Comprehensive Study Report
Cluff Lake Decommissioning Project

Canadian Nuclear Safety Commission

December, 2003

Comprehensive Study Report
Cluff Lake Decommissioning Project
Canadian Nuclear Safety Commission

December 2003

TABLE OF CONTENTS

Comprehensive Study Report
Cluff Lake Decommissioning Project
Canadian Nuclear Safety Commission

December 2003

APPENDIX A	Disposition of Comments Received on the Cluff Lake Comprehensive Study Technical Documents
APPENDIX B	CEAA EA Document Listing

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

1 INTRODUCTION

The Canadian Nuclear Safety Commission (CNSC) staff ensured the conduct of a comprehensive study and the preparation of this Comprehensive Study Report (CSR) for the proposed decommissioning of the Cluff Lake uranium mine facility. Cluff Lake is located in the Athabasca Basin of northern Saskatchewan, approximately 75 kilometers south of Lake Athabasca and 15 kilometers east of the provincial border with Alberta. The proponent of the decommissioning project is COGEMA Resources Inc. (COGEMA). COGEMA currently holds an operating licence for this facility.

The CSR was prepared for submission to the federal Minister of Environment (Minister) and the Canadian Environmental Assessment Agency (Agency) to fulfill the CNSC's obligations as the Responsible Authority (RA) for the Cluff Lake Decommissioning Project under the *Canadian Environmental Assessment Act* (CEAA). The CSR provides the assessment of the environmental effects of the proposed project.

The CSR was prepared to meet the CEAA's requirements, as defined in the Scope of Project and Assessment Report for the Cluff Lake Decommissioning Project, which was issued in October 1999 following consultation with expert federal authorities.

Pursuant to section 17 of CEAA, CNSC staff delegated, to COGEMA, public consultation and the preparation of the technical Environmental Assessment (EA) studies and its documentation (COGEMA 2000a, 2000b, 2000c). The results of the studies were summarized and submitted to the CNSC staff in the form of a draft CSR (COGEMA 2000d, 2000e, 2001, 2002a, 2002b). The document was reviewed by technical specialists from the CNSC, expert Federal Authorities (FAs), and various provincial agencies. Appendix A, attached, summarizes the responses to the comments received on the Cluff Lake Comprehensive Study technical documents. The initial CSR and the subsequent reviews and responses form the basis of this CSR.

The Comprehensive Study Report begins with a review of background information including a review of the history of operations and the previous environmental assessments. Section 3 proceeds with a review of applicability of CEAA to this project. Sections 4 and 5 provide a review of the project scope and the scope of this assessment.

Section 6 presents a description of the site and existing facilities which need to be decommissioned. The section also includes a detailed description of the existing environments and an assessment of the environmental effects resulting from past operations. Section 7 outlines the decommissioning objectives used in evaluating the various decommissioning alternatives and identifying the preferred approach. Section 8 identifies the various alternatives and the preferred decommissioning approach for each of the key project areas.

Section 9 assesses the environmental effects of the project and the mitigative measures for the preferred alternatives. Section 9 also describes the effect of the environment on the project and how these effects are mitigated. Finally, the section summarizes the cumulative environmental effects resulting from the past operations and the proposed decommissioning project.

Section 10 outlines the follow-up monitoring program and project contingencies. Section 11 summarizes the public and stakeholder consultations undertaken for the project. Section 12 provides the conclusions of the assessment while Section 13 lists the various references used throughout the document.

1.1 EA Conclusions

Since the primary objectives of this project are to mitigate any potential long term environmental effects resulting from past operations, the decommissioning activities, themselves, will have an overall positive effect on the environment. The environmental effects on completion of decommissioning are generally associated with existing environmental hazards resulting from past operations and the migration of contaminants from existing sources (e.g. tailings and waste rock piles) to groundwater and surface water.

The conclusion of this assessment is that the decommissioning of the Cluff Lake Project will not have any significant adverse effects. Some degradation in groundwater quality in the mining areas is anticipated, however, this will not adversely affect existing and potential reasonable use of the groundwater. Additional effects are also predicted for Island Lake where effluent discharges from the water treatment systems over the 23-year operating life have resulted in increased concentrations of key contaminants (e.g. uranium, molybdenum and selenium). These residual contaminants of concern (COC) may pose a risk to non-human biota. As noted in section 6, these potential adverse effects are not considered significant because they are moderate in magnitude, restricted to local populations in Island Lake and reversible, with substantial recovery in the first 50 to100 years.

