Canada's Nuclear Regulator

# Environmental Protection Review Report: **Cluff Lake Project**

**January 2024**

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

**Environmental Protection Review Report: Cluff Lake Project**



## Document availability

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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 | March 2019 |
| 001 | Licence revocation application | Updated information based on CNSC staff directions and related documentation submitted by Orano Canada Inc. | November 2022 |
| 002 | Revision 2 | Formatting revised to meet new accessibility requirements. | January 2024 |

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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 to describe the scientific and evidence-based findings from their review of the environmental protection measures put in place by Orano Canada Inc. (Orano), formerly Areva Resources Canada Inc., for the Cluff Lake Project. The Cluff Lake Project is located on Treaty 8 territory within the homeland of the Métis, and within the traditional territories of the Dene, Cree, and Métis peoples. CNSC staff have also considered Orano's application to revoke the Cluff Lake Project's current licence, UML-MINEMILL-CLUFF.00/2024, in order to transfer the regulatory oversight for the property, in northwestern Saskatchewan, from the CNSC to the Province of Saskatchewan's Institutional Control Program (ICP).

CNSC staff's EPR report focuses on items that are of Indigenous, public, and regulatory interest, such as the risk of radioactive nuclear (radiological) substances 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 2019 to 2022 and the results of CNSC staff's compliance activities, including the following:

- the results of Orano's environmental monitoring, as reported in Cluff Lake Annual Compliance Monitoring Reports
- Orano's 2019 Technical Information Document – Environmental Performance Volume 2 – Version 02 (Environmental Risk Assessment)
- Orano's 2019 Technical Information Document – Hydrogeology and Groundwater Modelling – Version 02
- Orano's 2022 Technical Information Document – Environmental Performance Volume 1 – Version 02
- the results of the CNSC's Independent Environmental Monitoring Program
- the results from studies (including those completed by other levels of government) in proximity to Orano's Cluff Lake Project

Based on their assessment and evaluation of Orano's documentation and data, CNSC staff have found that the potential risks from radiological and hazardous expsoure in the atmospheric, terrestrial, aquatic, and human environments are low to negligible, and that concentrations in the receiving environment are at levels similar to natural background or in line with the 2019 environmental risk assessment (ERA) predictions. CNSC staff are confident that in the future, the potential risks to the different components of the environment from the Cluff Lake Project will remain low to negligible. Furthermore, human health is not impacted by the Cluff Lake Project, and the health outcomes are indistiguishable from health outcomes found in similar northern Saskatchewan communities. CNSC staff have also found that Orano 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.

Should the Commission decide to revoke Orano's Cluff Lake Project licence, the Government of Saskatchewan assumes sole regulatory authority and manages the administrative controls over the properties, as well as the monitoring and maintenance requirements, to ensure the environment remains protected through the provincial ICP. CNSC staff are confident that the ICP, which was established in accordance with Canada's international obligations, will ensure that any risks to the environment and the health and safety of persons will be managed in the future.

CNSC staff's findings in this report 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 Cluff Lake Project, visit the CNSC's web page and Orano'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

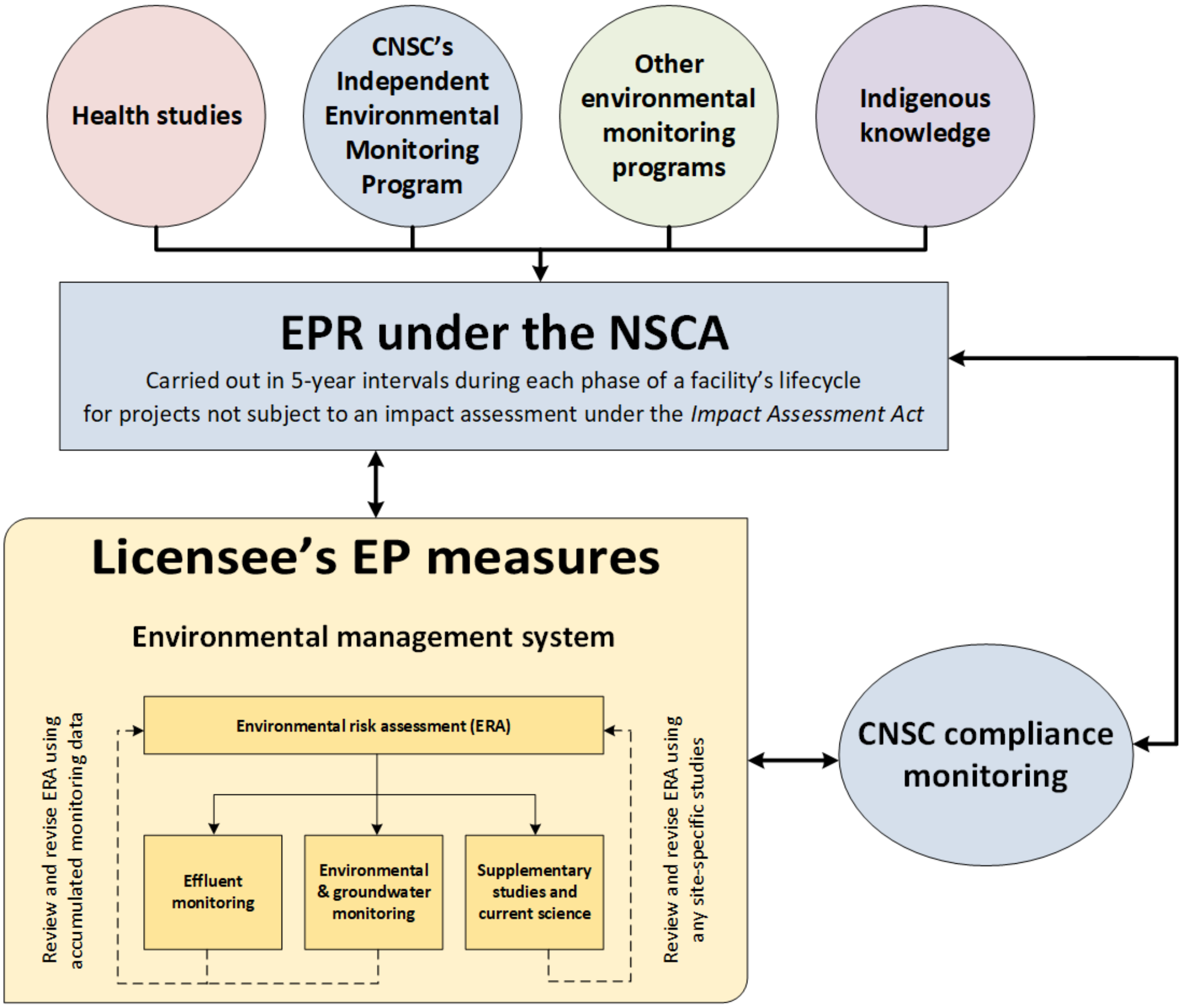
## 1.1 Purpose

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 during every phase of a facility's lifecycle. As shown in figure 1.1, an EPR is a science-based environmental technical assessment conducted by CNSC staff to support the CNSC's mandate for the protection of the environment as well as 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, based on the submission or update of an ERA, or a licensing action that warrants additional detail around CNSC staff's assessment. The reports are informed by the licensee's environmental protection (EP) program and documentation submitted by licensees as per regulatory reporting requirements.

As per the CNSC's Indigenous Knowledge Policy Framework [2], the CNSC recognizes the importance of considering and including Indigenous knowledge in all aspects of its regulatory processes. A summary of CNSC staff's consultation and engagement activities relating to the Cluff Lake Project, as well as issues and concerns raised by Indigenous Nations and Communities, are described in section 4 of Commission member document (CMD) 23-H8 [3]. 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, 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 Orano Canada Inc.'s (Orano's) EP measures and CNSC staff's health science and environmental compliance activities for the Cluff Lake Project. This review serves to assess whether Orano's environmental protection measures at the Cluff Lake Project adequately protect the environment and health and safety of persons.

**Figure 1.1: EPR framework**




CNSC staff's findings inform and support recommendations to the Commission in licensing and regulatory decision making, as well as inform CNSC staff's compliance verification activities. CNSC staff's findings do not represent the Commission's conclusions. The Commission is an independent, quasi-judicial administrative tribunal and court of record. The Commission's conclusions and decisions are informed by information submitted by CNSC staff, the licensee, Indigenous Nations and communities, and the public, as well as through any interventions made during public hearings on licensing matters. The information in this EPR report is also intended to inform Indigenous Nations and communities, members of the public, and interested stakeholders. CNSC staff may use the EPR reports as reference material when engaging with interested Indigenous Nations and communities, members of the public, and stakeholders.

This EPR report is informed by documentation and information submitted by Orano, compliance activities completed by CNSC staff from 2019 to 2022, as well as the following:

- regulatory oversight activities (section 2.0)
- CNSC staff's review of Orano's annual compliance monitoring reports for EP [4] [5] [6]

- Orano's 2019 Technical Information Document – Environmental Performance Volume 2 – Version 02 (Environmental Risk Assessment) [7] (section 3.2)
- Orano's 2019 Technical Information Document – Hydrogeology and Groundwater Modelling – Version 02 [8] (section 3.2)
- Orano's 2022 Technical Information Document – Environmental Performance Volume 1 – Version 02 [9] (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 the Cluff Lake Project (section 5.0)
- other environmental monitoring programs in proximity to the Cluff Lake Project (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, the potential transfer of contaminants 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 activities undertaken at the Cluff Lake Project, with additional information provided on other topics of Indigenous, public, and regulatory interest. CNSC staff also present information on relevant regional health monitoring, including studies conducted by the CNSC (such as the IEMP).

## 1.2 Facility overview

This section of the report provides general information on the Cluff Lake Project, 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 regulatory oversight activities.

### 1.2.1 Site description

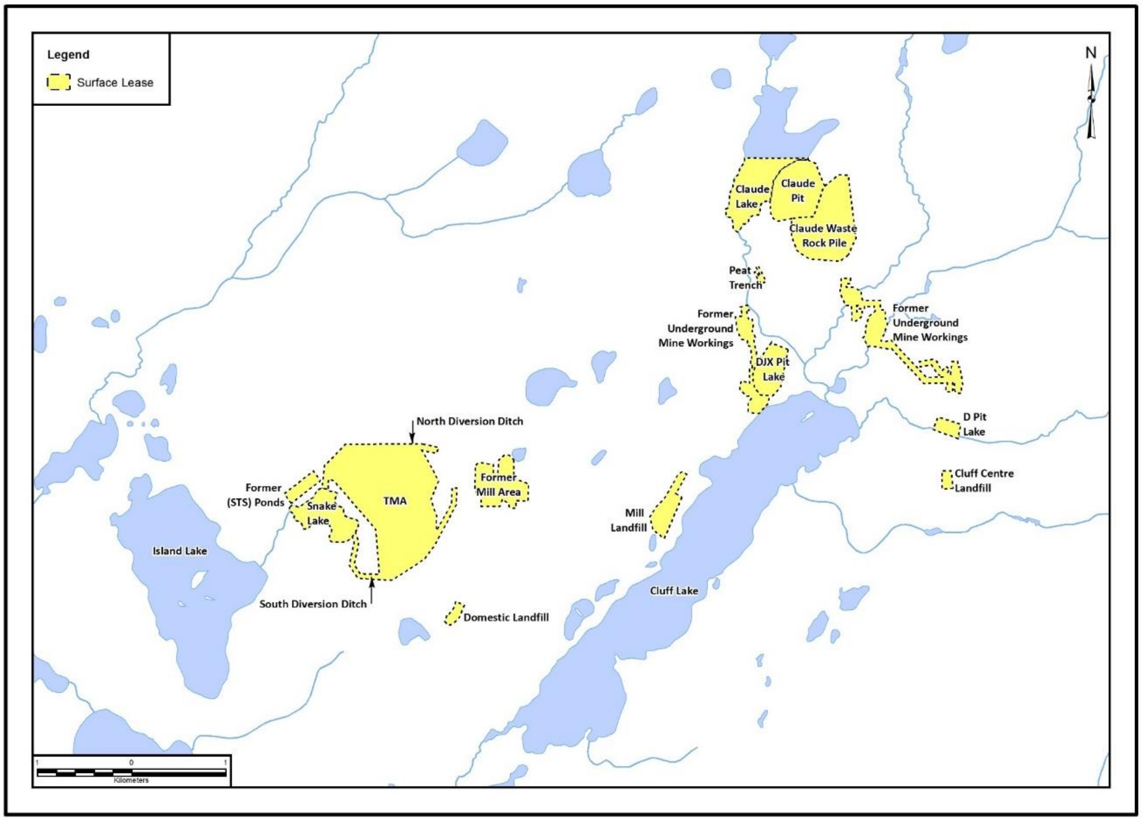
The Cluff Lake Project is a decommissioned uranium mine and mill site in northwestern Saskatchewan, approximately 75 kilometres (km) south of Lake Athabasca and 15 km east of the border with the Province of Alberta (figure 1.2). The Cluff Lake Project is located on Treaty 8 territory, the Homeland of the Métis, and is within the traditional territories of the Dene, Cree, and Métis peoples. Owned and operated by Orano, the Cluff Lake Project is located approximately 100 km from the closest community of Fort Chipewyan, Alberta (although there is no direct road) and 250 km by road from the communities of Clearwater River Dene First Nation and La Loche.

The former facilities at the Cluff Lake Project included 3 open pit mines, 2 underground mines, a central mill, a tailings management area (TMA) with a 2-stage liquid effluent treatment system, associated rock piles, and site infrastructure, including an airstrip and a residential camp. The Cluff Lake Project was fully decommissioned in 2018 and the site is currently accessible by Indigenous

Nations and communities and members of the public for hunting, fishing, camping, and harvesting (figure 1.3).

