5	0.4
Cobalt (µg/g)	6.5	-	-	-	-	8.5	8.9
Copper (µg/g)	7.3	35.7	19.7	22.2	268.8	17	41
Lead (µg/g)	17	35	91.3	36.7	412.4	7.2	6.3
Molybdenum (µg/g)	50	-	-	13.8	1238.5	1700	1040
Nickel (µg/g)	41	-	-	23.4	484	94.4	113
Selenium (µg/g)	5.8	-	-	1.9	16.1	65	62
Uranium (µg/g)	104	-	-	104.4	5874.4	46	43
Zinc (µg/g)	71	123	315	-	-	19	22
Lead-210 (Bq/g)	0.9	-	-	0.9	20.8	0.82	0.86
Polonium-210 (Bq/g)	0.84	-	-	0.8	12.1	0.85	0.69
Radium-226 (Bq/g)	0.35	-	-	0.6	14.4	0.12	0.14

(a) REF refers to the 2017 maximum mean concentration at 4 reference waterbodies.
(b) ISQG stands for the “Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life [67].
(c) PSQG stands for the “Canadian Probable Effects Level Sediment Quality Guidelines” [67].
(d) LEL stands for “Lowest Effects Levels” [75].
(e) SEL stands for “Severe Effects Levels” [75].

Table 3.19: Mean concentrations of COPCs in sediments in Little McDonald Lake (2013, 2016 and 2019) [63]

Parameter	REF[(a)]	ISQG[(b)]	PSQG[(c)]	LEL[(d)]	SEL[(e)]	2013	2016	2019
Arsenic (µg/g)	1390	5.9	17	9.8	346.4	175	154	188
Cadmium (µg/g)	1.4	0.6	3.5	-	-	1.5	1.5	1.7
Cobalt (µg/g)	36	-	-	-	-	528	438	510
Copper (µg/g)	14	35.7	19.7	22.2	268.8	24	25	26
Lead (µg/g)	30	35	91.3	36.7	412.4	76	69	81
Molybdenum (µg/g)	10	-	-	13.8	1238.5	9.4	8.2	11
Nickel (µg/g)	494	-	-	23.4	484	1134	1067	1270
Selenium (µg/g)	2.5	-	-	1.9	16.1	1.8	2.2	2
Uranium (µg/g)	1280	-	-	104.4	5874.4	1490	1378	1560
Zinc (µg/g)	158	123	315	-	-	400	366	460
Lead-210 (Bq/g)	17	-	-	0.9	20.8	8	7.3	6.9
Polonium-210 (Bq/g)	15	-	-	0.8	12.1	5.7	5.9	7.0
Radium-226 (Bq/g)	11	-	-	0.6	14.4	4.0	5.0	5.1

(a) REF refers to the 2010-2019 maximum mean concentration of 2 reference waterbodies.
(b) ISQG stands for the "Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life [67].
(c) PSQG stands for the "Canadian Probable Effects Level Sediment Quality Guidelines" [67].
(d) LEL stands for "Lowest Effects Levels" [75].
(e) SEL stands for "Severe Effects Levels" [75].

3.2.3.3 Aquatic habitat and species

The aquatic environment surrounding Key Lake Operation supports a wide variety of aquatic species. Within the 2020 ERA, the aquatic receptors (that is, fish, benthic invertebrates, zooplankton, phytoplankton, aquatic vegetation) were evaluated within the David Creek drainage, McDonald Creek drainage, Outlet Creek drainage, and Wheeler River drainage.

The primary fish species located within the waterbodies surrounding Key Lake Operation are typical of lakes within the Athabasca Basin and include arctic grayling, burbot, cisco, emerald shiner, lake chub, lake trout, lake whitefish, longnose sucker, ninespine stickleback, northern pike, pearl dace, round whitefish, slimy sculpin, spottail shiner, trout-perch, walleye, white sucker, and yellow perch.

Aquatic species at risk

The only aquatic species at risk identified as potentially inhabiting the site was the Northern Leopard Frog. However, site surveys have never observed northern leopard frog within the Key Lake Operation study area. However, the boreal chorus frog and the wood frog were detected and captured during surveys at the site and were, therefore, considered in the assessment. No aquatic reptiles were identified around the site and were therefore not considered for assessment CNSC staff reviewed the selection of aquatic species at risk, and determined it was appropriate.

ERA predictions

The most recent assessment of potential effects on aquatic biota near Key Lake Operation was provided in the 2020 ERA [14]. As discussed in section 2.3.3, the ERA fully complied with requirements of CSA N288.6-12, *Environmental risk assessments at Class I nuclear facilities and uranium mines and mills* [10] and incorporated recent environmental monitoring data.

Cameco selected a total of 5 aquatic receptor classes for the assessment based on knowledge of Key Lake Operation and its surrounding environment, and relevant field observations. They include primary producers, and primary, secondary, and tertiary consumers, and amphibians. 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 generally below the radiological dose benchmarks recommended in CSA 288.6-12 [35], which is, 400 µGy/h for aquatic receptors. The 2020 ERA indicated benthic invertebrates remained below the 400 µGy/h benchmark under the expected discharge scenario, but could be affected by radiation up to 2050 in Little McDonald Lake under the 95th percentile of the upper bound discharge scenario, the maximum dose being 520 µGy/h in 2020. It is worth noting the 95th percentile prediction represents an extreme scenario and is not likely refelctive of actual conditions. These potential influences on the aquatic community are limited to the near-field exposure zone and the aquatic community in the Wheeler River drainage is expected to remain protected and not adversely influenced by Key Lake Operation.

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, soil, 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).

The 2020 ERA identified water quality guideline exceedances of arsenic, cadmium, cobalt, copper, selenium, fluoride, nitrate, sulphate and total disolved solids within the David Creek drainage under the expected scenario for operation and decommisioning periods, reflective of historical contributions. Further, exceedances were predicted for cobalt within the McDonald Creek and Outlet Creek drainages during the post-decommissioning period.

The exceedances predicted in the David Creek, McDonald Creek and Outlet Creek were evaluated further to determine the potential for negative influences on aquatic biota in the downstream environment.