While institutional controls will be necessary to limit development in the mining areas and the tailings storage areas, upon completion of decommissioning, the site will be suitable for traditional land uses consisting of casual access, with trapping, hunting and fishing as the primary source of site activities.

Uncertainties in model predictions including source terms and issues relating to the potential effects of COC on aquatic and terrestrial biota have been identified. Follow-up programs, as noted in section 10, will ensure that these uncertainties are adequately reviewed and assessed, and that contingencies can be implemented to ensure that decommissioning objectives, as specified in section 7, continue to be met and that no significant adverse environmental effects result from the project.

2 BACKGROUND

2.1 Project Overview

The Cluff Lake Project, owned and operated by COGEMA, is a uranium mine and mill complex located in the Athabasca Basin of northern Saskatchewan, approximately 75 kilometers south of Lake Athabasca and 15 kilometers east of the provincial border with Alberta (Figure 2.1). Uranium mining and milling operations commenced in 1980. By the time milling operations ceased in 2002, the Cluff Lake Project had produced more than 62 million pounds of uranium concentrate (U_3O_8).

The operational facilities at the Cluff Lake Project included open pit and underground mines, a mill, a tailings management area (TMA) with a two-stage liquid effluent treatment system, a residential camp area, and various other support and site infrastructure facilities. Figure 2.2 shows the location of all of the facilities at the Cluff Lake Project, while Figure 2.3 details the mining area and surrounding waterbodies, and Figure 2.4 focuses on the mill and TMA area as well as the surrounding waterbodies.

COGEMA announced in August 1998 that it would indefinitely suspend operations at the Cluff Lake Project as of December 31, 2000, due to depletion of economically viable ore reserves and the volume of tailings approaching the authorized capacity of the existing TMA. Additional ore reserves, with a higher grade than the historical average, in one of the underground mines, made it economically feasible to extend the operation into 2002. The higher grade also reduced the rate at which tailings were generated, thereby extending the period until the TMA reached its authorized capacity. Mining production extended through May of 2002, while milling all of the remaining ore was completed in December of 2002. COGEMA plans to decommission the Cluff Lake site now that production has ceased.

2.2 Need for the Project

Permanently closed mines must be decommissioned and the mine sites restored as a requirement under both federal and provincial regulations. A decommissioning licence for the entire project site will follow more than 20 years of environmental assessment and licensing approvals.

The purpose of the project is to conduct all necessary activities including the removal or stabilization of all constructed structures and the reclamation of disturbed areas such that the:

- environment is safe for non-human biota and human use;
- long-term adverse effects are minimized;
- reclaimed landscape is self-sustaining; and
- restrictions on future land use are minimized.

In addition, any restrictions on future land use should not prevent traditional land use including casual access with trapping, hunting and fishing as the primary site activities.

2.3 The Project Proponent

COGEMA, a Canadian company with headquarters in Saskatoon, is one of the world's largest producers of uranium. COGEMA is part of the Areva group of companies based in France.