**Figure 1.2: Location of the Cluff Lake Project [7]**

**Figure 1.3: Aerial view of the current surface lease for the Cluff Lake Project [10]**

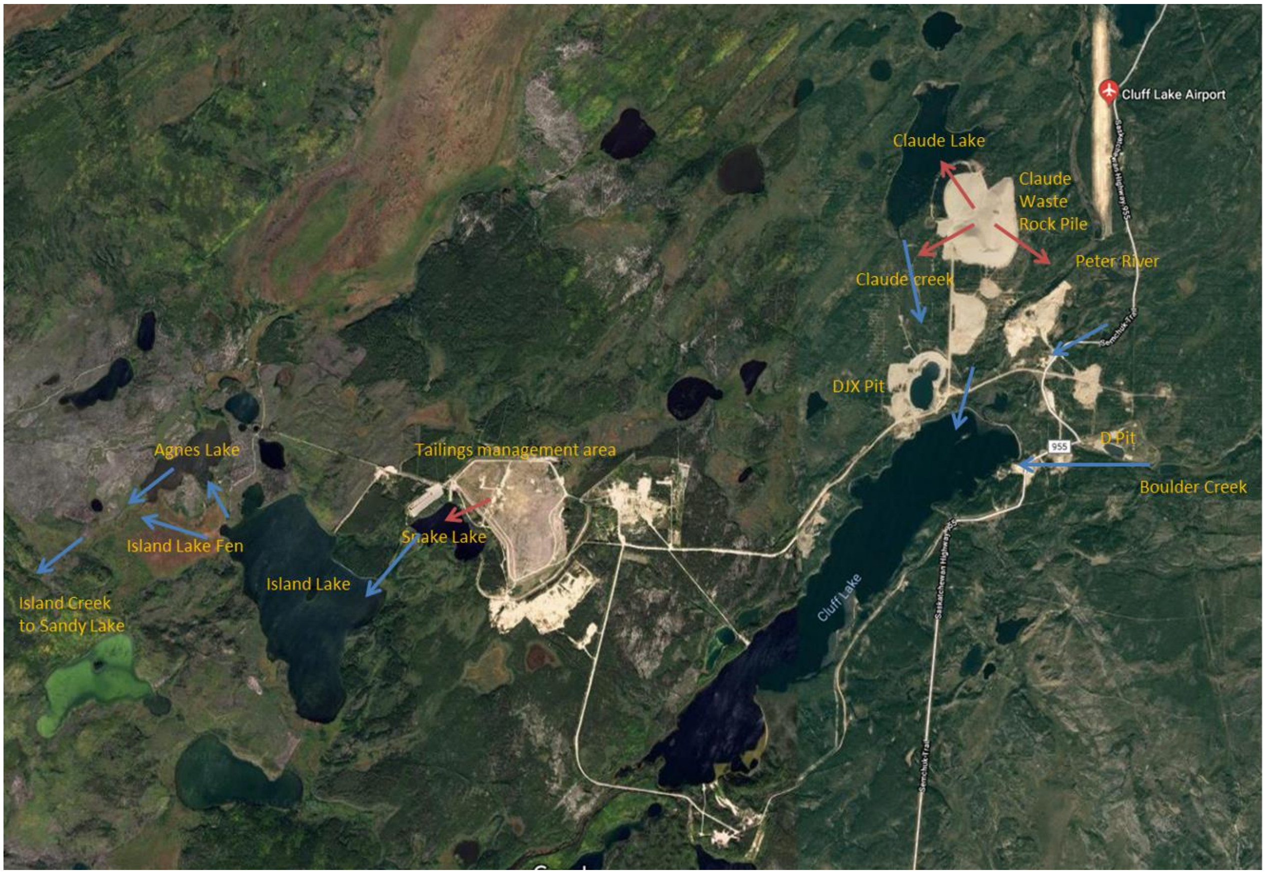


### 1.2.2 Project background

Uranium mining and milling operations commenced at the Cluff Lake Project in 1980 and continued until 2002, producing 28 million kilograms (kg) of uranium concentration throughout the facility's 22-year operating life. Uranium concentrate was extracted from 5 ore bodies using both underground and open pit mining techniques. While in operation, the Cluff Lake Project mine was the largest industrial employer in northwestern Saskatchewan.

At the Cluff Lake Project, there are 2 watersheds (figure 1.4). The first is the Island Lake watershed, where milling occurred and where tailings were disposed into a depressional area adjacent to Snake Lake, which is now the TMA. It should be noted that during operations, liquid effluent was discharged directly into Island Lake and no effluent was discharged into Snake Lake. Water from Island Lake flows toward the Island Lake fen, where 1 channel discharges directly into Island Creek and the other channel discharges into Agnes Lake, which is upstream of Island Creek. The second watershed is the Cluff Lake watershed, where 4 mining activities occurred, including: The D open pit mine area, the Claude open pit mine area, the DJ underground mine, and the DJX open pit mine area. The Claude Waste Rock Pile (CWRP) is the main remaining mining feature which was covered to reduce infiltration of rainwater and reduce contaminant leaching to the groundwater. Groundwater discharges into Claude Lake, Claude Creek, which is downstream of Claude Lake, and into the Peter River, which then discharges into Cluff Lake. On figure 1.4, the red arrows indicate see page and the blue arrows indicate the flow direction of the water.

## Figure 1.4: Aerial overview of the Cluff Lake Project watersheds



### 1.2.3 Decommissioning of the Cluff Lake Project

The planning for decommissioning the Cluff Lake Project began in 1998 and a licence for decommissioning was granted by the CNSC in April 2004. Most physical decommissioning activities were completed by 2006, including demolition of the mill complex buildings, backfilling of the Claude pit with waste rock from the DJX pit, flooding of the DJN and DJX pits (now referred to collectively as the DJX pit), grading, and revegetation. Some mining infrastructure, such as underground mine raises and declines, were decommissioned earlier, following the cessation of underground mining activities. By 2018, the final physical works described in the detailed decommissioning plan (DDP) were completed. More information on the decommissioning strategies for various infrastructure at the Cluff Lake Project can be found in the subsections below.

**Surface infrastructure**

Orano's decommissioning strategy for the surface infrastructure (including the mill complex) at the Cluff Lake Project was to:

- re-use components that were in good condition (that is, usable components of the mill were sent to the McClean Lake Operation)
- dispose of reagents
- demolish surface infrastructure
- vegetate the disturbed area

The decommissioning of the mill area was completed in 2005 and the demolition material was disposed of in the Claude pit. The area was then covered with glacial till, graded, and vegetated with tree seedlings. The decommissioning of the camp and remaining warehouses was completed in 2013, along with on-site roads and culverts (the last of which were removed in 2018).

**Tailings**

During operations of the Cluff Lake Project, Orano placed the tailings into the TMA along with solid wastes to facilitate consolidation. Water was treated in both primary and secondary water treatment plants and the tailings were isolated from the surface throughout the operations phase. At decommissioning, the tailings were covered with glacial till, the liquids pond was backfilled, storm water management features were constructed, the main dam was verified to ensure long-term stability under passive care, surface features were removed, and the till cover was seeded.

**D and DJX pit lakes**

During decommissioning at the Cluff Lake Project, Orano created pit lakes with stable chemoclines to ensure that high quality water is available at the surface of the lakes and that the lakes remain disconnected from the rest of the surface watershed. A chemocline refers to layers of liquid with different properties, which are characterized by a vertical chemical gradient. D-Pit was flooded in 1983 and the chemocline that was established during the flooding remains stable. DJX pit was flooded with water from Cluff Lake in 2006 and the chemocline was established within the same year and remains stable.

**Waste rock**

Orano's decommissioning strategy for the waste rock at the Cluff Lake Project was to utilize in-pit disposal whenever possible. The DJN waste rock was disposed of within the Claude pit, which was then backfilled with waste rock and demolition material, covered with till, and seeded with trees and shrubs. The waste rock piles were also re-contoured and compacted prior to covering with till, in an effort to limit the amount of precipitation infiltrating the pile.

**Underground mine areas**

Orano's decommissioning of the DJ and OP/DP underground mine areas at the Cluff Lake Project included backfilling 8 raises, covering with reinforced concrete caps, and covering with glacial till. In addition, 2 declines were backfilled to protect against crown pillar failure, covered with concrete plugs, and covered with glacial till.

# 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 Orano's EP measures for the Cluff Lake Project.

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

## 2.1 Environmental protection reviews and assessments

To date, 4 joint federal–provincial environmental assessments (EAs) and 2 EPRs (including this one) have been carried out for the Cluff Lake Project. Subsection 2.1.1 provides a description of the EAs conducted under provincial and federal legislation, including the Environmental Assessment and Review Process (EARP) [11] and the *Canadian Environmental Assessment Act* (CEAA 1992) [12], predecessor to the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) [13]. Subsection 2.1.2 provides information on the EPR conducted for the Cluff Lake Project. In 2019, the *Impact Assessment Act* (IAA) [14] came into force, replacing CEAA 2012. Orano's current activities at the Cluff Lake Project do not require an impact assessment under the IAA's *Physical Activities Regulations* [15]. The purpose of any 1 of these legislations and 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.

**Table 2.1: Federal environmental assessments completed for the Cluff Lake Project**

| Project | Applicable EA process and/or legislation | EA start date | EA decision date |
|---|---|---|---|
| Development of the Cluff Lake Project – Phase I | Environmental Assessment and Review Process | 1976 | 1978 |
| Development of the Cluff Lake Project – Phase II | Saskatchewan Environmental Assessment Policy | 1982 | 1983 & 1986 |
| Extension of the DJ mining operation | Environmental Assessment and Review Process | 1992 | 1997 |

| | | | |
|---|---|---|---|
| Decommissioning of the Cluff Lake Project | *Canadian Environmental Assessment Act* (1992) | 2000 | 2004 |

### 2.1.1 Previous EAs completed under federal and provincial legislation

**Development of the Cluff Lake Project – Phase I**

Exploration activities initially began in the Cluff Lake area in the 1960s by Amok Ltd. (Amok, the original proponent for the Cluff Lake Project). In 1976, Amok submitted an environmental assessment and safety report (EASR) [16] to the Province of Saskatchewan's Department of Environment following the discovery of the D ore body. The report proposed the development of a uranium mine and mill (phase I) around Cluff Lake. At the time of Amok's request, the Atomic Energy Control Board (AECB, predecessor to the CNSC) required that proponents provide certain information related to the operations of the proposed facility and the surrounding physical environment that may be affected by it, to support the licensing assessment. This information was provided by Amok within the EASR, which the federal Minister of Environment provided to the Board of Inquiry (often referred to as the Bayda Commission) for review. The Board of Inquiry was responsible for reviewing the implications and potential effects of expanding the uranium mining and milling industry in northern Saskatchewan. Following their review of the EASR and written interventions, along with public meetings and formal hearings, the Board of Inquiry recommended that the development of the Cluff Lake Project mine and mill be approved [17]. A licence was then granted by the AECB for the Cluff Lake Project.

**Development of the Cluff Lake Project – Phase II**

Phase II of the Cluff Lake site development was subject to a provincial EA under the Saskatchewan Environmental Assessment Policy (EAP) [18]. The assessment for the phase II development of the Cluff Lake site included the extraction of the uranium reserves known as the Claude, N, N40, OP, and Dominique-Peter (DP) ore bodies [19]. The EA was also reviewed by the AECB as a federal expert and was approved in June 1983. In 1985, Amok discovered a new ore body, known as the Dominique-Janine (DJ) ore body, which was deemed more appropriate for development than the N and N40 ore bodies. In late 1986, the federal and provincial regulatory agencies concluded that Amok could proceed with the development of the newly discovered DJ ore body, which was added to the existing operational licence.

**Extension of the DJ mining operation**

Following further investigations to delineate the DJ ore body, Amok found that the uranium mineralization extended further south toward the edge of Cluff Lake than originally identified. Amok's subsequent proposed extension of the DJ mining operation coincided with several other uranium mining projects being proposed in northern Saskatchewan by various proponents, including Midwest, McArthur River Operation, Cigar Lake Operation, and McClean Lake Operation. In response to these proposals, the Government of Canada and the Government of Saskatchewan appointed a joint Federal–Provincial Environmental Assessment Review Panel (Joint Panel) under their respective EA legislation (that is, the EARP and the provincial EAP). The mandate of the Joint Panel was to review the environmental, health, safety, and socioeconomic impacts of the proposed projects and assess their acceptability.

In 1993, following their review, the Joint Panel recommended to the Government of Canada and the Government of Saskatchewan that the proposed projects should be allowed to proceed [20].

During the Joint Panel's federal review under the EARP, CEAA 1992 came into force, repealing the EARP as the current federal EA legislation. However, CEAA 1992 contained provisions to maintain valid EAs being conducted (or recently conducted) under the previous legislation, allowing the Joint Panel to complete their review under the EARP. Following the Joint Panel's review, the proposed extension of the DJ mining operation at the Cluff Lake site proceeded with the licensing process.

**Decommissioning of the Cluff Lake Project**

In anticipation of decommissioning activities at the Cluff Lake Project, COGEMA Resources Inc. (COGEMA, predecessor to Orano) provided a DDP [21] to the CNSC in order to obtain a decommissioning licence. However, before the CNSC could consider granting said licence, COGEMA's decommissioning proposal required a comprehensive study under CEAA 1992, pursuant to the Comprehensive Study List Regulations [22] , along with a provincial environmental assessment. COGEMA submitted the Cluff Lake Project comprehensive study for decommissioning (CSD) to federal and provincial agencies in 2000 [23], along with relevant technical supporting documents. The CSD concluded that there were 2 ways in which the decommissioning of the Cluff Lake Project could impact the environment, namely through groundwater transport of contaminants from the TMA into the Island Creek watershed and through acid rock drainage and groundwater transport of contaminants from the Claude waste rock pile into Claude Lake, Claude Creek, and the Peter River systems. The CSD proposed mitigation measures to address the potential impacts, including the installation of a dry soil cover over the TMA and the construction of an engineered dry cover over the Claude waste rock pile. COGEMA determined in the CSD that the proposed project would not cause significant adverse environmental effects, considering the proposed mitigation measures outlined in the CSD.

In support of the decommissioning EA, CNSC staff developed a comprehensive study report (CSR) in 2003 [24] under CEAA 1992 [12]. The CSR was submitted to the federal Minister of Environment and the Canadian Environmental Assessment Agency to fulfill the CNSC's obligations as the Responsible Authority for the Cluff Lake Decommissioning Project under CEAA 1992. The CSR provided CNSC staffs assessment of the environmental effects of the proposed project, including long-term predictions of environmental quality.

The CSR also proposed a number of decommissioning objectives. These included Decommissioning Surface Water Quality Objectives (DSWQOs) and Decommissioning Sediment Quality Objectives (DSQOs) protective of water bodies in both the Island Lake and Cluff Lake watersheds. Radiological decommissioning objectives proposed included keeping radiation doses to nuclear workers and the general public below the regulatory limits and as low as reasonably achievable, through the final decommissioning and post-decommissioning phases. Decommissioning objectives were proposed for the post-decommissioning landscape to ensure the site was stable with a self-sustaining landscape. The objectives included that the site should be left in a relatively stable, self-sustaining and aesthetically acceptable state, similar in appearance and land capability as existed prior to mining activities, and that posed no unreasonable risk to humans or the environment [24] [25].

A decommissioning licence was granted in 2004 by the CNSC and an Approval to Operate Pollutant Control Facilities licence was granted by the Saskatchewan Ministry of Environment.

### 2.1.2 Previous EPR completed under the NSCA

In September 2018, Orano submitted a licence application to the CNSC to request a licence renewal for a 5-year term [26]. Orano's licence application included requests to:

- reduce the CNSC-licensed area to include only parcels of land where mining activities occurred and where radionuclide inventories were above exemption quantities
- reduce the financial guarantee to reflect the completion of decommissioning and the ongoing monitoring and maintenance activities proposed in the detailed PDP
- modernize the licence to reflect the post-closure activities on site

CNSC staff conducted an EPR under the NSCA to assess Orano's licence application and the documents submitted in support of compliance verification activities conducted at the Cluff Lake Project by CNSC staff. CNSC staff's EPR report for the Cluff Lake Project was posted in March 2019 as appendix D in CMD 19-H3 [25] and found that Orano had taken adequate provisions for the health and safety of persons and for the protection of the environment and would continue to do so in the future. CNSC staff also found that the Cluff Lake Project continued to meet the decommissioning objectives set out in the CSR, as previously discussed [24]. These decommissioning objectives, as well as their status at the time of the 2019 licence renewal, are described in more detail in the 2019 EPR report [25].