Within the David Creek Drainage, cobalt, copper, nickel (Wolf Lake only), nitrate, and sulphate, concentrations in surface water are at levels that exceed the 95% protection limit of species sensitivity distributions (SSD), meaning some species more sensitive to these COPCs could be affected however, other species of invertebrates, fish, and plans remain protected and no negative influences on the aquatic community are expected. Not all species identified in the SSD are present at the assessed locations, species present at these locations are less sensitive to these COPCs and remain protected. Furthermore, due to improvements in effluent treatment practices, concentrations are expected to decline throughout the Key Lake Operation period and into post-decommissioning, except for cobalt. Although water quality guideline exceedances were indicated for cobalt and nitrate in Delta Lake and cobalt in Far-field Pond, these concentrations fall below effects levels associated with the most sensitive aquatic species considered in the SSD and below the 95% protection limit. Therefore, negative influences on the aquatic communities of Delta Lake and Far-field Pond are not expected, as supported by routine monitoring.

For selenium, predicted water and fish tissue exceed the applicable criteria at the predicted mean and upper-limit levels throughout David Creek drainage in the operational and into the post-decommissioning period. Measured concentrations of selenium in all species and tissues from Delta Lake exceeded benchmarks in 2017, although recent sampling results represented the lowest mean concentrations recorded to date [6]. Defined effects were confirmed prior to the 2011 Investigation of Cause (IOC) for the David Creek drainage, which indicated that Delta Lake fish were larger at a given age and had smaller liver sizes. These effects were linked to the approved release of Key Lake Operation’s treated effluent in the 2011 IOC report [76]. Statistically significant differences in effect endpoints were identified in the 2014 and 2017 lake chub and spottail shiner population surveys. No confirmed effects were observed on relative liver size based on the 2014 and 2017 surveys. The elevated selenium is reflective of historical contamination from the site. Cameco undertook a molybdenum/selenium (Mo/Se) action plan at the request of the CNSC in the mid 2000's, which included the commissioning of a Mo/Se reduction circuit as part of the effluent treatment process in 2009 [77]. Following implementation, mean loadings of selenium and molybdenum in the 2010-2014 period decreased by 54% and 86% respectively in comparison to the 2005-2009 period. Since the installation of the Mo/Se reduction circuit, molybdenum and selenium in the environment have either decreased or stabilized; however, full recovery will take time. As such, monitoring results confirmed that current monitoring requirements were sufficient and the formal Molybdenum/Selenium Follow-up Program was concluded in 2019.

The 2017 survey indicated the benthic invertebrate community at that time was as taxonomically rich, diverse, and even in the exposure areas as in previous years, with values in the range of reference values observed in the region [76]. Consistent with previous monitoring phases, larger size-at-age was observed in the 2017 fish population survey.

The 2011 IOC report concluded that a unique combination of elevated constituents associated with the treated mill effluent from Key Lake Operation was likely causing these observed EEM-defined fish population effects [6]. Other statistically significant differences in effect endpoints included older male lake chub, smaller female spottail shiner relative gonad sizes, and larger male spottail shiner relative gonad sizes [6]. There were indications of lower concentrations of COPC in fish tissue in 2017 compared to previous sampling periods [6].

Considering the evidence from the EEM program, additional effects on the aquatic community in the David Creek drainage are not expected, as concentrations in the receiving environment are predicted to decline through the care and maintenance, operation, and decommissioning period. For most COPCs, predicted concentrations in the post-decommissioning period are within the range of historical or operational concentrations.

Within the McDonald Creek drainage, non-radionuclide exceedances are limited to cobalt in the post-decommissioning period. When comparing the SSD curve to predicted concentrations of cobalt, the value remains protective of 95% of species in the aquatic community in Little McDonald Lake, McDonald Lake, and Wilson Lake and therefore negative influences on the aquatic community are not expected.

Within the McDonald Creek drainage, EMP monitoring components for aquatic biota include benthic invertebrate communities, fish population, and fish tissue chemistry were most recently completed in 2019 for benthic invertebrates and in 2016 for fish. The benthic invertebrate communities in the McDonald Creek drainage sampling areas were as taxonomically rich, diverse, and even in 2019 as compared to previous sampling years [6]. Lake chub population endpoints were generally similar between 2016 and the previous monitoring cycle in 2010. Large- and small-bodied fish tissue chemistry was consistent with previous years' monitoring results.

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 SMoE. Cameco's aquatic environment monitoring programs are executed every three years in accordance with the facility's EMP [67]. Cameco collects and analyzes benthic invertebrate community, fish population and fish tissue chemistry data.

Within the David Creek drainage, aquatic monitoring aligns with the requirements of the MDMER, and are conducted on a three year cylce. The most recent sampling campaign within the David Creek drainage was completed in 2017. The current EEM is an investigation of cause to examine confirmed differences in the benthic invertebrate community and fish population over the previous two EEM campaigns in 2014 and 2017. Results were submitted in 2022.

Within the McDonald Creek drainage, sampling is conducted as part of the environmental monitoring program where benthic invertebrates are sampled on a three year cycle and fish chemistry is conducted on a six year cycle, the next sampling year for both is 2022.

3.2.3.4 Findings

Based on the review of Cameco's ERA, some potential effects have been identified for aquatic receptors in the near field of Key Lake Operation. CNSC staff have found that results of the 2020 ERA are consistent with the conclusions of the environmental impact statements and risk assessments that describe the site licensing basis for the Key Lake Operation. Concentrations of COPCs are expected to decrease in the future and the receiving environment is expected to recover, due to improvements in effluent treatment processes decreasing COPC loading into the environment. CNSC staff continue to maintain oversight on operations at Key Lake, including environmental monitoring and risk assessments to ensure concentrations of COPCs remain stable or decrease with time.

3.2.4 Hydrogeological environment

The geological and hydrogeological environment of the Key Lake Operation area has been extensively characterized through a series of studies, including the Key Lake Project EIS (KLMC, 1979), the Deilmann EIS (Cameco, 1994), the Key Lake Extension Project EIS [17], and a number of other studies that have been completed since. Assessment on the impacts to hydrogeological environment is mainly based on the ongoing groundwater monitoring program in the Key Lake Operation area [63, 4, 78].