Figure 2.1
Location of the Cluff Lake Project

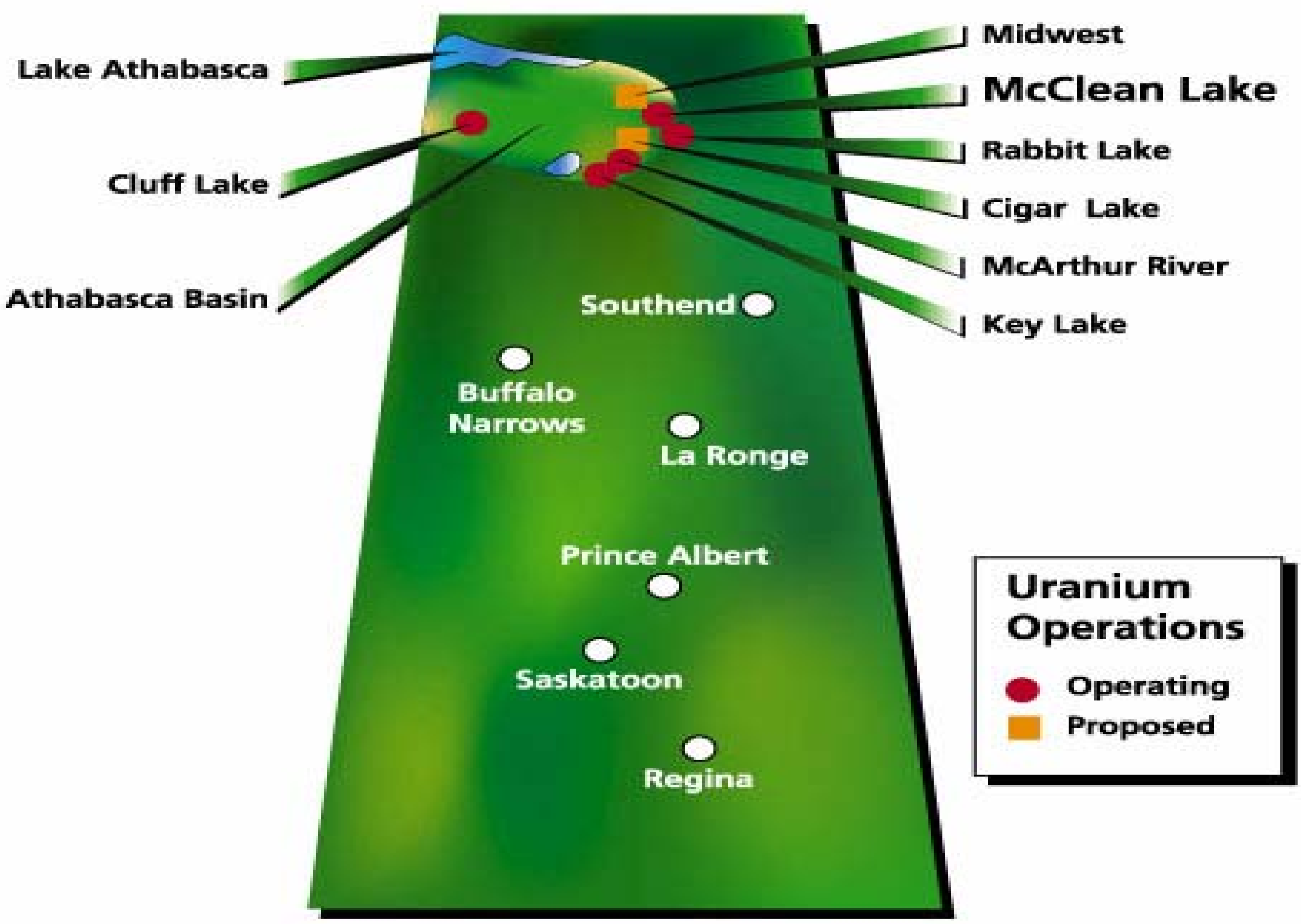


Figure 2.2

Figure 2.3

Figure 2.4

Areva is involved in all aspects of the nuclear fuel cycle, including uranium mining, conversion, enrichment, fuel fabrication, reactors and services, reprocessing and recycling, and all related engineering services.

In addition to the Cluff Lake Project, COGEMA Resources Inc. is operator and majority owner of the McClean Lake and Midwest uranium projects. The company is also a minority owner of the Key Lake, McArthur River, and Cigar Lake uranium projects. All of these projects are located in the Athabasca Basin of northern Saskatchewan.

2.4 Site History

2.4.1 Environmental Assessment History of the Cluff Lake Uranium Mines and Mill

Development in the Cluff Lake uranium mines and mill area began with exploration activities, which date back to the 1960's. Subsequent to the delineation of the "D" ore body, the initial environmental assessment for the development of a uranium mine and mill was submitted to the Department of Environment of Saskatchewan by, the proponent then, Amok Ltd. The Minister of Environment asked the Lieutenant-Governor-in-Council for a public inquiry to review the Report, and to "contemporaneously study what have been termed the 'broader implications' and 'global implications' of expanding the uranium industry in Saskatchewan" (Bayda 1978). The Board of Inquiry commonly referred to as the Bayda Commission reviewed the expansion of uranium mining in Northern Saskatchewan. The Atomic Energy Control Board (AECB) and other federal regulatory agencies, also participated actively in the Board of Inquiry.