Within the EPR report, CNSC staff also directed Orano to:

- adopt the Canadian Council of Ministers of the Environment (CCME) guideline for uranium as a screening tool and present conclusions in the upcoming ERA regarding the risks of uranium in surface water bodies
- submit an updated hydrogeology and groundwater modelling technical information document with more information regarding the effectiveness of the soil covers and the re-vegetation works on the CWRP
- submit an updated hydrogeology and groundwater modelling technical information document with more information regarding the performance of horizontal drains installed at the Claude Pit cover to eliminate ponding water and also bound the incremental contaminant loading from the drains to allow CNSC staff to assess if the drains are performing as designed

Orano submitted the updated documentation, which was reviewed and accepted by CNSC staff. CNSC staff's review and assessment of this documentation is discussed in more detail in section 3.2 of this report.

The Commission concluded that Orano was qualified to carry out the activities within the proposed licence and the Cluff Lake Project was granted a uranium mill licence (UML) for a period of 5 years, expiring on July 31, 2024 [27].

Through ongoing licensing and compliance reviews, as well as independent verification through consideration of IEMP results and regional health studies, CNSC staff would continue to confirm and ensure that the environment and health of persons was protected at, and around, the Cluff Lake Project.

## 2.2 Environmental regulatory framework and protection measures

The CNSC has a comprehensive EP regulatory framework that includes both radioactive nuclear and hazardous substances, physical stressors (such as noise), and the protection of Indigenous Nations and communities, the public, and the environment. Public dose is considered under the EP framework, as well as from a radiation protection standpoint. The focus of this section of the EPR report is on the EP regulatory framework and the status of Orano's environmental protection program (EPP) for the Cluff Lake Project. The results derived from this EPP are detailed in section 3.0 of this report.

Orano's EPP for the Cluff Lake Project was designed and implemented in accordance with regulatory document REGDOC-2.9.1, Environmental Principles, Assessments and Protection Measures (2017) [28] , as well as the CSA Group's (Canadian Standards Association) environmental protection standards listed in table 2.2.

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

| Regulatory document or standard | Status |
|---|---|
| CSA N288.4-10, *Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills* [29] | Implemented |
| CSA N288.6-12, *Environmental Risk Assessment at Class I Nuclear Facilities and Uranium Mines and Mills* [30] | Implemented |
| CNSC REGDOC-2.9.1, *Environmental Principles, Assessments and Protection Measures*, (2017) [28] | Implemented |

CNSC staff confirm that Orano 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 [31], the *Radiation Protection Regulations* [32] (for example, for action levels or dose limit exceedances), and the LCH [33].

Orano 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.

CNSC staff regularly report on licensee performance to the Commission for activities conducted at the Cluff Lake Project. For example, CNSC staff 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 reports web page [34]. CNSC staff may also report to the Commission on events, such as unplanned releases to the environment, through an initial event report.

### 2.2.1 Environmental protection measures

To meet the CNSC's regulatory requirements under REGDOC-2.9.1 (2017) [28], Orano is responsible for implementing and maintaining EP measures that identify, control, and monitor releases of radioactive nuclear substances and hazardous substances from the Cluff Lake Project, and the effects of those substances on human health and the environment. EP measures are an important component of the overall requirement for licensees to make adequate provisions to protect the environment and the health and safety of persons.

This subsection and the following ones under section 2.2 summarize Orano's EPP for the Cluff Lake Project 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, environmental quality objectives or guidelines, and ERA predictions; it also discusses, where applicable, any notable trends.

Orano is required to implement an environmental management system (EMS) that conforms to REGDOC-2.9.1 (2017) [28] and to submit an EPP for the Cluff Lake Project. Orano's EPP includes the following components to meet the requirements and guidance as outlined in REGDOC-2.9.1 (2017):

- EMS
- environmental risk assessment (ERA)
- environmental monitoring program (EMP)
    - soil and terrestrial vegetation monitoring
    - surface water monitoring
    - groundwater monitoring

Effluent and emissions control and monitoring is not applicable for the Cluff Lake Project because it is a decommissioned site with no releases to the environment.

### 2.2.2 Environmental management system

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

- identify and manage non-compliances and corrective actions within the activities, through internal and external inspections and audits
- summarize and report 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

Orano established and implemented an integrated management system (IMS) for the Cluff Lake Project in accordance with REGDOC-2.9.1 (2017) [28]. 1 of the components of Orano's IMS is environmental protection and serves the role of an EMS at the Cluff Lake Project. CNSC staff review the implementation of the EMS as part of their review of the annual reports on EP.

The results of these reviews demonstrate that Orano's EMS for the Cluff Lake Project meets CNSC requirements as outlined in REGDOC-2.9.1 (2017) [28]. The implementation of the EMS ensures that Orano continues to improve environmental performance at the Cluff Lake Project.

### 2.2.3 Environmental risk assessment

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

The first comprehensive ERA for the Cluff Lake Project was incorporated within the Cluff Lake Project CSD [23], which considered the operational history of the project and simulated the effects of decommissioning of the project on the environment. The CSD provided a comprehensive evaluation of potential effects to VCs, emphasizing site-specific information and receptor characteristics, and made a number of long-term predictions of the receiving environment. The output from the 2000 CSD was used to support the EA conclusions that the Cluff Lake Project decommissioning was not likely to cause significant adverse environmental effects.

In 2015, AREVA (predecessor to Orano) submitted to the CNSC the Cluff Lake Project – Environmental Performance Technical Information Document – Volume 1 (2015 EP TID Volume 1) [35] and the Cluff Lake Project Environmental Performance Technical Information Document – Volume 2 Environmental Risk Assessment Update (2015 EP TID Volume 2) [36]. The EP TID Volume 1 described the state of the environment of the Cluff Lake Project from 1979 pre-operational baseline conditions up until 2014. The EP TID Volume 2 provided an update to the 2000 ERA submitted as part of the CSD, describing the anticipated ecological and human health risks based on the updated environmental monitoring information, and evaluated the long-term performance of the decommissioned Cluff Lake Project. The 2015 updated ERA included an ecological risk assessment (EcoRA) and a human health risk assessment (HHRA) for radiological and hazardous contaminants and physical stressors. CNSC staff reviewed AREVA's ERA and found it to be compliant with CSA N288.6-12 [30].

In 2019, Orano submitted an update to 2015 EP TID Volume 2, the 2019 EP TID Volume 2 [7], in accordance with the requirements set out in CSA N288.6-12 [30]. The 2019 ERA was submitted to support Orano's application to transfer the site into institutional control. This submission addressed the first recommendation made under the 2019 EPR report under the NSCA, that Orano adopt the CCME guideline for uranium as a screening tool and present conclusions in the upcoming ERA regarding the risks of uranium in surface water bodies.

In addition, Orano submitted an update to the Cluff Lake Project Technical Information Document – Hydrogeology and Groundwater Modelling (2019 Groundwater TID) [8], which describes the nature of the tailings, waste rock, and groundwater flows, and how the groundwater model is used to make the predictions of the movement of metals and radioactive elements in the environment. It is a key supporting document used to inform the ERA. This submission addressed the final 2 recommendations made under the 2019 EPR report under the NSCA:

- submit an updated hydrogeology and groundwater modelling technical information document with more information regarding the effectiveness of the soil covers and the re-vegetation works on the CWRP
- submit an updated hydrogeology and groundwater modelling technical information document with more information regarding the performance of horizontal drains installed at the Claude Pit cover to eliminate ponding water and also bound the incremental contaminant loading from the drains to allow CNSC staff to assess if the drains are performing as designed

In response to the CNSC recommendation that more information be provided on the effectiveness of the CWRP soil cover to revegetate and limit infiltration of precipitation into the CWRP, Orano provided, in the 2019 Groundwater TID and supporting documentation, a detailed description on the progress of revegetation to date, including the increase in species richness of native plants on the cover and the presence of later successional tree and shrub species. The progress of vegetation to date suggests that the CWRP is moving away from many species which are considered early successional (species with traits such as fast growth, short life span, abundant seed production, and shade-intolerance) and moving towards those species which are considered later-successional (species with longer life spans, more extensive root systems, production of larger seeds, and more shade tolerance). These trends will likely result in establishment of mature forests compatible with local ecosystems.

In response to the CNSC recommendation that additional information regarding the performance of horizontal drains installed at the Claude Pit cover be provided, the 2019 Groundwater TID and supporting documentation included information on how the groundwater model was calibrated to account for flow and mass flux through the horizontal drains, as well as the backfill material and associated grain size distribution curves that were used to determine the expected hydraulic conductivity applied in the groundwater model.

CNSC staff provided their technical review comments in 2020, followed by a number of technical meetings. CNSC staff found the 2019 update of the ERA and 2019 Groundwater TID to be acceptable and that Orano had addressed staff's technical comments and recommendations, including incorporating additional monitoring as part of the long-term monitoring and maintenance plan (LTMMP) [37] [38] [39].

In 2022, Orano submitted an update to the 2015 EP TID Volume 1, entitled Cluff Lake Project - Environmental Performance Technical Information Document Volume 1 – Version 02 (2022 EP TID Volume 1) [9]. This update summarizes the results of monitoring conducted between 2015 and 2021.

The most recent ERA results and the findings of the 2019 review of the ERA and 2022 EP TID Volume 1 are discussed further in section 3.2.

### 2.2.4 Effluent and emissions control and monitoring

The Cluff Lake Project is a decommissioned uranium mine site with no liquid effluent discharge or atmospheric emissions. Therefore, Orano is not required to have an effluent monitoring program in place for the Cluff Lake Project.

### 2.2.5 Environmental monitoring program

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

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

More specifically, the program must gather the necessary environmental data to calculate public dose and demonstrate compliance with the public dose limit found in the *Radiation Protection Regulations* [32] of 1 millisievert (mSv) per year. The program design must also address the potential environmental interactions identified at the facility or site. Hazardous substances are the major focus at the Cluff Lake Project, though radionuclides were included within monitoring activities associated with liquid discharges and air emissions when the Cluff Lake Project was in operation. Orano's EMP for the Cluff Lake Project consists of the following components:

- soil and terrestrial vegetation monitoring
- surface water monitoring

Monitoring frequency is specified in the EMP. Surface water monitoring is conducted annually, while soil and terrestrial vegetation monitoring are conducted every 5 years. Groundwater monitoring was removed from the EMP in 2022 with CNSC staff's approval.

Orano's EMP is required to comply with REGDOC-2.9.1 (2017) [28] and relevant standards, including CSA N288.4-10 [29].

Based on compliance activities, CNSC staff have found that Orano is compliant with REGDOC-2.9.1 (2017) [28] and continues to implement and maintain an effective EMP for the Cluff Lake Project that adequately protects the environment and the health and safety of persons.

## 2.3 Orano's request to move to Provincial regulatory oversight and its impacts on environmental protection

In February 2020, Orano requested the transfer of regulatory oversight for the Cluff Lake Project from the CNSC-issued licence to the Province of Saskatchewan's Intitutional Control Program (ICP), which is subject to a Commission decision [40]. In this application, Orano is applying to the CNSC to transfer responsibility for the currently licensed activities to possess, manage, and store radioactive waste at the Cluff Lake Project (that is, in-situ decommissioned waste rock and tailings) to the Province of Saskatchewan and exempt the Cluff Lake Project from licensing by the CNSC. A CNSC exemption from the obligation to hold a licence under the NSCA must be granted to the Government of Sasktachewan, as it is a prescribed condition for acceptance of the decommissioned Cluff Lake Project property into the Province of Saskatchewan's ICP.

The Province of Saskatchewan's ICP defines and implements a process for the long-term monitoring and maintenance of decommissioned mine and/or mill sites located on provincial Crown land in Saskatcehwan. Institutional control refers to the control of residual risks at a site after it has been decomissioned and can include active measures (such as water treatment, monitoring, maintenance) and passive measures (such as land use restrictions, markers), in perpetuity. The definition of institutional control recognizes that regulatory oversight is required; however, if the appropriate mechanisms are in place, CNSC licensing may no longer be required and oversight may be given to a competent provincial or territorial agency.

### 2.3.1 Long-term monitoring and maintenance plan

Orano has proposed a robust LTMMP to be administered under the ICP by the Province of Saskatchewan. The LTMMP is proposed to continue for decades, at a sample frequency focused on confirming the site's environmental performance against predicted performance and relative to decommissioning objectives. The scope and complexity of the LTMMP is informed by the 2019 update to the ERA and supporting documentation (discussed in section 3.2) and has taken into account CNSC staff recommendations.

The LTMMP focuses on 4 key areas. The first area is geotechnical inspections to confirm stability of key decommissioning features, monitor areas for public safety concerns, monitor for low likelihood accident and malfunction scenarios, and monitor for indications of site use. In addition, with the design for stability under passive care, maintenance is expected to be limited to potential settling of landfills and potential minor erosion repair on covers. Required maintenance would be identified during scheduled geotechnical inspections.

The second area of focus of the LTMMP is on monitoring future risk, in order to validate the predicted environmental performance and recovery of the Island Creek and Cluff Creek watersheds. This will include the periodic monitoring of surface water at locations within the Island Creek and Cluff Creek watersheds for key COPCs identified in the ERA.

The third area considers monitoring for recovery, and includes monitoring of sediment, benthic invertebrates, fish, and vegetation (in 2030 and 2055), in order to document site recovery, provide a characterization of the environmental conditions at that time and inform interested stakeholders, and address stakeholder questions about future cover performance.

The fourth area of focus of the LTMMP is on incorporating some additional surface water sample locations in areas of interest to known land users to provide additional assurance that the water will remain safe over time.

# 3.0 Status of the environment

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

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

## 3.1 Releases to the environment

Radioactive nuclear and hazardous substances that have the potential to cause an adverse effect to ecological or human receptors are identified as COPCs. During the operation and decommissioning of the Cluff Lake Project site, routine releases of treated effluent to Island Lake occurred from the Wastewater Treatment Plant until effluent releases ceased in October 2005 and the plant was completely decommissioned in 2013. In addition, with decommissioning activities having been completed, atmospheric emissions have also ceased.

As discussed in section 2.2.1, there are currently no releases to the environment (that is, air or surface water) from the Cluff Lake Project. As there are no releases, there are also no licence limits for releases to the environment in Orano's CNSC licence for the facility. The only pathways for COPCs to enter the receiving environment are from the very slow migration (over several thousands of years) of contaminants contained within the covered tailings or covered waste rock, into groundwater, and through the subsurface environment until it enters a surface water body, which is further discussed in section 3.2.2.

## 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 of persons.

Orano conducted a detailed ERA in 2019, to assess both the short-term and long-term effects on human health and the environment, based on the current site conditions and evolution of the site over time. The assessment applied a conservative long-term groundwater model to predict concentrations of contaminants (metals and radionuclides) that will migrate slowly over the long-term through the covered tailings and covered waste rock masses and into the surface water environment [7] [8]. Based on the predictions of water quality from the groundwater model over several thousand years, Orano assessed the potential risk to human health and ecological receptors and concluded that environmental impacts were limited and that the environment and human health would be protected into the future.

CNSC staff reviewed Orano's assessment of current and predicted effects on the environment and health of persons due to licensed activities included in the ERA (see subsection 2.2.3). The 2019 ERA was performed in a stepwise manner, as follows:

- identify the environmental interactions 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 health of persons is and will continue to be protected

To inform this section of the report, CNSC staff reviewed Orano's 2019 ERA [7], along with the Groundwater TID [8].

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 licensing requirements; certain components were also selected because they have historically been of interest to the Commission, Indigenous Nations and communities, and the public.

### 3.2.1 Atmospheric environment

During the construction, operation and active decommissioning of the facility, activities resulted in releases of nuclear and hazardous substances to the atmospheric environment. However, as the site has been decommissioned and active decommissioning activities were completed by 2006, the impact on air now and in the future is negligible.