3.2.4.1 Geological conditions

The regional surficial geology of Key Lake Operation is dominated by glacial and proglacial deposits, overlying Precambrian sedimentary rocks of the Athabasca Group. The regional geomorphology is dominated by landforms associated with continental glaciation, including drumlins, moraines, eskers, kames and outwash plains. Glacial deposits range in thickness from 20 metres (m) near lakes and up to 80 m in drumlins. Sandstone is the primary parent material of the glacial deposits [79].

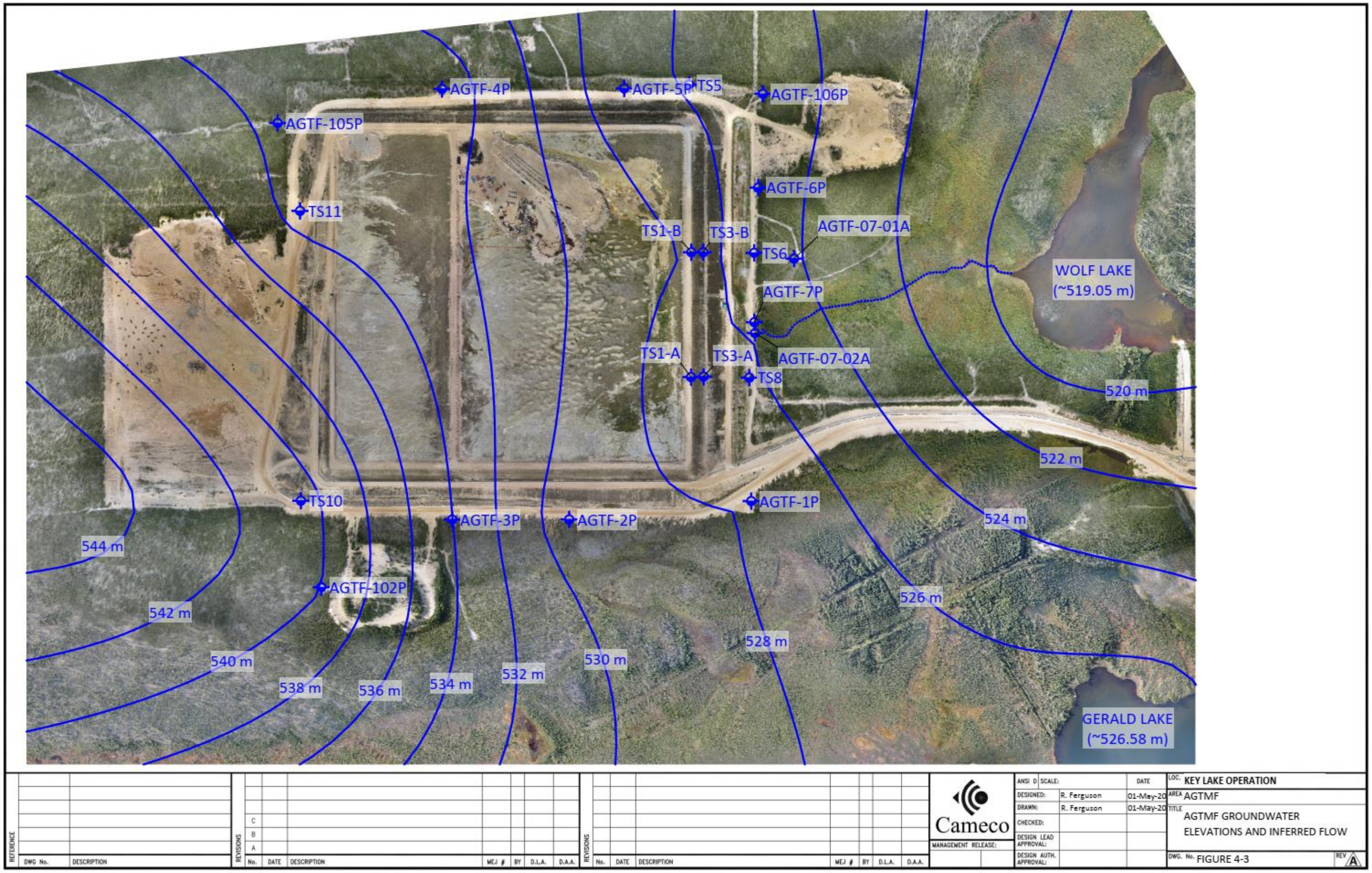
The uppermost bedrock unit of the Athabasca Basin is comprised of relatively undisturbed Athabasca Group sedimentary rocks of Helikian or Middle Proterozoic age (approximately 1,000 to 1,750 million years old). These rocks overlie highly contorted metamorphic basement rocks of Aphebian, or Lower Proterozoic, age (more than 1,750 to 2,500 million years old). The surface of the basement rocks was subjected to extensive weathering creating a lateritic zone approximately 50 m thick. The contact between the sandstone and the underlying basement rock is unconformable, meaning that a portion of the underlying basement was removed prior to deposition of the sandstone. The unconformity at the base of the Athabasca Group is host to much of the uranium mineralization found in the basin [79].

3.2.4.2 Groundwater quantity and quality

Groundwater monitoring and sampling at Key Lake Operation consists of 102 wells, organized between the AGTMF area, Mill area, and DTMF area and has two primary objectives. The first is to monitor groundwater level, flow direction, receptors of groundwater from various areas, and to confirm the ongoing hydraulic containment function of the dewatering system around the DTMF. The second is to monitor groundwater quality to identify changes in water quality that may be the result of operational activities.