The Board of Inquiry recommended that development of the Cluff Lake mine and mill proceed, and that the uranium industry be allowed to expand in northern Saskatchewan. The AECB also used the findings and recommendations of the Board of Inquiry to proceed through the AECB initial licensing phases.

The initial site development, termed Phase I, entailed the development of a mine and mill. Development began in 1979, and consisted of mining the D ore body, a high grade uranium deposit, and the construction of a mill to process the ore.

Phase II of Cluff Lake site development was also the subject of a provincial environmental assessment. The Phase II assessment encompassed uranium reserves identified as the Claude, N, N40, OP, and Dominique-Peter (DP) ore bodies (Cluff Mining 1982). Once again, provincial and federal agencies, including the AECB, provided input into this EA.

In 1985, Amok Ltd. advised the regulatory agencies that it had discovered a new ore body that was more appropriate for development than the N ore bodies. In late 1986, the regulatory agencies agreed that Amok Ltd. could proceed with the development of the Dominique-Janine (DJ) ore body. In 1989, regulatory approval was received to proceed with open pit mining of the Dominique-Janine ore body

(DJ). Further investigations to delineate the DJ ore body indicated uranium mineralization extended continuously southward toward the edge of Cluff Lake (Amok Ltd. 1992).

The proposed extension of the DJ mining operation to encompass the reserves identified south of the existing mine development became the subject of an environmental assessment by the Joint Federal-Provincial Panel on Uranium Mining Developments in Northern Saskatchewan. After public review, the Panel recommended the Dominique-Janine Extension be allowed to proceed, based on the conclusion that the project would provide substantial benefits in the form of employment, business opportunities and royalties, while causing only a small incremental increase to existing environmental and health risks [Joint Federal Provincial Panel (JFPP) 1993]. The preliminary decommissioning plans arising from this last EA have formed a firm basis for the currently proposed decommissioning options.

2.4.2 Site-Wide Development History

Cluff Lake Site Phase I development entailed the development of the D ore body open pit mine, and concurrent construction of the Mill Complex and associated facilities, and the Germaine Permanent Camp. Provincial Road 955 and air transport provided site access. The road and airport infrastructure had developed during the mineral exploration period. Road access to the site was controlled through a security facility; “South Gate”. During the Phase I construction period, construction activities were managed from “Cluff Centre”; an area previously established as an exploration camp for the coordination of exploration activities in the area.

The Mill Complex included the development of the mill and associated support facilities such as the warehouse, maintenance shop and administrative building, an above-ground tailings management facility, and the primary and secondary effluent treatment systems. Germaine Camp, which includes residential and recreational facilities, was also constructed during this period. Once construction was complete, the management infrastructure, originally located at Cluff Centre, was relocated to the Mill Complex administrative building. The Cluff Centre area remained as a support facility for ongoing exploration activities in the Cluff Lake area.

Phase II development entailed the development of the Claude, OP, DP and DJ orebodies, and the modification/expansion of the Mill Complex. The Claude open pit mine was the first to be developed in 1983. The development of the OP/DP underground mines began in 1984. These ore bodies were accessed from a common underground ramp. The initial development of the DJ ore body began in 1988 with the excavation of the DJ North (DJN) pit. Claude pit was mined from 1983 to 1989. The OP underground mine was mined from 1984 to 1985. The DP underground mine was mined from 1984 to 1999. The DJN pit was mined from 1989 to 1991.

The mine extension plan to encompass the additional DJ ore body reserves was the subject of the JFPP 1993. The expansion plan outlined in the Environmental Impact Statement (EIS) entailed the development of an open pit extending out into Cluff Lake. Subsequent to the Joint Federal-Provincial Review Panel recommendation to proceed, an evaluation of mining alternatives during licensing led to an alternative plan for the development of the remaining DJ ore body (COGEMA 1994). The alternative development plan involved a combination of open pit, and underground mining methods, and the testing of a Jet Bore mining method. The alternative development plan had the potential to reduce the environmental impacts associated with the original development proposal by minimizing encroachment into Cluff Lake.