Air quality monitoring, including monitoring of radon emanating from the site, was removed from the site-wide monitoring program in 2019, as previous monitoring had demonstrated that air quality had returned to background.

The updated ERA does consider exposure of VCs (that is, terrestrial environment) from the deposition of historic atmospheric emissions on soil and vegetation, but no impacts were identified.

**Findings**

Based on the review of Orano's ERA and the results of historic atmospheric monitoring, CNSC staff have found that ambient air quality has returned to background and is at levels protective of human health and the environment.

### 3.2.2 Geological and hydrogeological environment

This section discusses the geological and hydrogeological environment around the Cluff Lake Project that is used in the development of the groundwater and contaminant transport model used to simulate the migration of radionuclides to the receiving environment and informs the ERA.

**Geological Conditions**

The Cluff Lake Project is located in an area known as the Carswell Structure, a unique geological phenomenon located on the west side of the Athabasca sedimentary basin. In the Athabasca basin, the Athabasca Group rock formation unconformably overlies the Canadian Shield basement rock. The Carswell Structure is probably 1 of the most conspicuous, large diameter ring-type geological structures in Canada. In the Carswell Structure, the local geology is dramatically disturbed by what appears to be an upward thrust, which caused Aphebian basement rock to punch out the sandstone cover, turning it upside down. The origin of this structure is thought to be a meteorite impact that occurred during Ordovician time (485.4 to 443.8 million years ago). The Athabasca sandstone surrounds the Carswell Structure. Very few sedimentary blocks are encountered within the structure, as erosion has removed most of them. A major intricated and faulty circular zone encloses the Carswell Structure. A network of faults and fractures have developed around the Carswell Structure and play an important role in controlling groundwater flow in the bedrock.

Around the TMA, the overburden stratigraphy typically consists of sandy glacial till directly overlying the sandstone bedrock. This area is bounded to the northeast by lower hydraulic conductivity Archean basement rock (4,000 to 2,500 million years old), to the southwest by lower conductivity Douglas Formation dolomite and siltstone, and the northwest and southeast by the Bridle Lake fault system and the Cluff Lake fault system, respectively [41].

Around the mining area, the surficial geology consists of a continuous cover of permeable, drumulinized sandy till, interspersed with glaciofluvial and glaciolacustrine deposits [42]. Underlying the overburden are the low permeability Peter River, Earl Creek, and transition zone gneisses, with the upper 10 m being weathered and, therefore, having a higher permeability than deeper, unweathered bedrock.

**Hydrogeological conditions**

Regionally, deep groundwater flow across the Athabasca basin is generally northward to the lower elevations of Lake Athabasca. In the area around the Carswell Structure, the regional flow is disrupted due to the low permeability Archean core of the structure and the numerous structural discontinuities surrounding the core. As a result, deep groundwater flow in the Cluff TMA region is south-westward and that in the mining area generally flows from north to south, discharging at Cluff Lake.

Uplands are present across the area northeast of the TMA, whereas lowlands exist coincident with the Cluff Lake and Bridle Creek Fault systems to the southeast and northwest of the TMA, respectively. These lowlands lead toward a major lowland associated with the Douglas River valley to the southwest of the TMA. The uplands are groundwater recharge areas and the lowlands are groundwater discharge areas. The TMA exists on the margin of the regional lowland in the groundwater discharge area.

Field investigations have been conducted for the Cluff Lake Project to characterize hydraulic properties of the various formations. The Archean basement and the Douglas Formation siltstone (pelitic sandstone) are estimated to have the lowest hydraulic conductivities based on their lithology. This means that groundwater will move slower in these units. The sandstone is estimated to have a higher hydraulic conductivity and the Cluff Lake and Bridle Lake Fault systems are estimated to have the highest hydraulic conductivity due to the abundance of late structural discontinuities within these entities. The contact zone between the Archean basement and the sandstone is expected to have variable hydraulic conductivities due to intense silicification along parts of the contact zone and lack of secondary silicification in other parts of the zone. Stratigraphic units with high hydraulic conductivities tend to be the preferential pathways for groundwater flow. Therefore, groundwater will tend to flow through the sandstone unit and Cluff Lake and Bridle Lake Fault systems.

**Tailings management area**

The pelitic sandstone unit, which underlies 2 thirds of the TMA, acts as a low permeability barrier to groundwater flow. Consequently, groundwater flow across the pelitic sandstone is under sub-artesian or artesian pressures. Groundwater discharge occurs in the topographically low areas within the pelitic sandstone. Groundwater recharge occurs on the uplands adjacent to the TMA and immediately south of the pelitic sandstone contact and in the Liquids Pond area.

Snake Lake and the TMA lie within the Island Lake drainage basin, and Snake Lake forms a major groundwater discharge for the watershed. Groundwater flow within the basin is radial toward the TMA and Snake Lake.

Both upward and downward vertical hydraulic head gradients are present at the site. Downstream from the Main Dam, the vertical hydraulic head gradients are generally upward, and artesian conditions exist at several locations. Artesian conditions are also present beneath the western half of the TMA (figure 1.4). At the southeast extension of the Main Dam and along the east side of the TMA, the vertical gradient is downward. Although artesian and sub-artesian conditions were found in some areas, they are not expected to impact groundwater flow through the tailings.

**Mining area**

In the mining area, surface drainage, topography, and bedrock structure control shallow groundwater flow. Cluff Lake is the ultimate receptor for groundwater and surface water flows. Shallow groundwater flow discharges into various streams such as Boulder Creek, Claude Creek, Earl Creek, and Peter River.

A groundwater divide is present beneath the CWRP, resulting in groundwater flowpaths towards Claude Lake, Claude Creek, and Peter River. Groundwater in the vicinity of the batch plant and OP/DP areas flows towards Earl Creek, while groundwater in the vicinity of D-Pit flows towards Boulder Creek. In the DJX pit area, groundwater flows towards Cluff Lake.

### Groundwater flow and contaminant transport modeling

With an understanding of climate, topography, geology, hydrogeology, and source terms, Orano conducted groundwater flow and contaminant transport modeling exercises to simulate the groundwater flow path and the mass flux moving from sources to various receptors. The predicted mass flux to various receptors has served as input to surface water models to predict long-term surface water quality in downstream receptors, which subsequently informs the EcoRA and HHRA.

The particle path analysis indicates that contaminants originating from the TMA are transported through the underlying till and sandstone in groundwater toward Snake Lake.

The groundwater flow modelling indicates that a groundwater divide is present beneath the CWRP. The particle path analysis shows that potential contaminants of concern on the east side of the groundwater divide travel to Peter River and Earl Creek, and potential contaminants of concern originating from the west side of the groundwater divide travel to Claude Lake and Claude Creek. Potential contaminants of concern originating from the south side of the pile travel to Cluff Lake.

The particle path analysis also indicates that potential contaminants of concern originating from the Claude pit travel only to Claude Lake, and potential contaminants of concern originating in the DJX pit lake travel only to Cluff Lake.

The modelling results are consistent with the groundwater monitoring results.

The covered CWRP and TMA are key engineered features for the containment of contaminants on the site. The engineered covers will limit the infiltration of precipitation into the waste rock mass and tailings mass; however, over time, some precipitation will infiltrate. Infiltrated precipitation will migrate through the waste rock and tailings and into the surrounding geological environment, resulting in a slow discharge of contaminants into groundwater and subsequently into the respective surface water bodies.

As depicted in figure 1.4, groundwater will flow through CWRP and discharge into Claude Lake, Claude Creek, and Peter River, where contaminants will eventually make their way to Cluff Lake. Likewise, groundwater passing through the TMA will discharge into Snake Lake, with contaminants eventually making their way into Island Lake and migrating further downstream.

It is important to note that as contaminants flow through groundwater and into surface water, they will pass through the sediment layer in both Snake Lake and Claude Lake, which provides attenuation by removing some COPCs, such as uranium, before mobilizing in surface waters.

In order to assess the potential environmental impacts, Orano conducted an assessment of the predicted long-term contaminant loading to the surface water from these pathways through a base case scenario. In doing so, Orano took into consideration the expected performance of the engineered cover to limit infiltration, the anticipated groundwater flows over time, and the solute concentrations of contaminants in waste rock and tailings pore water.

The migration of COPCs via groundwater to surface water will occur over various time periods based on their mobility, attenuation, and decay characteristics, and on advective and diffusive transport mechanisms. Movement of COPCs from the CWRP and the TMA to groundwater and subsequently to surface water will continue for hundreds to thousands of years after decommissioning [8]. This slow movement of contaminants in groundwater to the receiving environment (surface waters and sediment), and the subsequent exposure to ecological receptors and people, was simulated from the calendar year 2018 to the calendar year 7000.

In order to assess whether the receiving environment would be protected now and in the future, the predicted concentrations in surface waters and sediment in exposed areas around the Cluff Lake Project site were compared to the DSWQOs and Sediment Quality Guidelines (SQGs). In addition, the predicted exposures to ecological receptors in the aquatic and terrestrial environments were compared to protective benchmark values, while predicted exposures to people were compared to the radiological public dose limit. The results of these assessments are discussed in the sections that follow.

Orano also conducted bounding cases to compare to the base case and determine a future range of performance. In the bounding cases, less likely model assumptions or accident and malfunction scenarios were considered, to bound the assessment results [8]. These bounding cases consider an increase in net percolation into the covers because of climate change, cover damage, lower cover performance, and a decrease in the attenuation rates of sediments.

### Findings

CNSC staff reviewed Orano's post-decommissioning predictions of groundwater discharge and contaminant transport modelling for both the base case and bounding cases and found them acceptable. However, given the very long-time frame associated with the predictions, CNSC staff requested that additional surface water monitoring be incorporated in the LTMMP at locations where groundwater is expected to discharge into surface waters, to provide an early indication of the performance of containments and to validate the accuracy of the model predictions. In response, Orano has included 4 additional surface water quality monitoring stations, 2 located at Claude Lake and 2 located in Cluff Lake, near the points of groundwater discharge [38].

### 3.2.3 Aquatic environment

An assessment of potential effects on aquatic biota at the Cluff Lake Project and the surrounding area consists of characterizing the local habitat and species (including considering federal and provincial species at risk) and assessing the possibility of their exposure to radiological and hazardous substances, as well as physical stressors that may be disruptive to ecological receptors.

**Surface water quality**

The potential effects of the project on water quality in the receiving environment were evaluated by comparing predicted COPC concentrations in water to available water quality guidelines (WQGs). As described in section 2.1.1, the CNSC CSR included long-term water quality predictions and proposed DSWQOs for several water bodies in both the Island Creek and Cluff Creek watersheds, including Snake Lake, Island Lake, Claude Lake, Claude Creek, Peter River, Earl Creek, Cluff Lake, and the flooded pits [12].

Since the time of the CSR, some WQGs have been revised and others established. As part of the 2019 Cluff Lake project licence renewal, CNSC staff directed Orano to adopt the uranium CCME environmental water quality guideline for the protection of aquatic life of 15 µg/L as a screening tool and apply it in the next update to the ERA. This WQG was used as a screening tool in the 2019 ERA update [7].

**Island Creek watershed**

The Island Creek watershed is influenced by the past release of treated effluent during the operational period. Since cessation of operations in 2006, it has demonstrated strong recovery, with decreasing contaminant concentrations. In the future, once contaminants migrating in groundwater from the decommissioned TMA make their way into sediments and surface water, it is predicted that there will be an increase in the concentration of some contaminants in the Island Creek watershed over the post-decommissioning period. In both Snake Lake and Island Lake, monitoring to date has shown that the DSWQOs are currently being met (table 3.1) and they are expected to continue to be achieved in the future based on long-term modelling results. Under the Cover Erosion and Climate Change bounding scenarios, marginal exceedances of the Ra-226 DSWQO of 0.11 becquerels per litre (Bq/L) were predicted in Snake Lake at a peak mean concentrations of 0.12 Bq/L. Given the unlikelihood of these events, and the level of the exceedance, any potential impacts would be negligible.

**Cluff Creek watershed**

The Cluff Creek watershed was not influenced by operational releases but is, and is expected to continue to be, influenced by groundwater contaminant transport through the waste rock piles, most notably the CWRP. Monitoring data has demonstrated that current DSWQOs in the Cluff Lake watershed are being met (table 3.1). Predicted peak concentrations are expected to remain below DSWQOs, as demonstrated by long-term modelling results. Some exceedances were predicted for the bounding cases. Under the Cover Erosion bounding scenario, exceedances of nickel and uranium DSWQOs in Claude Creek were predicted. In the Climate Change bounding scenario, exceedances of the uranium DSWQO in Claude Creek was predicted. In the sediment attenuation scenarios, cobalt, copper, nickel, and uranium DSWQOs in Claude Lake and Claude Creek were predicted. In all cases, the peak mean concentrations were less than an order of magnitude above the DSWQOs and were predicted to decrease back to below the DSWQOs. Given the low probability of the scenarios occurring, the inherent conservativeness in the modelling assumptions and assessment approach, and the magnitude of the exceedances, any potential impacts would be low, temporary, and highly unlikely.

Peak mean surface water quality predictions for the base case scenario are presented in table 3.2 and compared to DSWQOs and current WQGs. The results show that there are localized (that is, to an individual water body) and temporary exceedances of current WQGs. In the Island Creek watershed, current exceedances of sulphate selenium, uranium, and iron resulting from historical effluent discharges, are expected to drop below current WQGs in the immediate future.

In the Island Creek watershed, short-term exceedances of predicted chloride in Snake Lake and selenium in Island Lake are expected to quickly drop below their WGQs by the year 2030 and 2050, respectively. Uranium exceedances in Island Lake is expected to drop below the CCME WQG of 15 micrograms per litre (µg/L) in approximately 150 years (that is, calendar year 2170). Only iron is anticipated to exceed the current surface WQGs in Snake Lake beyond the modelled period; however, iron is naturally present at levels that exceed the WQGs in Snake Lake.

In the Cluff Creek watershed, future exceedances of WQGs are predicted for cadmium, copper, cobalt, nickel, and uranium. Cadmium and copper are expected to exceed WQGs in Claude Lake and Claude Creek around the year 2050 and are expected to decrease below WQGs by the year 3100. Cobalt is expected to exceed the WQG in Claude Creek around the year 2200 and return below the WQG by the year 2700. Nickel in Claude Creek, which currently exceeds the WQG, is expected to recover below WQGs in approximately 2600. Uranium is predicted to exceed WQGs in Claude Creek by the year 2050 and return to below the WQG by the year 3800.

These localized and temporal exceedances of the current WQGs are not expected to impact aquatic life, as the WQGs are conservative. The water and sediment quality guidelines represent conservative levels considered to be protective of aquatic species. Exceedances of these benchmarks, including the CCME WQG for uranium, do not indicate that negative effects will occur; rather, exceedances are used as a screening tool to guide the EcoRA and flag COPCs that need to be examined further with respect to potential effects on aquatic species, to better understand the potential magnitude and extent of potential effects. The long-term predictions show that there are several areas where the surface water quality currently exceeds or is predicted to exceed WQG due to decommissioning groundwater contaminant transport and/or residual contamination from the operational period. Orano further assessed the WQG exceedances through its ERA to improve understanding of the potential effects on the aquatic and terrestrial communities. CNSC staff’s assessment of these potential effects are described in section 3.23 and 3.24, respectively.