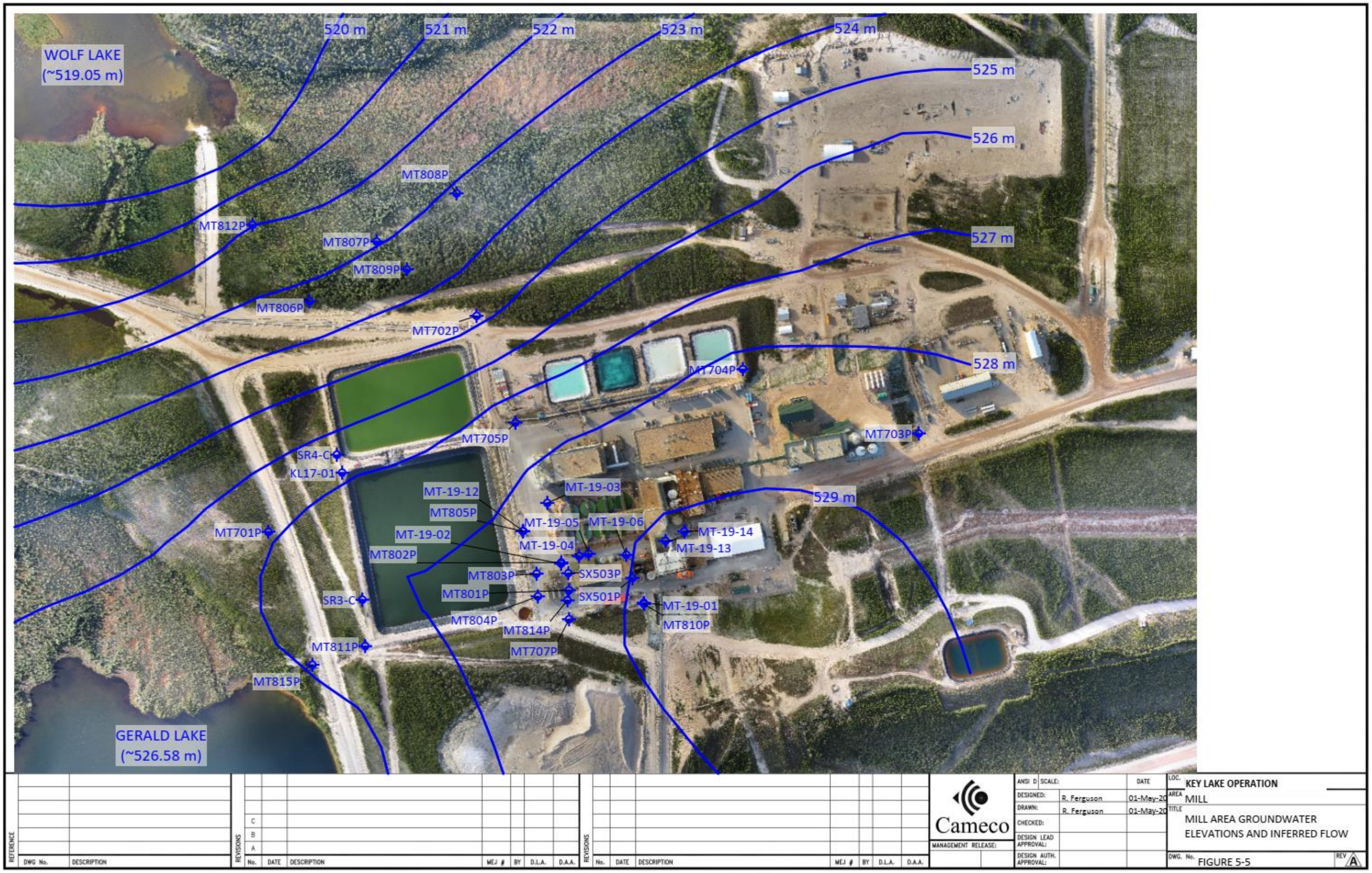
Within the AGTMF area, shallow groundwater flows from the AGTMF and enters Wolf Lake, near the headwaters of the David Creek drainage (figure 3.4). Changes in groundwater quality relative to baseline and background ranges demonstrate that the AGTMF influences downgradient groundwater quality. These changes can be seen in the surface expression of groundwater upstream of, and at, Wolf Springs. The water quality at Wolf Springs remains near or below available water quality guidelines for the protection of freshwater aquatic life for most parameters, with the exception of arsenic, cadmium, and cobalt. [4].

Figure 3.4: Groundwater flow directions at the AGTMF [63]



Within the mill area, groundwater flows towards Wolf Lake, near the headwaters of the David Creek Drainage (figure 3.5). A small portion of shallow groundwater flow along the southwest corner of the Mill area moves towards Gerald Lake, which ultimately discharges to Wolf Lake. Groundwater quality data for the Mill Area is complex, with several areas of varying evidence of impacts from the milling and water treatment operations over the years. Based on the available data, groundwater effects are present in the Mill Area, most notably beneath and immediately surrounding the Mill Terrace. The highest concentrations are in the immediate vicinity of the mill process area along the south side of the Mill Terrace. The status of the mill terrace has been assessed by Cameco who have proposed corrective actions to the CNSC, such as updating the soil management plan, and installing additional recovery wells. It should be noted that an ERA completed for the COPCs in the existing recovery wells indicated no discernable influence on receptors in the nearest surface water receiving bodies.

Figure 3.5: Groundwater flow directions at the Mill Area [63]