The alternative mine plan resulted in the development of the DJX open pit, and DJ underground mines, and the DJ Pods Jet Bore test mining area. The development of the DJX open pit included the partial backfilling of the DJN pit with clean waste rock (<0.03% uranium). DJX open pit mining occurred from 1994 to 1997. The DJ underground mine was developed in 1994 and ore production continued until mining operations ceased in 2002. Jet Bore test mining was conducted near the shore of Cluff Lake. The development entailed the construction of a working surface platform, known as DJ Pods, which encroached into the near shore area of Cluff Lake. Test mining was conducted in 1996.

To facilitate milling of the lower grade ores generated from the Phase II mining activities, the mill underwent modification/expansion in 1983-84. A gold recovery plant was subsequently added to allow reprocessing of the Phase I leach tailings which had been stored onsite in concrete containers.

To accommodate the additional tailings generated from the Phase II mine developments, the TMA was sequentially expanded. Two additional dams were built (1982) and a dike was constructed to divide the tailings pond into a solids pond and a liquids pond area (1984). In 1986, a berm was constructed across the solids area to segregate the Phase I tailings.

To optimize the TMA area, internal berms were constructed in the 1990s to further segregate tailings and improve existing storage capacities. To divert clean surface water around the TMA, the North and South Diversion Ditches were constructed in 1999 and 2000.

2.5 Current and Proposed Licensing

For the Cluff Lake Project, COGEMA currently holds a CNSC operating licence (UMOL-MINEMILL-CLUFF.04/2004) under section 24 of the *Nuclear Safety and Control Act*, and a Saskatchewan Environment (SE) Approval to Operate Pollutant Control Facilities (Approval No. IO-176) under various sections of *The Mineral Industry Environmental Protection Regulations*, *The Environmental Management and Protection Act*, *The Hazardous Substances and Waste Dangerous Goods Regulations*, and the *Clean Air Act*. Both the CNSC licence and SE approval are valid until April 30, 2004. Under the terms of the CNSC licence, COGEMA is currently authorized to mine and mill ore and remediate the facilities at the project site subject to the condition that significant modifications require written consent from the CNSC. The SE approval authorizes COGEMA to operate a variety of pollutant control facilities associated with facility operations, sewage treatment, landfills, hazardous substances and dangerous goods waste storage, and potable water treatment systems.

As noted previously, COGEMA is proposing to decommission the Cluff Lake Project. Under the *Nuclear Safety and Control Act* and associated regulations, a uranium mining facility may only be decommissioned in accordance with a CNSC licence. The issuing of a decommissioning licence by the CNSC represents the exercise, by a federal authority, of a regulatory duty covered under the *Law List Regulations* of the *Canadian Environmental Assessment Act* (CEAA) and thus triggers the application of the CEAA. A comprehensive study is required for the project pursuant to the *Comprehensive Study List Regulations*, section 19(b).

3 APPLICATION OF THE *CANADIAN ENVIRONMENTAL ASSESSMENT ACT*

CNSC staff determined that, pursuant to paragraph 5(1)(d) of the CEAA, regulatory approval of the proposed decommissioning project would require that a prior environmental assessment of the project be completed pursuant to the provisions of the CEAA. Specifically, it was determined that the CNSC, as the RA for the project, would be required to ensure that a comprehensive study be conducted and that a CSR be prepared and submitted to the federal Minister of Environment (Minister) and the Canadian Environmental Assessment Agency (Agency), pursuant to section 21 of the CEAA.

CNSC staff subsequently established and managed an environmental assessment process for this purpose. Pursuant to section 12 of the CEAA and the *Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures and Requirements*, the following federal departments were identified as expert Federal Authorities for the purpose of providing expert assistance to the CNSC during the assessment: Environment Canada, Fisheries and Oceans Canada, Health Canada, and Natural Resources Canada. CNSC staff further established, in consultation with Saskatchewan Environment (SE), that an environmental assessment of the project was not required by the *Saskatchewan Environmental Assessment Act*. However, SE agreed to participate as a technical reviewer in the assessment process. SE will also review and approve the decommissioning plan prior under the provincial process. In preparation of this CSR, COGEMA and the CNSC considered the guidelines provided in the regulatory guide document G-219, *Decommissioning Planning for Licensed Activities.*

Pursuant to section 22 of CEAA, the Agency is expected to make this CSR available for public review and comment. Following a review of the CSR and any public comments received on it, the Minister is expected to make a decision on the environmental effects of the project pursuant to section 23 of the CEAA.