**Table 3.1: 2020 and 2021 surface water monitoring results in the Island Creek and Cluff Creek watersheds [4]**

| Parameter | DSWQOs | Current WQGs | Island Creek watershed | | | |
|---|---|---|---|---|---|---|
| | | | Snake Lake | | Island Lake | |
| Year | N/A | N/A | 2020 | 2021 | 2020 | 2021 |
| Chloride (mg/L) | - | 120[d] | 28 | 40 | 51 | 31 |
| Sulphate (mg/L) | - | 128-429[bf] | 60 | 67 | 65 | 41 |
| Arsenic (µg/L) | 50 | 5[a] | 0.3 | 0.3 | 0.7 | 1 |
| Cadmium (µg/L) | 1 | 0.04-0.37[bd] | 0.01 | 0.02 | 0.01 | <0.01 |
| Cobalt (µg/L) | 20[g] | 0.73[e] | 0.2 | 0.4 | <0.1 | 0.1 |
| Copper (µg/L) | 10 | 2-4[ab] | <1 | 1.6 | <0.2 | <0.2 |
| Iron (mg/L) | 3.2 (Snake Lake) 1.0 (Island Lake) | 0.3[a] | 1.4 | 2.53 | 0.1 | 0.2 |
| Molybdenum (µg/L) | 73 (500 Island Lake) | 31,000[a] | 1.7 | 1.1 | 93 | 73 |
| Nickel (µg/L) | 25 | 25-150[ab] | 2.8 | 2.2 | 1.4 | 1.4 |
| Selenium (µg/L) | 10 | 1[a] | <0.1 | <0.1 | 0.5 | 0.6 |
| Uranium (µg/L) | 88[b]/274[h] | 15[a] | 1.7 | 2.3 | 24 | 15 |
| Polonium-210 (Bq/L) | - | 0.1[c] | 0.02 | <0.01 | <0.01 | <0.01 |
| Lead-210 (Bq/L) | - | 0.2[c] | <0.04 | <0.04 | <0.04 | <0.04 |
| Radium-226 (Bq/L) | 0.11 | 0.11[a] | 0.01 | 0.02 | 0.01 | <0.005 |
| Thorium-230 (Bq/L) | - | 0.6[c] | <0.02 | <0.02 | <0.02 | <0.02 |

| Parameter | DSWQOs | Current WQGs | Cluff Creek watershed | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Claude Lake | | Claude Creek | | Cluff Lake | |
| Year | N/A | N/A | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Chloride (mg/L) | - | 120[d] | 1 | 2 | 1 | 2 | 2.5 | 3.2 |
| Sulphate (mg/L) | - | 128-429[bf] | 76 | 120 | 140 | 230 | 8.4 | 9.4 |
| Arsenic (µg/L) | 50 | 5[a] | 0.4 | 0.4 | 0.4 | 0.5 | 0.1 | 0.1 |
| Cadmium (µg/L) | 1 | 0.04-0.37[bd] | 0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 |
| Cobalt (µg/L) | 20[g] | 0.73[e] | 1 | 1 | 2.2 | 4.6 | <0.1 | <0.1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Copper (µg/L) | 10 | 2-4[ab] | 0.2 | <0.2 | 0.5 | 0.3 | 0.2 | <0.2 |
| Iron (mg/L) | 3.2 (Snake Lake)<br>1.0 (Island Lake) | 0.3[a] | 1.5 | 0.4 | 0.6 | 1.1 | 0.2 | 0.2 |
| Molybdenum (µg/L) | 73 (500 Island Lake) | 31,000[a] | 0.2 | 0.2 | <0.1 | 0.1 | 0.2 | 0.2 |
| Nickel (µg/L) | 25 | 25-150[ab] | 8.2 | 13 | 16 | 46 | 1.1 | 1.6 |
| Selenium (µg/L) | 10 | 1[a] | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 |
| Uranium (µg/L) | 88[b]/274[h] | 15[a] | 2.3 | 4.3 | 0.7 | 0.8 | 0.4 | 0.4 |
| Polonium-210 (Bq/L) | - | 0.1[c] | <0.005 | 0.007 | <0.005 | <0.005 | <0.005 | <0.005 |
| Lead-210 (Bq/L) | - | 0.2[c] | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Radium-226 (Bq/L) | 0.11 | 0.11[a] | <0.005 | <0.005 | <0.005 | <0.005 | 0.005 | <0.005 |
| Thorium-230 (Bq/L) | - | 0.6[c] | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

Definition of units: mg/L = milligrams per litre; ug/L = micrograms per litre; Bq/L = becquerels per litre.
[a] Saskatchewan Environmental Quality Guidelines [43].
[b] Objective depends on hardness. Guideline values correspond to a hardness of 44 mg/L (based on levels at reference stations).
[c] Thorium-230, Lead-210 and Polonium-210 objectives based on Canadian Drinking Water Quality Guidelines [44].
[d] Cadmium and chloride objectives based on federal guideline value [45].
[e] Cobalt objective based on the Federal Environmental Quality Guidelines [46]; calculated based on a hardness of 44 mg/L.
[f] Sulphate objective based on British Columbia's Water Quality Guideline to Protect Aquatic Life [47].
[g] For dissolved fraction.
[h] Not considered to exceed DSWQO [7]. The hardness dependent criteria were selected using a regional background hardness of 44 mg/L (DSWQO = 2xhardness); however, the average hardness measured in Island Lake (at station ISL4000S) over the recent period (2013 to 2017) was substantially higher, at 230 mg/L. A short-term hardness of 137 mg/L was adopted for the initial long-term period as this represents a hardness half-way between the current hardness (230 mg/L) and the regional background hardness (44 mg/L), in other words a hardness half-way to recovery to background levels. Concentrations of uranium in Island Lake are currently around 120 µg/L, which is substantially below the DSWQO corresponding to the hardness selected for the initial long-term period. Therefore, it is not expected that the uranium levels in Island Lake will exceed the appropriate hardness-dependent DSWQO during any given year.

**Table 3.2: Predicted future peak mean surface water quality in the Island Creek and Cluff Creek watersheds [7]**

| Parameter | DSWQOs | Current WQGs | Island Creek watershed | |
|---|---|---|---|---|
| | | | Snake Lake | Island Lake |
| Chloride (mg/L) | - | 120[d] | 72 | 65 |
| Sulphate (mg/L) | - | 128-429[bf] | 133 | 117 |
| Arsenic (µg/L) | 50 | 5[a] | 1.1 | 1.3 |
| Cadmium (µg/L) | 1 | 0.04-0.37[bd] | 0.02 | 0.04 |
| Cobalt (µg/L) | 20[g] | 0.73[e] | 0.16 | 0.19 |
| Copper (µg/L) | 10 | 2-4[ab] | 0.24 | 0.2 |
| Iron (mg/L) | 3.2 (Snake Lake)<br>1.0 (Island Lake) | 0.3[a] | 1** | 0.21 |
| Molybdenum (µg/L) | 73 (Snake Lake)<br>500 (Island Lake) | 31,000[a] | 27 | 144 |
| Nickel (µg/L) | 25 | 25-150[ab] | 0.91 | 2.3 |
| Selenium (µg/L) | 10 | 1[a] | 0.6 | 1.2** |
| Uranium (µg/L) | 88[b]/274[h] | 15[a] | 8.4 | 97**[h] |
| Polonium-210 (Bq/L) | - | 0.1[c] | 0.02 | 0.04 |
| Lead-210 (Bq/L) | - | 0.2[c] | 0.03 | 0.04 |
| Radium-226 (Bq/L) | 0.11 | 0.11[a] | 0.11 | 0.05 |
| Thorium-230 (Bq/L) | - | 0.6[c] | 0.01 | 0.02 |

| Parameter | DSWQOs | Current WQGs | Cluff Creek watershed | | | |
|---|---|---|---|---|---|---|
| | | | Claude Lake | Claude Creek | Peter River | Cluff Lake |
| Chloride (mg/L) | - | 120[d] | 3.2 | 3.1 | 1.8 | 3.7 |
| Sulphate (mg/L) | - | 128-429[bf] | 202** | 196** | 21 | 12 |
| Arsenic (µg/L) | 50 | 5[a] | 0.8 | 1.1 | 0.19 | 0.13 |
| Cadmium (µg/L) | 1 | 0.04-0.37[bd] | 0.47** | 0.5 | 0.05 | 0.03 |
| Cobalt (µg/L) | 20[g] | 0.73[e] | 5.4** | 18** | 1.7** | 0.98** |
| Copper (µg/L) | 10 | 2-4[ab] | 2.8 | 7.3** | 0.86 | 0.49 |
| Iron (mg/L) | 3.2 (Snake Lake)<br>1.0 (Island Lake) | 0.3[a] | - | - | - | - |
| Molybdenum (µg/L) | 73 (Snake Lake)<br>500 (Island Lake) | 31,000[a] | 7.2 | 8.6 | 0.93 | 0.47 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Nickel (µg/L) | 25 | 25-150[ab] | 18 | 126[h] | 13 | 6.8 |
| Selenium (µg/L) | 10 | 1[a] | 0.32 | 0.45 | 0.15 | 0.12 |
| Uranium (µg/L) | 88[b]/274[h] | 15[a] | 50** | 152**[h] | 25** | 11 |
| Polonium-210 (Bq/L) | - | 0.1[c] | 9.0E-03 | 9.0E-03 | 4.0E-03 | 6.0E-03 |
| Lead-210 (Bq/L) | - | 0.2[c] | 0.02 | 0.02 | 0.02 | 0.02 |
| Radium-226 (Bq/L) | 0.11 | 0.11[a] | 8.0E-03 | 8.0E-03 | 6.0E-03 | 6.0E-03 |
| Thorium-230 (Bq/L) | - | 0.6[c] | 8.0E-03 | 8.0E-03 | 0.01 | 0.01 |

** values indicate peak exceedances of current WQGs.
Definition of units: mg/L = milligrams per litre; ug/L = micrograms per litre; Bq/L = becquerels per litre.
[a] Saskatchewan Environmental Quality Guidelines [43].
[b] Objective depends on hardness. Guideline values correspond to a hardness of 44 mg/L (based on levels at reference stations).
[c] Thorium-230, Lead-210 and Polonium-210 objectives based on Canadian Drinking Water Quality Guidelines [44].
[d] Cadmium and chloride objectives based on federal guideline value [45].
[e] Cobalt objective based on Federal Environmental Quality Guidelines [46]; calculated based on a hardness of 44 mg/L.
[f] Sulphate objective based on British Columbia's Water Quality Guideline to Protect Aquatic Life [47].
[g] For dissolved fraction.
[h] Not considered to exceed DSWQO [7]. The hardness dependent criteria were selected using a regional background hardness of 44 mg/L (DSWQO = 2xhardness); however, the average hardness measured in Island Lake (at station ISL4000S) over the recent period (2013 to 2017) was substantially higher, at 230 mg/L. A short-term hardness of 137 mg/L was adopted for the initial long-term period as this represents a hardness half-way between the current hardness (230 mg/L) and the regional background hardness (44 mg/L), in other words a hardness half-way to recovery to background levels. Concentrations of uranium in Island Lake are currently around 120 µg/L, which is substantially below the DSWQO corresponding to the hardness selected for the initial long-term period. Therefore, it is not expected that the uranium levels in Island Lake will exceed the appropriate hardness-dependent DSWQO during any given year.

## Sediment quality

The potential effects of the site on sediment quality in the receiving environment were evaluated by comparing predicted COPC concentrations in sediment to SQGs. Due to the uncertainty surrounding SQGs, several guidelines are considered for evaluating predicted COPC sediment concentrations in the long term. These include the Lowest Effect Level (LEL) and Severe Effects Level (SEL) [65].

### Island Creek watershed

Island Creek watershed received liquid effluent during operations and contaminants have accumulated in sediments in Island Lake. With the end of liquid effluent discharge, the contaminated sediments are predicted to recover, as clean sediments accumulate on top of the contaminated sediment. This has been supported by recent improvements to sediment quality in the exposure lakes relative to previous years. In the Cluff Creek watershed, widespread negative effects on the benthic community in the Island Creek watershed are not expected.

Table 3.3 provides a list of the SQGs as well as the peak mean sediment quality predictions for the base case scenarios.

Within the Island Creek watershed, future exceedances of the LELs are predicted for arsenic, molybdenum, nickel, selenium, uranium, radium-226, lead-210, and polonium-210 at some locations. No mean levels are expected to exceed the SEL values except in the case of selenium at the very beginning of the modelled period in Island Lake and Island Lake fen. Predictions indicate that by the end of the modelled period (that is, calendar year 7000), concentrations of COPCs will have dropped below guidelines.

### Cluff Creek watershed

Within the Cluff Creek watershed, sediment predictions expected to exceed the applicable sediment LEL values at the maximum means are arsenic, copper, molybdenum, nickel, selenium, and uranium in Claude Lake and arsenic, nickel, selenium, and uranium in Cluff Lake. With the exception of selenium, all sediment predictions are expected to fall below the LEL value before the year 3500. Background concentrations of selenium in sediment are close to the LEL values, thus the additional groundwater load, although small, results in the concentration slightly exceeding the LEL. No mean levels are expected to exceed the SEL values. Predictions indicate that by the end of the modelled period, concentrations of COPCs will have dropped below guidelines.

As discussed earlier, exceedances of these benchmarks do not indicate that negative effects will occur but are instead used to identify those COPCs that require a more detailed analysis to better understand the potential magnitude and extent of potential effects on aquatic species and the benthic community.

**Table 3.3: Predicted future peak mean sediment quality in the Island Creek and Cluff Creek watersheds [7]**

| Parameter | Canadian interim sediment quality guidelines for the protection of aquatic life [45] | Canadian Probable Effects level sediment quality guidelines [45] | LEL [48] | SEL [48] | No effect level(a) | Island Creek watershed | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Snake Lake | Island Lake | Island Lake fen |
| Arsenic (µg/g) | 5.9 | 17 | 9.8 | 346.4 | 522 | 10.6 | 12.5 | 24 |
| Copper (µg/g) | 35.7 | 197 | 22.2 | 268.8 | - | 8.8 | 12 | 3.7 |
| Molybdenum (µg/g) | - | - | 13.8 | 1238.5 | 245 | 115 | 467 | 548 |
| Nickel (µg/g) | - | - | 23.4 | 484 | 326 | 21 | 42 | 12 |
| Selenium (µg/g) | - | - | 1.9 | 16.1 | 29.7 | 7.6 | 22* | 19* |
| Uranium (µg/g) | - | - | 104.4 | 874.1 | 2296 | 64 | 395 | 355 |
| Lead-210 (Bq/g) | - | - | 0.9 | 20.8 | - | 0.72 | 0.21 | 0.2 |
| Polonium-210 (Bq/g) | - | - | 0.8 | 12.1 | - | 0.63 | 0.34 | 0.39 |
| Radium-226 | - | - | 0.6 | 14.4 | - | 0.8 | 0.44 | 0.41 |

| Parameter | Canadian interim sediment quality guidelines for the protection of aquatic life [45] | Canadian Probable Effects level sediment quality guidelines [45] | LEL [48] | SEL [48] | No effect level(a) | Cluff Creek watershed | |
|---|---|---|---|---|---|---|---|
| | | | | | | Claude Lake | Cluff Lake |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Arsenic (µg/g) | 5.9 | 17 | 9.8 | 346.4 | 522 | 8.8 | 32 |
| Copper (µg/g) | 35.7 | 197 | 22.2 | 268.8 | - | 36 | 23 |
| Molybdenum (µg/g) | - | - | 13.8 | 1238.5 | 245 | 57 | 7.4 |
| Nickel (µg/g) | - | - | 23.4 | 484 | 326 | 318 | 111 |
| Selenium (µg/g) | - | - | 1.9 | 16.1 | 29.7 | 2.6 | 2.1 |
| Uranium (µg/g) | - | - | 104.4 | 874.1 | 2296 | 489 | 137 |
| Lead-210 (Bq/g) | - | - | 0.9 | 20.8 | - | 0.06 | 0.4 |
| Polonium-210 (Bq/g) | - | - | 0.8 | 12.1 | - | 0.17 | 0.68 |
| Radium-226 | - | - | 0.6 | 14.4 | - | 0.25 | 0.68 |

* values represent those above the SEL.