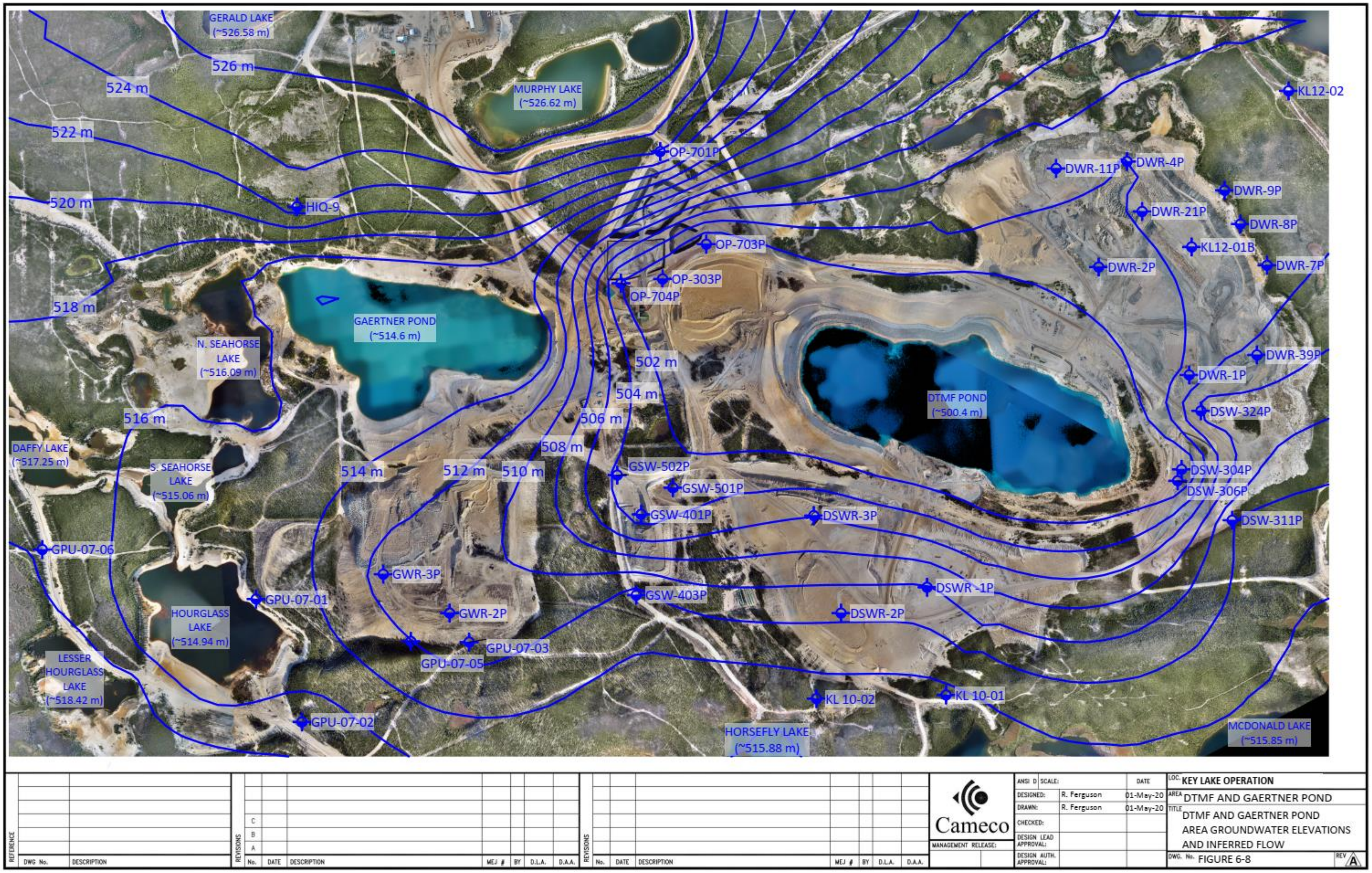


Groundwater flow around the DTMF and Gaertner Pond Area is towards the DTMF, with flow from the various facilities positioned in this area being towards the DTMF (figure 3.6). Any influence on groundwater from the facilities of the DTMF would therefore be expected to ultimately report to the dewatering wells. Groundwater chemistry beneath and downgradient of waste rock piles and special waste storage facilities in the Gaertner Pond and DTMF Area generally aligned with expectations in the current reporting period given established source terms. However, nickel concentrations in wells beneath the GWRP footprint were elevated above source term values calculated for this pile. Additionally, uranium was measured above source term predictions in several wells in the DNWRP area, along with sulphate, nickel, and zinc, to a lesser extent. Because groundwater in the DNWRP area and the GWRP footprint flows towards the DTMF, impact of elevated concentrations of these parameters are hydraulically contained within the Garter Pond and DTMF area.

Through email communication with Cameco, it is confirmed that, to address the elevated concentrations in the GWRP and DNWRP areas, monitoring of groundwater beneath the GWRP footprint is ongoing, and the monitoring results are being evaluated routinely to confirm that the removal of basement rock from the pile will result in the expected reduction in observed nickel concentrations in groundwater over time. In addition, Cameco initiated an investigation in 2021 to verify previously established source term estimates from the DNWRP. This work included the installation and monitoring of new nested monitoring wells and geochemical analysis of waste rock core samples. Field scale geochemical testing on the waste rock is also planned over the next several years and water quality from monitoring wells will be used to back calculate pile seepage water quality.

As part of the 2020 ERA, future influence on surface waterbodies from groundwater movement was assessed. In conclusion, there are no exceedances of water quality guidelines expected in the Wheeler River drainage due to future groundwater loads from the AGTMF, DTMF, and waste rock piles.

Figure 3.6: Groundwater flow directions at the DTMF [63]



3.2.4.3 Findings

Based on CNSC staff's review of the groundwater conditions and monitoring results at the Key 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 Key Lake Operation consists of identifying representative persons located within or in proximity to the site and determining whether radiological or hazardous COPCs could impact their health by breathing the air, being on the land, drinking and swimming in surface water, and eating plants, fish and wildlife from Key Lake Operation area. In general, human receptors may be exposed to contaminants through four primary routes: dermal (skin), inhalation, incidental ingestion (soil) and ingestion of food and water. 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.

Cameco's 2020 ERA [14] included a HHRA to assess the risk to humans from both radioactive and hazardous substances released from activities at Key Lake Operation. The human receptors were selected to capture a range of people who are likely to be the most exposed individuals. The receptors selected for the assessment are a non-nuclear energy worker (for example, camp worker) who resides at Key Lake Operation camp during Key Lake Operational and decommissioning period, a hypothetical seasonal resident and local fisher/trapper at Russell Lake during Key Lake Operational, decommissioning, and post-decommissioning periods, and a hypothetical permanent resident was evaluated at the site during the post-decommissioning period. The non-camp worker COPCs are based on information collected from people local to the area, and are meant to reflect realistic land use practices.