4 SCOPE OF PROJECT

The scope of the Cluff Lake Decommissioning Project was established pursuant to section 15 of the CEAA.

The scope of the Cluff Lake Decommissioning Project includes the closure, dismantling, waste management, site remediation, care and maintenance, and continued monitoring and surveillance of the following areas and facilities:

- Tailings Management Area (TMA) facilities
- Effluent treatment systems
- Sewage treatment systems
- Mill complex, including support facilities and storage areas
- Open-pit mines
- Underground mines and surface openings
- Access to, or facilities on or near, the shore of lakes or streams
- Waste-rock storage areas
- Waste-disposal areas
- Domestic landfill area
- Other landfill areas
- Pumps, pipelines, wells, piezometers, access casings
- Water handling, containment, or diversion systems
- Storage and handling facilities (tanks, warehouses, ponds, berms, pads, liners)
- Power plant
- Power lines
- Haul and access roads, including stream crossings
- Germaine Camp and associated facilities
- Cluff Centre
- Borrow areas
- Concrete batch plant and area
- Airstrip facilities
- Site access
- Exploration complex
- Ancillary facilities
- Associated environmentally impacted areas
- Lease area(s).

5 SCOPE OF ASSESSMENT

5.1 Environmental Assessment Factors

The scope of the environmental assessment, including the factors considered in the assessment, was established in accordance with section 16 of the CEAA. These factors include:

(i) the environmental effects of the project, including the environmental effects of malfunctions or accidents that may occur in connection with the project and any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out;
(ii) the significance of the effects referred to in paragraph (i);
(iii) comments from the public that are received in accordance with the CEAA and its regulations;
(iv) measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project;
(v) the purpose of the project;
(vi) alternative means of carrying out the project that are technically and economically feasible and the environmental effects of any such alternative means;
(vii) the need for, and the requirements of, any follow-up program in respect of the project; and
(viii) the capacity of renewable resources that are likely to be significantly affected by the project to meet the needs of the present and those of the future.

5.2 Environmental Assessment Methodology

An EA provides a systematic approach to identifying the environmental effects of proposed projects. By identifying adverse environmental effects before they occur, EAs allow decision-makers to modify plans so that the effects can be minimized or eliminated. Subsection 2(1) of the CEAA defines the environment as:

> *“The components of the Earth, and includes*
> *(a) land, water and air, including all layers of the atmosphere,*
> *(b) all organic and inorganic matter and living organisms, and*
> *(c) the interacting natural systems that include components referred to in paragraphs (a) and (b)*

and environmental effect, in respect of a project, is defined as:

> *(a) any change that the project may cause in the environment, including any effect of any such change on health and socio-economic conditions, on physical and cultural heritage, on the current use of lands and resources for traditional purposes by aboriginal persons, or on any structure, site or thing that is of historical, archaeological, paleontological or architectural significance, and*
> *(b) any change to the project that may be caused by the environment, whether any such change occurs within or outside Canada.”*

As discussed in section 2.0, the Cluff Lake Project must be decommissioned in accordance with a CNSC licence; in addition, the CEAA and regulations stipulate that a Comprehensive Study is required prior to the issuance of that licence. In compliance to these requirements, this EA has considered the potential effects on the environment of a number of activities and scenarios in the process of choosing a suitable means of carrying out the Cluff Lake decommissioning project.

Effects to environmental components – air quality, ambient radiological levels, hydrology, geology, terrestrial ecology, aquatic ecology, human health, and land use were considered. The current environmental conditions which have been affected by past operations were first assessed to establish a baseline by which the effects of the decommissioning project could be better assessed. The existing environment, including current effects, was used as the baseline for modeling the post-project water, sediment, and air quality.

Decommissioning objectives were established to facilitate the evaluation of alternative means of carrying out the decommissioning project. Predicted water, sediment, and air quality for the preferred alternatives were then used as inputs to evaluate potential effects on human health, non-human biota, and land use.

The decommissioning objectives are presented in section 7, and the project description including a review of alternatives is presented in section 8. The assessment of the environmental effects relative to the objectives and the potential effects to valued ecosystem components is presented in section 9. The assessment methodologies are detailed in subsection 5.2.3 below.