(a) NE2 stands for “No Effect Level” and represents site-specific benchmark values that should be protective of aquatic habitats and populations in general, although may not be protective of individual species [7].

### Aquatic habitat and species

An assessment of potential effects on aquatic biota at the Cluff Lake Project 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.

The list of relevant VCs for the aquatic environment that were considered in the assessment included aquatic plants (as primary food consumed by moose, muskrat, and other animals) phytoplankton, zooplankton, benthic invertebrates that live and feed within sediments, and forage fish (including lake whitefish (*Coregonus clupeaformis*) and white sucker (*Catostomus commersonii*)) and predatory fish (including northern pike and lake trout).

In Saskatchewan, the federal *Species at Risk Act* (SARA) [49] applies to species at risk. To comply with the legislation, and as part of the 2019 ERA [7], Orano identified wildlife species at risk that may potentially be found at or near the site. For the aquatic environment, a precautionary approach was taken and, although its presence is not confirmed, the northern leopard frog (*Lithobates pipiens*) was selected from the list to be carried forward into the assessment.

### Exposure to radiological substances

The ERA assessed radiological exposures to the aquatic receptors over the long-term model time frame (that is, up to calendar year 7000) and compared their modelled exposures to the aquatic radiological benchmark of 9.6 milligray per day (mGy/d) [30]. All model results showed that doses to aquatic receptors were well below the benchmark throughout both the Island Creek and Cluff Creek watersheds. No impacts from radiological exposures to aquatic biota are expected [7].

### Exposure to hazardous substances

The ERA conducted a more in-depth assessment of aquatic biota exposed to COPCs that exceeded WQGs, as described earlier. As part of the assessment, predicted surface water quality concentrations were compared to species sensitivity distribution (SSD) curves, which are statistical representations of all available toxicity data that exists for a specific COPC for all species that have been tested. This assessment allows a more detailed and site-specific approach to be taken, whereby the predicted concentrations in surface water can be compared to the effect levels of more representative species (or surrogate species) that exist in the Cluff Lake Project area.

With respect to species at risk, the northern leopard frog was identified as a species at risk that is potentially in the area. To address potential risk to this receptor, amphibian toxicity data, where available, were included in the development of COPC SSDs. The model results showed that risks to amphibians were not expected at the modelled surface water concentrations for any COPCs in either the Cluff Creek or Island Creek watersheds.

### Cluff Creek watershed

In the Cluff Creek watershed, concentrations of arsenic, molybdenum, and chloride are expected to remain below the WQGs over the assessment timeframe (that is, up to calendar year 7000), as discussed in earlier. No effects are expected from exposure to these COPCs.

For other contaminants assessed, including cadmium, cobalt, copper, nickel, uranium, and selenium, peak predicted concentrations in Claude Lake and Claude Creek are expected to temporarily exceed effects levels of some aquatic invertebrates and aquatic plants in the future, depending on the COPC. However, the majority of aquatic species are demonstrated to be protected. For example, the assessment of cadmium showed a 90% protection level for the aquatic community in Claude Lake and Claude Creek. This provides evidence that most aquatic species would remain unaffected by these exposures.

With respect to potential effects on benthic communities, as there were no operational releases to the Cluff Creek watershed, no impacts are expected. The most recent monitoring program results have shown that benthic communities in the exposed lakes are similar to those in corresponding reference lakes, which suggests that the benthic invertebrate community is relatively stable and unimpacted.

**Island Creek watershed**

In the Island Creek watershed, concentrations of cadmium, cobalt, copper, molybdenum, and nickel are expected to remain below the applicable WQGs over the assessment timeframe (that is, up to calendar year 7000), as discussed above. No effects are expected from exposure to these COPCs.

For other contaminants assessed, including chloride, iron, uranium and selenium, peak predicted concentrations in Snake Lake, Island Lake, and Island Lake fen are expected to temporarily exceed effects levels of some aquatic invertebrates and aquatic plants in the future, depending on the COPC. However, the majority of aquatic species are demonstrated to be protected.

With respect to selenium, which is known to bioaccumulate through aquatic food webs, Orano conducted a more detailed assessment by comparing selenium exposures in the Island Creek watershed to a protective fish tissue concentration of 11.3 µg/g dry weight (dw). In Island Lake, selenium is currently elevated due to the previous operational release of treated effluent to this waterbody. The assessment results showed that the concentrations are expected to fall steadily towards and then below the benchmark in the future in Island Lake. As future concentrations in Island Lake are expected to be lower than current conditions, the concentrations from the recent monitoring were used in a weight-of-evidence assessment. Monitoring has indicated that average selenium concentrations in the ovaries of fish taken from Island Lake in 2020, of 10.1 µg/g (dw), was below the U.S. EPA selenium benchmark of 15.1 µg/g (dw). In addition, the abundance of white sucker in Island Lake has been generally increasing in recent years, with a higher catch per unit effort in both 2009 and 2014 as compared to previous years [9]. In light of the evidence, impacts to fish from selenium exposure is expected to be low.

With respect to potential effects on benthic communities, Island Lake watershed was influenced by operational releases. The 2014 EMP provides evidence of sediment quality improvement in the exposure lakes in 2014 relative to previous years, and spatial and temporal evaluations of the benthic invertebrate communities in the shallow lakes within the Island Lake drainage suggest recovery is occurring. Taxa composition in Island Lake and Snake Lake was more similar to reference communities than in previous monitoring years. Furthermore, density, biomass, and richness in Island Lake continued to increase in 2014 and were thus more similar to levels in the reference lakes than in previous years. As a result, potential effects on the benthic community are localized and variable by COPC; widespread negative effects on the benthic community in the Island Creek Watershed are not expected.

**Findings**

Based on CNSC staff's review of Orano's ERA and supporting documentation for the Cluff Lake Project, CNSC staff found that although there is potential for effects to some species in the aquatic environment, the majority of aquatic species will remain protected. In addition, for those species that may be affected, potential impacts are expected to be localized and temporary. It is important to note that the model results and the benchmarks used have an inherent level of conservatism applied, sometimes as high as several orders of magnitude, providing a large margin of safety. In light of this, and considering any potential impacts are expected to be localized, temporary, and influence a small number of aquatic species, the risk is anticipated to be low.

### 3.2.4 Terrestrial environment

An assessment of potential effects on terrestrial biota at the Cluff Lake Project 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.

The list of relevant VCs for the terrestrial environment that were considered in the assessment included terrestrial birds, such as the nighthawk and bald eagle, as well as terrestrial-based mammals, such as hare and moose, which are an important aspect of a traditional land use diet. The full list included moose, eagle, mink, beaver, muskrat, otter, mallard, merganser, scaup, yellowlegs, nighthawk, and hare.

In Saskatchewan, the federal SARA [49] legislation applies to species at risk. To comply with the legislation, and as part of the 2019 ERA [7], Orano identified wildlife species at risk, which may potentially be found at or near the site. A list of these species is provided in table 3.3.

**Table 3.3: Species at Risk assessed in the ERA [7]**

| Common name | Scientific name | SARA designation | Detected at site | Considered in assessment |
|---|---|---|---|---|
| Common nighthawk | *Chordeiles minor* | Threatened | Yes | Yes |
| Horned grebe | *Podiceps auritus* | Special concern | Yes | Scaup and mallard used as surrogate |
| Olive-sided flycatcher | *Contopus cooperi* | Threatened | Yes | Nighthawk used as surrogate |
| Peregrine falcon | *Falco peregrinus* | Special concern | No | Eagle used as surrogate |
| Rusty blackbird | *Euphagus carolinus* | Special concern | Yes | Nighthawk used as surrogate |

Due to similarities between diets, the scaup and mallard were also selected to serve as surrogate species for the horned grebe, while the eagle served as a surrogate species for the peregrine falcon. The common nighthawk, an insectivore, served as a surrogate for 2 other listed avian insect-eating species that may be in the area, namely the olive-sided flycatcher and the rusty blackbird.

### Exposure to radiological substances

The ERA assessed radiological exposures to the terrestrial receptors over the assessment time frame (that is, up to calendar year 7000), and compared their modelled exposures to the terrestrial radiological benchmark of 2.4 mGy/d [7]. All results showed doses to terrestrial receptors were well below the benchmark throughout both the Island Creek and Cluff Creek watersheds. The highest dose in the Island Creek watershed was 0.62 mGy/d to yellowlegs at Island Lake fen, and in the Cluff Creek watershed was 0.53 mGy/d to yellowlegs at Claude Lake [7].

For species at risk, a dose threshold value of 1 mGy/d was applied and is internationally accepted to represent a dose rate with no observable effects to biota. All terrestrial receptors were well below this dose. No impacts from radiological exposures to terrestrial biota are expected [7].

### Exposure to hazardous substances

The ERA assessed the potential for effects to terrestrial biota from exposure to hazardous substances in the area over the assessment timeframe (that is, up to calendar year 7000). A probabilistic approach was taken to account for variability in a number of model parameters, where both mean and upper bound predictions were calculated. As per CSA N288.6, the daily intake rates of hazardous substances were compared to the lowest observable adverse effect levels (LOAELs), which are protective at the population level. For species at risk, the no observable adverse effect levels (NOAELs) were applied, as they provide an extra margin of safety where potential risk to individuals is of concern.

### Cluff Creek watershed

The long-term model results showed no exceedances of the LOAELs at the mean predicted concentrations for the base case scenario to any of the terrestrial receptors in the Cluff Creek watershed. There were a few instances where the upper-bound results of the assessment did exceed the LOAELs for several receptors in Claude Lake. These included uranium and cobalt exposures to muskrat in Claude Lake, which are attributed in part to high variability between stations. There was also a slight exceedance of uranium and selenium in yellowlegs; however, given the inherent conservativeness in the assessment, this risk is considered to be low.

For species at risk, the nighthawk’s (representing nighthawk, olive-sided flycatcher, and rusty blackbird) mean arsenic exposures in Cluff Lake exceeded the NOAEL benchmark in 2018, with levels currently decreasing and expected to be below the NOAEL after several hundred years. This exceedance is driven by naturally high arsenic concentrations in Cluff Lake sediment, which are conservatively assumed to transfer to insects. These receptors consume insects, and it was assumed that all insects can be represented by benthic invertebrate concentrations. It is unlikely that the nighthawk would only consume emergent aquatic insects, and their diet would be more varied to include terrestrial insects such as bees and beetles, with rusty blackbirds similarly consuming terrestrial insects and plant materials. Olive-sided flycatcher primarily consumes bees. Therefore, the assessment is quite conservative, and impacts to terrestrial birds are not expected.

For the horned grebe (represented by the scaup and mallard) and peregrine falcon (represented by the eagle), exposures remained below the NOAELs, and no impacts are expected for individuals that may be present in the Cluff Creek watershed either currently or in the future.

**Island Creek watershed**

The long-term model results showed no exceedances of the LOAELs to moose or hare in the Island Creek watershed.

The mean predicted intakes of several other terrestrial receptors did exceed their respective LOAELs. This included selenium exposures in mink, which is associated with the large number of fish that mink consume. In Snake Lake, the upper-bound predictions showed slight exceedances of the LOAEL and were attributed to future selenium loading in groundwater. In Island Lake, exceedances of the LOAEL were attributed to current conditions associated with the past release of treated effluent during operation, and risks are predicted to decrease in the future. It should be noted that this is a conservative assessment as mink are assessed on a waterbody basis but have a home range between 0.06 and 16.3 $km^2$ and thus are not expected to be associated with a single waterbody. As a result, potential adverse effects are considered localized to Snake Lake and temporary, as recovery is expected.

In addition, the model results indicated that current levels of molybdenum, selenium, and uranium are above the benchmark in muskrat at Island Lake; however, this is attributed to the effluent released to Island Lake during operations. Levels are expected to decline over time as the system recovers from operational releases. Similarly, exposure to selenium exceeded the benchmark in yellowlegs in Island Lake at current conditions, and exposures are expected to decline as the system recovers.

With respect to the nighthawk, exceedances of the selenium benchmark were observed for current exposures in Island Lake and the Island Lake fen as a result of past operations and are predicted to decrease in the future with recovery.

With respect to species protected under SARA, the results show that under conservative exposure assumptions, there are limited predicted effects on individuals from the Island Creek watershed from exposure to arsenic (nighthawk, olive-sided flycatcher, rusty blackbird, and horned grebe) and selenium (nighthawk, olive-sided flycatcher, rusty blackbird, and horned grebe). The assessment of SAR was completed under a number of additional conservative assumptions, including characterizing insectivore bird diets exclusively with emergent aquatic insects at specific receptor locations and characterizing the peregrine falcon diet to be predominantly fish rather than small birds. These highly conservative assumptions, and the demonstration by the model results that the exposures are localized and temporary, provide confidence that the risk is low.

**Findings**

The results from Orano's 2019 ERA show that there is currently some potential for effects to terrestrial animals that may use Island Lake and the fen exclusively as a result of past operations. However, CNSC staff consider the risk to be low and exposures are expected to continue to decrease as recovery continues.

There is a very low likelihood, but some possibility, for effects to mink, muskrat, yellowlegs, and nighthawk that may use the Snake Lake or Claude Lake area during the time of peak concentrations in the future; however, these exposures are expected to be localized and temporary.

Based on the review of the 2019 ERA and supporting documentation, and given the conservativeness applied in the assessment approach, CNSC staff have found that the potential for impacts to the terrestrial environment is low and terrestrial biota are expected to remain protected.

### 3.2.5 Human environment

An assessment of the human environment at the Cluff Lake Project 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 around the Cluff Lake Project area. In general, human receptors may be exposed to contaminants through 4 primary routes: dermal (skin), inhalation, incidental ingestion (soil) and ingestion of food and water. 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.

Orano's 2019 ERA [7] included a HHRA to assess the risk to humans from both radioactive and hazardous substances released from activities at the Cluff Lake Project. The base case scenario considered an adult, a child, and a toddler visiting the Cluff Lake Project and accessing both the Island Creek and Cluff Creek watershed exposure areas on a casual basis. These receptors were assumed to spend 6% (23 days) each year doing activities such as fishing, hunting, gathering berries, and camping in the immediate project area. In addition to ingestion of local foods, the receptors also drink water in the area. These assumptions are based on a 2005 workshop held on the decommissioning of the Cluff Lake Project with members of local indigenous communities to gain insights into the historic, current, and expected future traditional use of the land [7].