3.2.5.1 Exposure to radiological substances

The CNSC's *Radiation Protection Regulations* [39] prescribe 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, depending on the circumstances. The annual effective dose limit for a member of the public is 1 mSv per year.

The predicted maximum incremental dose resulting from Key Lake Operation was 0.49 mSv per year for the camp worker, mostly from radon exposure. The majority of incremental radiation dose to the camp worker was from radon exposure, while the trapper and resident receptors are exposed via ingestion of fish and mallard ducks. All receptors assessed were well below the CNSC dose limit. CNSC staff reviewed Cameco's assessment and determined it was adequately conservative and risk to human health from radionuclide exposure from the Key Lake Operation was negligible.

Over the licensing period (2013 to 2021), Cameco continued to ensure protection of members of the public in accordance with the *Radiation Protection Regulations* [39].

3.2.5.2 Exposure to hazardous substances

In the Key Lake Operation HHRA [28], the exposure of representative receptors to hazardous substances (arsenic, cadmium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium, and zinc) was evaluated by use of daily intakes rates and compared to available toxicity reference values. Each receptor was assessed using pathways from drinking water, soil contact, inhalation and food obtained from local sources as well as store-bought foods. In addition, Cameco assessed the incremental exposure risk from carcinogenic non-radionuclides, such as arsenic, as well as exposure to airborne COPCs such as NO_2, SO_2, and dust.

The HHRA found that all non-radiological hazardous substances were below the appropriate toxicity reference values, with the exception of arsenic. However, the exceedance of arsenic was overwhelmingly driven by the generic Canadian intakes of supermarket foods (milk, cereal etc.). Contributions driven by food sourced from around Key Lake Operation did not add perceptively to the overall exposure. No adverse effects are expected from hazardous substances to receptors assessed, as a result of operation of Key Lake Operation.

Selenium did not exceed toxicity reference values for human receptors. Similar to arsenic, the contribution to selenium intake was overwhelmingly driven by generic Canadian intakes of supermarket foods, with negligible intake attributed to food and water sourced from around the Key Lake Operation.

The exposure to airborne NO_2 and SO_2 was assessed through an incremental one hour maximum exposure and annual maximum exposure to these COPCs and compared to health-based criteria [80, 81]. Both NO_2 and SO_2 were below available guidelines, therefore negligible risk is expected for these constituents. Dust exposure was assessed through expsure to PM_{10} and $PM_{2.5}$ over a 24 hour period. The evaluated air modelling scenario conservatively assumed that all future activities are operated concurrently at their individual maximum rates of production. Dust exposure was assessed through exposure to PM_{10} and $PM_{2.5}$ over a year and resulted in an exceedance for the camp worker for 52 days and 49 days per year for PM_{10} and $PM_{2.5}$, respectively. It is important to note that the maximum concentrations at each receptor location typically occur during different meteorological conditions (that is, different days) and do not occur simultaneously.

3.2.5.3 Findings

During the reporting period (2013 to 2021), the estimated radiological doses for the selected human receptors have remained constant between assessments and below the public dose limit of 1 mSv per year [82, 14]. Further, during the reporting period (2013 to 2021), recorded radiological doses to the public have also remained below the annual public dose limit of 1 mSv per year, indicating that radiological releases from Key Lake Operation pose a negligible risk to human health (that is, potential risk to humans is similar to health outcomes in similar northern communities).

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

Based on assessments conducted for the Key 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 Key Lake Operation are negligible, and that people living and working near the facility remain protected, given the highly conservative assumptions of the dispersion modelling likely overestimates the results.

4.0 CNSC Independent environmental monitoring program (IEMP)

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 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 measuring and analyzing the amount of radiological and hazardous contaminant substances in those samples. For the uranium mines and mills in northern Saskatchewan, a qualified contractor, with the assistance of CNSC staff if feasible, collect the samples and send them to an accredited laboratory for testing and analysis.

4.1 IEMP at the Key Lake Operation

In 2021, for the most recent campaign, a qualified contractor conducted IEMP sampling around Key Lake Operation. CNSC staff developed the 2021 site-specific sampling plan with input from relevant 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 Key Lake Operation:

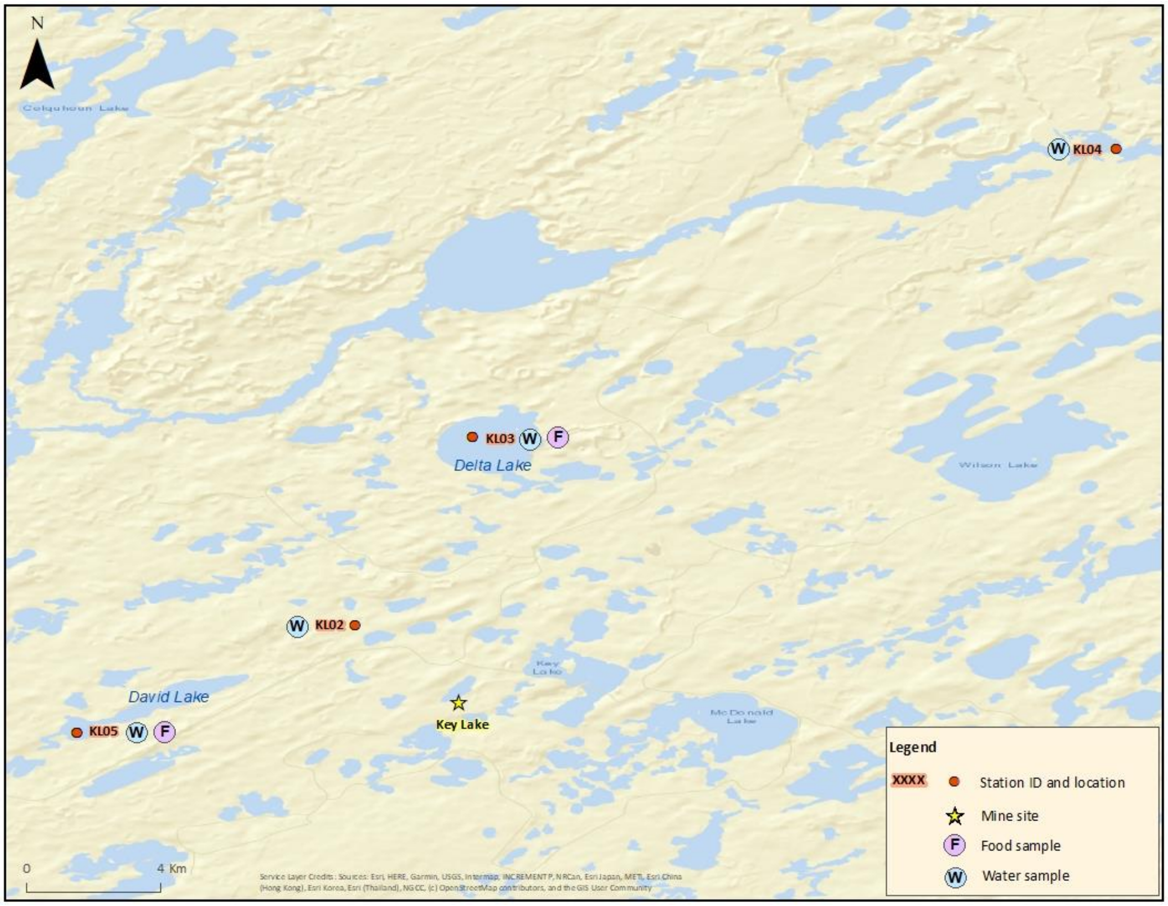
- water (2 locations, 3 samples per location)
- fish (2 locations, 3 samples of a benthic fish (lake whitefish) and 3 samples of a pelagic fish (northern pike) per location)
- Labrador tea (2 locations, 1 sample per location)
- blueberries (2 locations, 1 sample per location)
- moose (2 locations, 1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