The assessment assumes that the traditional food obtained around the Cluff Lake Project during those 23 days is consumed for 6 months of the year, with the exception of moose, which is assumed to be consumed over the whole year. Consumption rates of traditional food are based on the Uranium City Country Foods Study, which is represenatative of a western northern Saskatchewan diet, and includes a high fish consumption diet [50]. These receptors were considered to be the most exposed individuals for potential radiological and hazardous contaminant exposures from the site. The human exposure assessment was considered for calendar year 2018 to calendar year 7000. The HHRA did not consider expsosure in air since the Cluff Lake Project has been decommissioned and there are no remaining COPC pathways from the project to air.

#### Exposure to radiological substances

The CNSC's *Radiation Protection Regulations* [32] prescribe radiation dose limits to protect workers and the public from exposure to radiation from licensed activities. Doses are either monitored by direct measurement or by estimation of the quantities and concentrations of any nuclear substance released as a result of the licensed activities. The annual effective dose limit for a member of the public is 1 mSv per year.

With respect to radiological exposures, the highest predicted annual mean incremental (that is, not including background) total effective radiological dose was to the toddler receptor, of 0.305 mSv/year in the year 4000. This value is well below the CNSC regulatory public dose limit of 1 mSv/yr. Maximum doses to the adult receptor peaked around 0.1 mSv/yr and around 0.2 mSv/yr to the child receptor over the model timeframe. For all 3 receptors, the primary dose contributers are from the consumption of fish, mallard, and exposure to groundshine, with other exposure pathways being considered negligible. The reason why the toddler recieves a higher dose than the child or adult is primarily due to its age and size. Although a toddler is assumed to consume roughly half the amount of fish than the adult does, the toddler is considerably smaller, resulting in a higher dose.

As a bounding scenario, Orano conducted an assessment of a family living at the site full-time. In this assessment, conservative assumptions were used, whereby it was assumed that the resident obtains 70% of their drinking water from Cluff Lake and 30% from a background lake, such as Carswell Lake, which is a well known fishing lake about 15km north of the Cluff Lake Project site. In this scenario, which assumes the family also eats locally hunted and gathered foods, the predicted annual mean incremental total effective radiological dose was also to the toddler receptor, which reached 0.306 mSv/year at year 4000, and is comparable to the base case scenario.

The reason the peak mean dose in the bounding scenario is comparable to the base case scenario is due to several factors. As discussed above, consumption of fish, mallard, and exposure to groundshine are the primary factors contributing to dose. All other exposure pathways considered continue to result in a neglibile dose contribution in comparison, including from the increase in the consumption of local water. In addition, the consumption rates of the full-time resident remained the same as that of the base case receptor (that is, consumption of local moose all year, and other local traditional food 6 months of the year, taking into account seasonal changes in availability of traditional foods). The 0.001 mSv/year difference is primarily attributed to the additional dose from groundshine, as a result of increased exposure to the project area.

**Exposure to hazardous substances**

With respect to chronic exposures to hazardous substances, the HHRA calculated daily intakes of arsenic, cadmium, cobalt, coppper, molybdenum, nickel, selenium, and uranium, assuming a diet of traditional food obtained at and near the Cluff Lake Project for 6 months of the year. These mean daily intakes were compared to appropriate Health Canada Toxicity Reference Values (TRVs) [51].

For the base case scenario, daily intake rates for the adult, child, and toddler receptors remained well below their applicable TRVs for cadmium, cobalt, copper, molybdenum, and nickel. Arsenic and selenium had marginal TRV exceedances. However, arsenic and selenium total intakes are dominated by the intake from supermarket foods in a general Canadian diet, and the contribution from the Cluff Lake Project was marginal. Uranium intakes from the Cluff Lake Project in the near term contribute more to the total intakes than supermarket food; however, total intakes remain below the TRV with the exception of the upper-bound intake for the toddler currently and the toddler and child in year 2400.

Considering that it is a conservative assessment, the results of the assessment do not indicate that changes to the health outcomes of people using the site and consuming country foods are expected, and it is safe to occasionally drink water from areas around the Cluff Lake Project, including Island Lake.

Similarily to the radiological HHRA, a bounding scenario was applied considering a family living at the site full-time. For non-radiological COPCs, the results were similar to the base case scenario (casual visitor), with the exception of uranium. Uranium daily intakes increased due to the increase in on-site drinking water. However, the mean daily intake rates remained below the TRV for all receptors and time periods. It should be noted that uranium concentrations are predicted to remain below the drinking water quality guideline in Cluff Lake throughout post-decommissioning.

**Findings**

The primary goal of decommissioning the Cluff Lake Project is to ensure that the site will be stable and safe for traditional land use both in the short term and the long term.

The results of the HHRA indicated that casual visitors (adult, child, and toddler) to the site who hunt, fish, and trap over a lifetime at the Cluff Lake Project, as well as consume the food over a 6-month period (considering availability during different seasons), will not experience adverse effects from exposure to radionuclides or non-radionuclides.

The results of the risk assessment indicate that the site is safe for people who may hunt, fish, drink water, and gather (such as tea, berries) from the site. CNSC staff conducted detailed technical evaluations of Orano’s 2019 ERA and confirmed that human health around the Cluff Lake Project will be protected in both the short term and the long term.

### 3.2.6 Cumulative effects

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

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).

# 4.0 CNSC Independent Environmental Monitoring Program

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

## 4.1 IEMP at the Cluff Lake Project

CNSC staff conducted IEMP sampling around the Cluff Lake Project in 2017. The sampling plan focused on radiological and hazardous contaminants with the consideration of Orano's EMP and the CNSC's regulatory knowledge of the site.

In 2017, CNSC staff collected the following samples in publicly accessible areas outside the perimeter of the Cluff Lake Project:

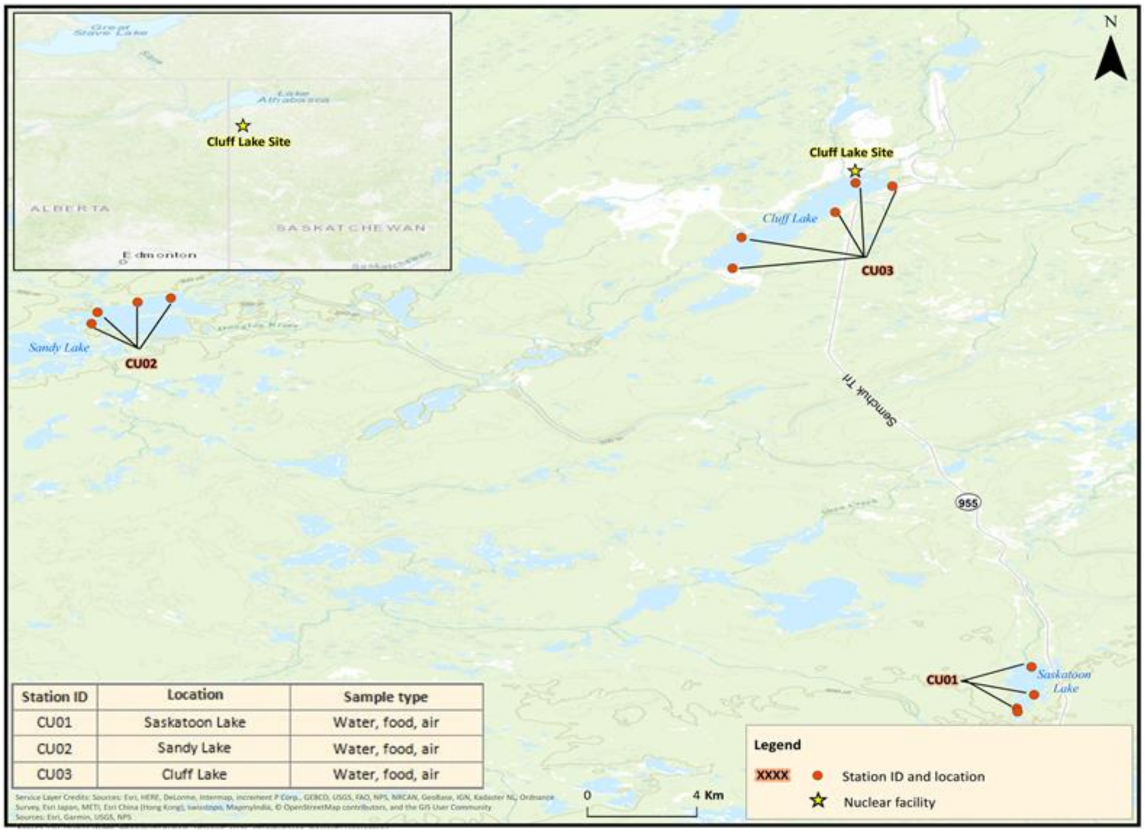
- radon in ambient air (3 locations, 3 samples per location)
- water (3 locations, 1 sample per location)
- fish (3 locations, 5 samples of a benthic fish (lake whitefish) and 5 samples of a pelagic fish (northern pike) per location)
- Labrador tea (3 locations, 5 samples per location)
- blueberries (3 locations, 5 samples 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 (TSS). Labrador tea and blueberry samples were also analyzed for moisture content to allow CNSC staff to convert the results from dry weight into wet weight to compare against the screening levels.

The radon samples were submitted to Radonova Inc. for analysis. Radonova Inc. is a company that is fully accredited with numerous global organizations to conduct radon measurements.

Figure 4.1 provides an overview of the sampling locations for the 2017 IEMP sampling campaign around the Cluff Lake Project. The IEMP results are published on the CNSC's IEMP web page for the Cluff Lake Project [52].

**Figure 4.1: Overview of the 2017 IEMP sampling locations [52]**



## 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 July 2017, in advance of the IEMP sampling campaigns at the Cluff Lake Project, notification emails were sent to the following Indigenous Nations and communities near the Cluff Lake Project: Athabasca Chipewyan First Nation, Clearwater River Dene Nation, Métis Nation of Saskatchewan Northern Region 2, Birch Narrows Dene Nation, and Buffalo River Dene Nation. Notification emails were also sent to certain individuals who had previously expressed interest in the Cluff Lake Project. CNSC staff invited the communities and individuals to send suggestions for species of interest, VCs, or potential sampling locations where traditional practices and activities may take place. CNSC staff did not receive any responses from the Indigenous Nations and communities or the individuals.

## 4.3 Summary of results

Most of the parameters in the samples measured during the 2017 IEMP sampling campaign at the Cluff Lake Project were below available guidelines and/or 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. 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 IEMP web page for the Cluff Lake Project [52].

The 2017 IEMP technical report for the Cluff Lake Project included CNSC staff's assessment of the chemistry results of a moose that was gathered near the Cluff Lake Project by an intervenor for the Commission meeting on the 2015 ROR for uranium mines and mills in Canada [53]. Samples of the moose were analyzed by a third-party laboratory, independent of the CNSC. CNSC staff's assessment of the chemistry results of the moose samples is provided in appendix A. CNSC staff found that the sampled moose was safe for consumption.

The CNSC's IEMP results from 2017 are consistent with the results submitted by Orano, supporting the CNSC's assessment that the licensee's EP program at the Cluff Lake Project is, and has been, effective. The results add to the body of evidence that the health and safety of persons and the environment in the vicinity of the Cluff Lake Project are protected.

# 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 Cluff Lake Project, 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 Cluff Lake Project. Disease rates of communities living near the Cluff Lake Project 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 Cluff Lake Project; 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 Cluff Lake Project, including studies conducted by the CNSC to assess the health effects of workplace radiation exposure among Saskatchewan uranium workers.

CNSC staff continue to review health studies and reports conducted by the community health authorities and conduct CNSC-based health studies to assess the protection of human health. CNSC staff review any new publications and data related to the health of populations living near nuclear facilities. For additional information on health studies related to nuclear facilities, visit the CNSC's web page on health studies [54].

## 5.1 Population and community health studies and reports

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

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

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

The PHU has published 2 Northern Saskatchewan Health Indicators reports, 1 in 2004 [55] and another 1 in 2011 [56], and updates and publishes health monitoring chapters on its Population Health Unit - Northern Saskatchewan web page [57]. In addition, older reports (from 1998) are 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)** [58]

## Community characteristics

Northern Saskatchewan is made up of the Keewatin Yatthé Health Region (KYHR), Mamawetan Churchill River Health Region, and 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% and 32% of its population is under 15 years of age, while only between 5% and 7% of residents are 65 years of age or older. Most people (85%) in northern Saskatchewan identify as Indigenous (approximately 68% as First Nation and 19% as Métis). 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

Smoking rates in northern Saskatchewan have remained high over the last number of years. The overall smoking rate in northern Saskatchewan for 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 social determinants of health (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 2009-2010 to 2013-2014, 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 [59].

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

Injuries are the leading cause of death in most age groups in the north, with intentional self-harm, motor vehicle traffic accidents, assault, and accidental poisonings being most common. In the older age groups, chronic disease becomes the leading cause 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 [60], the smoking rate in some northern Saskatchewan Indigenous Nations and communities is estimated to be approximately 4 times the provincial rate, at 79%. Therefore, the impact of tobacco use on cancer in northern Saskatchewan may be even greater than in the province as a whole due to a substantially higher smoking rate [61].

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 [62].

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

The NITHA is an Indigenous partnership organization between the Prince Albert Grand Council, Meadow Lake Tribal Council, Peter Ballantyne Cree Nation, and Lac La Ronge Indian Band. The NITHA provides and maintains health services and public health programs in 33 Indigenous Nations and communities in northern Saskatchewan. The 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. The 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 [63]. According to the latest health status report from 2017, the leading causes of death for the NITHA's partner communities from 2010 to 2015 were cancer (32%), heart diseases (16%), accidental deaths (15%), and diabetes (8%) [63]. Lung cancer was the most common cause of death from cancer, representing approximately 32% of all cancer deaths [64].

### 5.1.2 Saskatchewan health status reports (latest 2016)

The Province of Saskatchewan produces health status reports that 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 [65], the leading causes of mortality in Saskatchewan in 2009 were circulatory diseases, cancer, injuries, and respiratory disease. While the Province of Saskatchewan's website does not indicate when the latest report was published, the data used is older than 2011 (with most data ranging from 1995 to 2009).

A fact sheet on the prevalence of asthma, COPD, diabetes, ischemic heart disease (IHD), and heart failure in Saskatchewan from 2012 and 2013 [66] 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.

### 5.1.3 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 [67]. In partnership with 5 Indigenous communities across the province, the SCA collected information within these communities to ensure that they had access to appropriate cancer care programs and services. Working closely with communities was essential to this project, particularly in northern Saskatchewan, where engaging community members is important for proper communication on cancer prevention; for early detection; for cancer awareness, education, and surveillance; and for finding ways to support cancer patients and their families [68]. 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 [69] combines the 3 northernmost health authorities (namely Mamawetan Churchill River, Keewatin Yatthé, and Athabasca) into 1 region called "the North". This region of the province is unique because its population is small and much younger than in the rest of the province. The northern Saskatchewan Health Indicators reports use the data in the Cancer Control reports. Cancer is most common in people over age 50. In 2014, 90% of new cancer cases diagnosed were in people aged 50 and over, with 96% of cancer deaths occuring among those aged 50 and over. This age group is growing in Saskatchewan and continues to comprise an increasing proportion of Saskatchewan's population. Thus, as the northern Saskatchewan population ages, one can expect to see more cancer cases and deaths. This has important implications for planning cancer screening, diagnostic, and treatment services.