Samples collected were analyzed by qualified laboratory specialists in an accredited laboratory, using appropriate protocols. As requested by CNSC staff, the laboratory specialists measured 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 were also analyzed for ammonia, hardness, pH, and total suspended solids. Labrador tea and blueberry samples were also analyzed for moisture content for CNSC staff to convert the results from dry weight into wet weight to compare against the screening levels.

Figure 4.1 provides an overview of the sampling locations for the 2021 IEMP sampling campaign around Key Lake Operation. The IEMP results are published on the CNSC's website [83].

In addition, in 2014, CNSC staff collected water samples at three sites downstream of the effluent discharge point, and at a one background location upstream for comparison.

Figure 4.1: Overview of the 2021 sampling locations



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 February 2021, in advance of the IEMP sampling campaigns at Key Lake Operation, notification emails were sent to all Indigenous Nations and communities near Key Lake Operation, inviting suggestions for species of interest, VCs or potential sampling locations where traditional practices and activities may take place.

In 2021, the CNSC met with English River First Nation (ERFN). 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 lakes in proximity to the Key Lake Operation. The following section summarizes CNSC staff`s collaboration with ERFN during the 2021 sampling campaign.

4.2.1 Engagement with the English River First Nation

In June 2021, CNSC staff sent the draft IEMP sampling plan to ERFN and held teleconferences with the ERFN to collaborate on it. As part of their review, ERFN shared the draft IEMP sampling plan with a community elder. The community elder reviewed the draft sampling plan and concluded that the sampling locations were acceptable. In their review, ERFN indicated that their community members frequently gather moose at locations near Key Lake. As a result, ERFN suggested including moose in the IEMP. CNSC staff incorporated two moose samples into the final sampling plan, with the samples to be collected by ERFN.

CNSC staff worked with both ERFN and a contractor on the logistics of collecting the moose samples. The contractor provided ERFN with the instructions for collecting and submitting moose samples to ensure that the samples are collected, stored, and shipped properly. ERFN successfully collected the three moose samples in the fall of 2021 and shipped them to the contractor.

CNSC staff arranged with the accredited contractor to have a qualified and experienced member of ERFN join the sampling team. Unfortunately, the individual was unable to participate at the last moment. Due to the time constraints,, the accredited contractor included a qualified and experienced member of their staff, who is a member of the Lac La Ronge Indian Band, on their sampling team.

4.3 Summary of results

Most of the parameters in the samples measured during the 2021 IEMP sampling campaign were below available guidelines/screening levels. There were some exceedances of the CNSC's conservative screening levels in polonium-210 and selenium in fish tissue, at both the reference (far from site) and exposure (close to site) locations. There were also exceedances of zinc and polonium-210 in moose tissue. 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. Results for all campaigns and CNSC staff's assessment of the screening level exceedances are published on the CNSC's website [83].

The CNSC's IEMP results in 2014 and 2021 are consistent with the results submitted by Cameco, supporting the CNSC's assessment that the licensee's EP program 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 Key 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 McArthur River 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 McArthur River Operation. Disease rates of communities living near the McArthur River 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 McArthur River 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 McArthur River Operation, including studies conducted by the CNSC to assess the health effects of workplace radiation exposure among Saskatchewan uranium workers.

CNSC staff continue to carefully monitor and conduct health studies to ensure 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 [84].

5.1 Population and community health studies and reports

5.1.1 Northern Saskatchewan Population Health Unit reports (latest 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 published 2 Northern Saskatchewan Health Indicators reports, one in 2004 [85] and another one in 2011 [86], and updates and publishes health monitoring chapters on its Population Health Unit - Northern Saskatchewan website [87]. 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) [88]

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 themselves as Indigenous (approximately 68% as First Nations 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 any 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 an important 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 in 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 [89].

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 (IHD), 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 [90], the smoking rate in some northern Saskatchewan Indigenous 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 [91].

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 [92].

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

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 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 [93]. 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%) [93]. Lung cancer was the most common cause of death from cancer, representing approximately 32% of all cancer deaths [94].