### 5.1.4 Saskatchewan First Nations 2018 Health Status Report [70]

Overall, many Saskatchewan Indigenous Nations and communities continue to experience health disparities related to the SDOH [70]. These SDOH affect a community's health and wellness, and contribute to the majority of health challenges faced by Saskatchewan Indigenous Nations and communities. Specifically, poverty, inadequate and overcrowded housing conditions, and food insecurity have contributed to the persistent burden of communicable and chronic diseases. Some of the highlights of this report are as follows:

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

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

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

- Approximately 41% of the people living in Saskatchewan Indigenous Nations and communities speak an Indigenous language; Cree (26%) and Dene (10%) were the most common languages spoken at home. Culture and language are an SDOH for Indigenous peoples in Canada, and revitalization of Indigenous peoples' culture and language is considered a significant aspect to improve their health status.
- In 2015, 37% of Indigenous households in Saskatchewan Indigenous Nations and communities were classified as food insecure; 27% of the households were moderately insecure and 10% were severely insecure.
- The percentage of severely overcrowded households in Saskatchewan Indigenous Nations and communities remained relatively high but unchanged between 2006 and 2016 (16.2% and 16.6%, respectively). This compares to approximately 1% for people with non-Indigenous identities. In addition, households in Saskatchewan Indigenous Nations and communities in 2016 were 7.6 times more likely to need major repairs compared to households in non-Indigenous communities (51.1% and 6.7%, respectively).
- Saskatchewan Indigenous peoples ages 25 to 54 years attained higher levels of education in 2016 compared to 2006. About 56% of people in Indigenous Nations and communities had a high school diploma or equivalency certificate or greater in 2016.
- Between 2006 and 2016, the median income for Indigenous peoples ages 25 to 54 years old in Saskatchewan Indigenous Nations and communities increased by 40.2% from $11,312 to $15,861, respectively. However, there is a large income gap between Indigenous Nations and communities and non-Indigenous populations (median income $50,253 in 2016) in Saskatchewan.
- In Saskatchewan Indigenous Nations and communities, the employment rates among Indigenous peoples ages 25 to 54 decreased between 2006 and 2016 from 45.2% to 37.7%. This compares to the decrease from 86.8% to 85.0% for non-Indigenous identity people for the same time period.

## 5.2 Health studies of uranium mine workers

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

The CNSC, Government of Saskatchewan, University of Saskatchewan, and industry stakeholders are currently working in partnership to conduct the new Canadian Uranium Workers Study (CANUWS) [71], 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 [72] [73] 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 [74] and Port Radium [75] mine sites from 1950–1980.

Part 1 of the SUMC Study makes the following conclusions:

- Most past uranium workers were male and, overall, uranium mining, milling, and processing workers were as healthy as the general Canadian male population.
- Lung cancer was the only disease that consistently showed significantly higher death and cancer incidence rates among uranium workers.
- Overall, the excess risk of lung cancer death and cancer incidence increased linearly with increasing radon exposure.
- There was no relationship between radon exposure and any disease, other than lung cancer.

Part 2 of the SUMC Study [76] determined whether it was scientifically possible to assess the number of excess lung cancers from the relatively low radon exposure in modern miners from 1975 onward. The type of risk assessed was the increased risk of lung cancer resulting from radon exposure. The study considered factors such as smoking and residential radon exposure as potential confounding factors of the relationship between lung cancer and radon.

Part 2 of the SUMC Study made the following conclusions:

- Present-day Saskatchewan uranium miners have radon exposures that are significantly lower than those of past miners because of dose limits, improved mining techniques, and other radiation protection practices.
- By the year 2030, about 24,000 workers will have spent time working at a uranium mine. During the period under study, 141 miners are expected to develop lung cancer, primarily from tobacco smoking. Only 1 additional miner could expect to get lung cancer from exposure to radon in the workplace.

- It is not feasible to investigate the risk of excess lung cancer in modern miners because exposures are so low. It is also practically impossible to correct for the effects of smoking and residential radon, factors that could greatly affect the study results.

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

### 5.2.2 The Canadian Uranium Workers Study [71]

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 [77]. 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 2022–2023; 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. In addition, annual study progress reports are communicated to interested parties, such as impacted workers and Indigenous Nations and communities.

## 5.3 Summary of health studies

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

The population and community health studies and reports indicate that the most common causes of death among the northern Saskatchewan population are cancer and heart disease, alongside injuries, 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 [77].

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 [78]. 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 [78] [79]. 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 [58] [60]. Furthermore, the proportion of Saskatchewan residents who reported daily or occasional smoking was significantly higher than that of Canadian residents [80]. In Canada, exposure to indoor radon is the second leading cause of lung cancer [81]. 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 [69].

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

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

# 6.0 Other environmental monitoring programs

In instances where monitoring programs are carried out by other levels or bodies of government, CNSC staff will review their findings as additional confirmation that the environment and the health and safety of persons around the facility in question are protected. A summary of these programs and their findings is provided below.

## 6.1 Eastern Athabasca Regional Monitoring Program

Due to community concerns related to cumulative impacts from multiple operations, the Eastern Athabasca Regional Monitoring Program (EARMP) was launched in 2011 with funding by the Government of Saskatchewan and industry (Cameco and Orano). The CNSC became a funding partner in 2017-2018. The following year, the EARMP was extended with the signing of a 5-year funding agreement (from 2018-2019 to 2022-2023) between the CNSC, the Government of Saskatchewan, and the uranium mine and mill industry. It should be noted that the EARMP does not include the Cluff Lake Project, as it falls outside of the EARMP's study area.

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. 4 cumulative assessment areas (one at each outlet of Wollaston Lake, Waterbury Lake, and Crackingstone Inlet on Lake Athabasca) and 3 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 [82].

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).

### 6.1.1 Findings

Although the Cluff Lake Project is not included in the EARMP study area, CNSC staff chose to include a summary of the EARMP in this EPR report given its importance to northern Saskatchewan and for informational purposes as comparison to operational mines and mills. 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, that fall within the EARMP study area. 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 [83].

### 6.1.2 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. 1 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.

# 7.0 Findings

This EPR report focused on items of Indigenous, public, and regulatory interest, including physical stressors and future predictions at the Cluff Lake Project. Based on CNSC staff's assessment and evaluation of Orano's documentation, including the 2019 ERA and supporting documentation, CNSC staff have found the following:

- The potential for impacts to human health and the environment from radiological exposures is considered negligible.
- The potential for impacts to human health and the majority of environmental receptors from non-radiological exposures is considered negligible.
- There is potential for some impacts in the current environment to selected aquatic and terrestrial species from exposure to certain metals. However, given that the impacts are localized and temporary, and given the conservativeness applied in the model and assessment approach, the likelihood of these impacts is low.

Orano has developed a robust LTMMP that will be followed by the Province of Saskatchewan to confirm the predictions in the 2019 ERA and ensure that the engineered covers are performing as expected. CNSC staff are satisfied that the implementation of the LTMMP will ensure the protection people and the environment in the long-term, and that the remaining residual risks can be adequately and confidently addressed under the Province of Saskatchewan’s ICP.

As part of CNSC staff’s review, a number of technical recommendations were made, including on the LTMMP. Orano has addressed all of the CNSC’s comments and recommendations, and has included the following recommendations in an update to the LTMMP:

- Include 4 additional surface water quality monitoring stations, 2 located at Claude Lake and 2 located in Cluff Lake, near the points of groundwater discharge.
- Geotechnical inspections of the TMA cover could inform the need to monitor radon using a tiered approach.
- Should ponding water continue to be observed as part of geotechnical inspections, localized depressions on the TMA should be filled and remedial grading completed.

Orano has committed to including these as a recommendation in the LTMMP for the Province of Saskatchewan to consider and has allocated funds in the revised LTMMP to conduct these monitoring and maintenance activities.

CNSC staff’s findings from this EPR report inform and support staff recommendations to the Commission in future licensing and regulatory decision making that pertain to the Cluff Lake Project. These findings are based on CNSC staff’s reviews of documents associated with Orano’s Cluff Lake Project, 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 to substantiate their findings. CNSC staff also conducted IEMP sampling around the Cluff Lake Project in 2017.

# Abbreviations

## Units

| | |
|---|---|
| Bq | becquerel |
| kg | kilogram |
| km | kilometer |
| L | litre |
| mg | milligram |
| mGy | milligray |
| mSv | millisievert |
| µg | microgram |

## Acronyms

| | |
|---|---|
| AECB | Atomic Energy Control Board |
| Amok | Amok Ltd. |
| 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* |
| CMD | Commission member document |
| CNSC | Canadian Nuclear Safety Commission |
| COGEMA | COGEMA Resources Inc. |
| COPC | contaminant of potential concern |
| COPD | chronic obstructive pulmonary disease |
| CSA | Canadian Standards Association |
| CSD | comprehensive study for decommissioning |
| CSR | comprehensive study report |
| CWRP | Claude Waste Rock Pile |
| DDP | detailed decommissioning plan |
| DJ | Dominique-Janine |
| DP | Dominique-Peter |
| DSQO | Decommissioning Sediment Quality Objectives |

| | |
|---|---|
| DSWQO | Decommissioning Surface Water Quality Objectives |
| DW | dry weight |
| EA | environmental assessment |
| EAP | Environmental Assessment Policy |
| EARMP | Eastern Athabasca Regional Monitoring Program |
| EARP | Environmental Assessment Review Process |
| EASR | environmental assessment and safety report |
| EcoRA | ecological risk assessment |
| EMP | environmental monitoring program |
| EMS | environmental management system |
| EP | environmental protection |
| EPP | environmental protection program |
| EPR | environmental protection review |
| ERA | environmental risk assessment |
| HHRA | human health risk assessment |
| IAA | *Impact Assessment Act of Canada* |
| ICP | Institutional Control Program |
| IEMP | Independent Environmental Monitoring Program |
| IMS | integrated management system |
| KYHR | Keewatin Yatthé Health Region |
| LCH | licence conditions handbook |
| LEL | lowest effect level |
| LOAEL | lowest observable adverse effect levels |
| LTMMP | long-term monitoring and maintenance plan |
| mSv | Millisievert |
| NITHA | Northern Inter-Tribal Health Authority Health |
| NOAEL | no observable adverse effect levels |
| NSCA | *Nuclear Safety and Control Act* |
| Orano | Orano Canada Inc. |
| PHU | Population Health Unit |
| ROR | regulatory oversight report |
| SARA | *Species at Risk Act* |
| SCA | Saskatchewan Cancer Agency |

| | |
|---|---|
| SEL | severe effects level |
| SSD | species sensitivity distribution |
| SUMC Study | Saskatchewan Uranium Miners' Cohort Study |
| SQG | sediment quality guidelines |
| TMA | tailings management area |
| TRV | toxicity reference values |
| TSS | total suspended solids |
| UML | uranium mill licence |
| VC | valued component |
| WQG | water quality guidelines |

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# Appendix A: CNSC staff's assessment of the moose gathered near the Cluff Lake Project

In December 2016, as an intervention for the CNSC's Regulatory Oversight Report for Uranium Mines and Mills and Historic and Decommissioned Sites in Canada: 2015, an intervenor presented the chemistry results of a moose that he shot near the Cluff Lake decommissioned site. The chemistry results were provided by SRC Analytical Laboratories. The following 2 paragraphs show CNSC staff's assessment of the chemistry results of the moose.

CNSC staff conclude that concentrations of contaminants in this specific moose, shown in table A.1, are typical of other moose sampled to date from various areas in the boreal forest in Saskatchewan and elsewhere in Saskatchewan. Relevant detailed information for interpretation of risks are found in a sampling program and risk assessment by Patricia Thomas et al. in a technical journal article in the May 2005 edition of Health Physics. This study analyzed tissues from 2 moose from Cluff Lake, 12 from other uranium mining sites in northern Saskatchewan, 20 moose and 4 cattle from southern Saskatchewan as a control. This study also made some comparisons from a previous study to a group of barren ground caribou that temporarily resided in the Wollaston Lake area.

As a relevant example of the consequences of a traditional diet consisting of considerable moose, the dose to a person consuming 100 grams per day of meat plus 1 liver and 1 kidney per year was found to be no higher than 0.31 mSv/year for the uranium mining area moose, versus 0.089 mSv/year for moose from southern Saskatchewan. For comparison, the dose from similar consumption rates for Wollaston caribou meat was 1.66 mSv/year because of polonium-210 and its association with lichens. As a result, CNSC staff conclude that the moose is safe to eat. It should be noted that as with any consumption of big game species in most parts of Canada, consideration should be given to limit the intake of kidney and liver due to the presence of some toxic metals such as cadmium, which highly accumulates in kidneys of large ungulates [84].

**Table A.1: Results of the moose tissue analysis provided by SRC Analytical Laboratories**

| Parameter | Units | Moose tissue type | | | |
|---|---|---|---|---|---|
| | | Kidney | Liver | Muscle | Bone |
| Lead-210 | Bq/g | <0.004 | 0.003 | <0.004 | 0.032 |
| Polonium-210 | Bq/g | 0.025 | 0.015 | 0.001 | 0.014 |
| Radium-226 | Bq/g | <0.0003 | <0.0002 | <0.0002 | 0.0126 |
| Thorium-230 | Bq/g | <0.0004 | <0.0003 | <0.0004 | <0.0051 |
| Aluminum | µg/g | <2.2 | 2.2 | 2.8 | 1.5 |
| Antimony | µg/g | <0.09 | <0.05 | <0.08 | <0.06 |
| Arsenic | µg/g | 0.09 | 0.03 | <0.04 | <0.03 |
| Barium | µg/g | 1.3 | 0.44 | 0.12 | 260 |
| Beryllium | µg/g | <0.009 | <0.005 | <0.008 | <0.013 |
| Boron | µg/g | <0.9 | <0.5 | <0.8 | 1.4 |
| Cadmium | µg/g | 36.2 | 1.5 | 0.03 | <0.01 |
| Chromium | µg/g | <0.4 | <0.3 | <0.4 | <0.3 |
| Cobalt | µg/g | 0.241 | 0.122 | 0.012 | 0.430 |
| Copper | µg/g | 11.2 | 115 | 4.3 | 0.21 |
| Iron | µg/g | 170 | 188 | 114 | 11 |
| Lead | µg/g | <0.009 | 0.011 | <0.008 | 0.051 |
| Manganese | µg/g | 3.5 | 3.0 | 0.47 | 0.92 |
| Molybdenum | µg/g | 0.45 | 1.14 | <0.08 | <0.06 |
| Nickel | µg/g | 0.13 | <0.03 | 0.08 | 0.05 |
| Selenium | µg/g | 1.61 | 1.52 | 0.43 | 0.04 |
| Silver | µg/g | <0.009 | 0.098 | <0.008 | <0.01 |
| Strontium | µg/g | 0.45 | 0.14 | 0.08 | 140 |
| Thallium | µg/g | <0.04 | <0.03 | <0.04 | <0.03 |
| Tin | µg/g | <0.04 | <0.03 | <0.04 | <0.03 |
| Titanium | µg/g | <0.04 | <0.03 | <0.04 | 0.11 |
| Uranium | µg/g | <0.004 | <0.003 | <0.004 | <0.01 |
| Vanadium | µg/g | <0.09 | <0.05 | <0.08 | <0.06 |
| Zinc | µg/g | 94 | 95 | 189 | 72 |

Results are reported on a dry weight basis.