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 [95], 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, IHD and heart failure in Saskatchewan from 2012 and 2013 [96] 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 [97]. 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 so important for proper communication on cancer prevention; for early detection; cancer awareness, education, and surveillance; and for finding ways to support cancer patients and their families [98]. 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 [99] 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 occurring 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

Overall, many Saskatchewan Indigenous Nations and communities continue to experience health disparities related to the SDOH [100]. 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 2006–2016. 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 as strong social determinants of health for Indigenous peoples in Canada so revitalization of Indigenous peoples' culture and language is considered significant to improve their health status.
- In 2015, 37% of the 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 ~1% in 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 (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) [101], 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 [102, 103] 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 [104] and Port Radium [105] mine sites from 1950 to 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 other disease, other than lung cancer.

Part 2 of the SUMC Study [106] 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:

- Today's 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

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 [107]. 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 [100] 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, respiratory 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 [108].

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 [109]. 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 [109, 110]. 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 [88, 90]. Furthermore, the proportion of Saskatchewan residents who reported daily or occasional smoking was significantly higher than that of Canadian residents [111]. In Canada, exposure to indoor radon is the second leading cause of lung cancer [112]. 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 [99].

Studies of uranium workers help us assess workers' health and understand the relationship between workplace radiation and health. Part one 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.

Based on exposure and health data, CNSC staff have not observed and do not expect any adverse health outcomes to northern Saskatchewan communities or workers resulting from the presence of the McArthur River Operation.

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 environmental risk assessments, 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 (that is, 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 developed.

The McArthur River 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 conclusion from these programs is 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). 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 mine and mill industry.

The EARMP is an environmental monitoring program designed to gather data on potential cumulative impacts downstream of uranium mine and mill 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 mining and milling 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 Athabasca) 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 asssessment campaign completed in 2015. The assessment concluded there was little evidence of change from the baseline monitoring period and the assessment period [113].

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 prgram 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 EARMP technical reports and data are available on the EARMP website [114].

6.2.2 Future of 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 capabailities regarding active participation and engagement in environmetal 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 environmetal 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 [51], 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 [115]

CNSC staff conducted a search of the NPRI database and found that the uranium mines and mills (namely Cigar Lake, Key Lake, McArthur River, Rabbit Lake and McClean Lake) 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 [116].

7.0 Findings

This EPR report focused on items of current Indigenous, public, and regulatory interest including physical stressors and airborne and waterborne releases from ongoing operations at Key Lake Operation. CNSC staff have found that the potential risks from physical stressors, as well as from radiological and hazardous releases to the atmospheric, terrestrial, aquatic, and human environments from Key Lake Operation are low, 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 Key Lake Operation. These findings are based on CNSC staff's technical assessments associated with Cameco's Key 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 environmental monitoring programs conducted by other levels of government, to substantiate their findings. CNSC staff also conducted IEMP sampling around Key Lake Operation in 2021.

Based on their assessment of Cameco's documentation, CNSC staff have found that the potential risks from physical stressors, and from radiological and hazardous releases to the atmospheric, aquatic, terrestrial and human environments from Key Lake Operation are low to negligible. The potential risks to the environment from these releases or stressors are similar to natural background, and the potential risks to humans health are indistiguishable to health outcomes in similar northern 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 are protected.

8.0 Abbreviations

Units

Bq/L	becquerels per litre
kg	kilogram
km	kilometer
m^3	cubic meters
mg/L	milligrams per litre
mSv	millisievert
μGy/h	microgray per hour

Acronyms

AECB	Atomic Energy and Control Board
AGTMF	above ground tailings management facility
AL	action level
ALARA	as low as reasonably achievable
BATEA	*Best Available Technology Economically Available*
Cameco	Cameco Corporation
CANUWS	Canadian Uranium Workers Study
CCME	Canadian Council of Ministers of the Environment
CEAA 1992	*Canadian Environmental Assessment Act*, 1992
CEAA 2012	*Canadian Environmental Assessment Act, 2012*
CEPA 1999	*Canadian Environmental Protection Act*, 1999
CMD	Commission member document
CNSC	Canadian Nuclear Safety Commission
CO	carbon monoxide
COPC	contaminant of potential concern
COPD	chronic obstructive pulmonary disease
CSA	Canadian Standards Association
DDP	detailed decommissioning plan
DNWRP	Deilmann North Waste Rock Pile
DTMF	Deilmann in-pit Tailings Management Facility
EA	environmental assessment

ECCC	Environment and Climate Change Canada
ECOP	Environmental Code of Practice
EEM	Environmental effects monitoring
EIS	Environmental Impact Statement
EMP	environmental monitoring program
EMS	environmental management system
EP	environmental protection
EPP	environmental protection program
EPR	environmental protection review
ERA	environmental risk assessment
ERFN	English River First Nation
FUMP	follow-up and monitoring program
GHG	greenhouse gas
HHRA	human health risk assessment
IAA	*Impact Assessment Act*
IEMP	Independent Environmental Monitoring Program
IHD	Diabetes, Ischemic Heart Disease
IOC	Investigation of Cause
ISQG	Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life
ISO	International Organization for Standardization
Key Lake	Key Lake Operation
KLMC	Key Lake Mining Corporation
KYHR	Keewatin Yatthé Health Region
LEL	Lowest Effects Levels
LCH	licence conditions handbook
MCRHR	Mamawetan Churchill River Health Region
MDMER	*Metal and Diamond Mining Effluent Regulations*
MO	molybdenum
MOU	Memorandum of Understanding
NITHA	Northern Inter-Tribal Health Authority
NO_X	nitrogen oxides
NPRI	National Pollutant Release Inventory

NSCA	*Nuclear Safety and Control Act*
Orano	Orano Canada Inc.
PDP	preliminary decommissioning plan
PHU	Population Health Unit
PM	particulate matter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
PSQG	Canadian Probable Effects Level Sediment Quality Guidelines
RO	reverse osmosis
ROR	regulatory oversight report
SARA	*Species at Risk Act*
SDOH	Social determinants of health
Se	selenium
SEL	Severe Effects Levels
SEQG	Saskatchewan Environmental Quality Guidelines
SMoE	Saskatchewan Ministry of Environment
SO_2	sulphur dioxide
SSD	Species Sensitivity Distributions
SUMC	Saskatchewan Uranium Miners' Cohort
TSP	total suspended particulate
TSS	total suspended solids
VC	valued component

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