5.2.1 Study Boundaries – Spatial

5.2.1.1 Site Study Area

The site study area is defined as the previous mining and milling areas as depicted in Figure 2.2. This encompasses the current CNSC licensed area.

5.2.1.2 Local Study Area

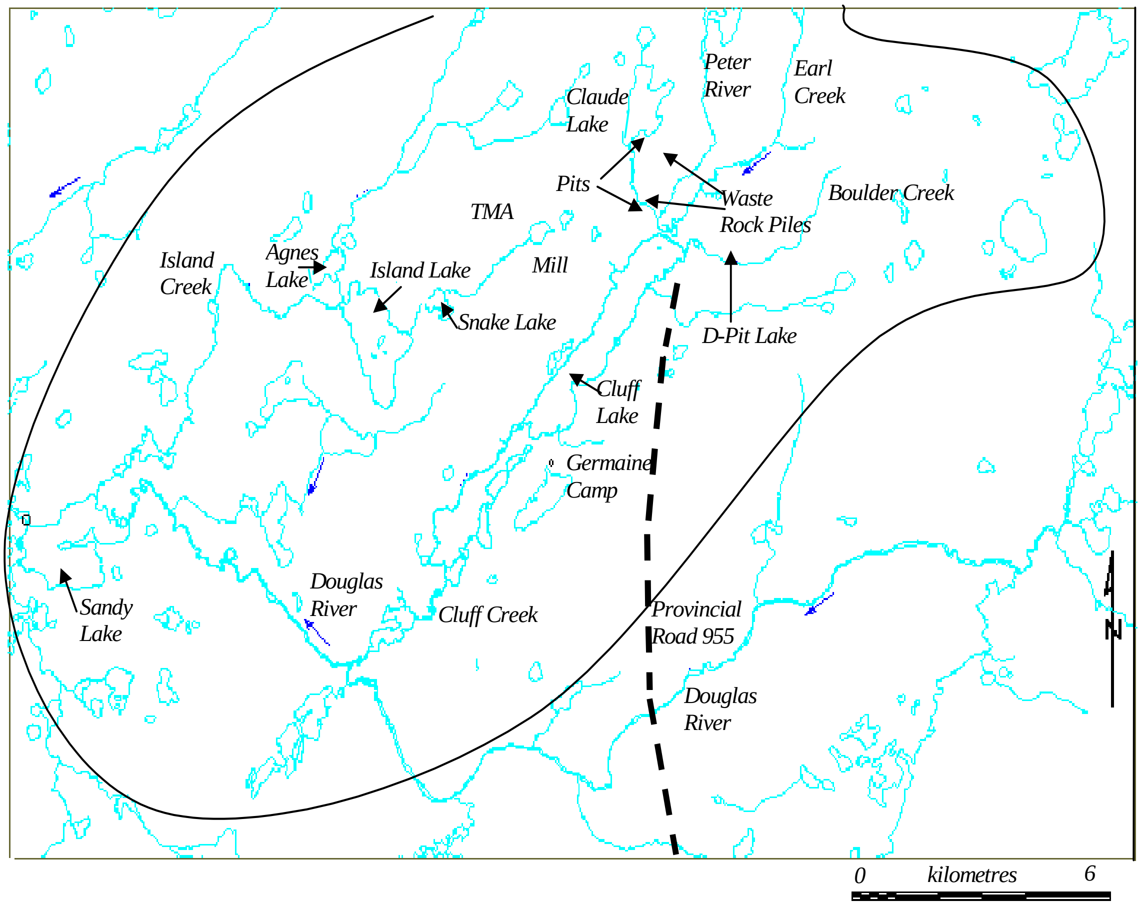
The area immediately surrounding the mill and mine sites, the Cluff Lake and Island Creek watersheds, Sandy Lake, and the confluence of these two drainage systems, combine to form the local study area (Figure 5.1). This area is the spatial extent of the potential effects of decommissioning and where potential effects of the activities on air, water, sediment, flora, and fauna have been analysed.

The portion of Provincial Road 955 that lies within the surface lease area was also included in the study area. As no other developments contribute to impacts on the drainage area, the area shown is sufficient to assess all potential effects.

5.2.1.3 Regional Study Area

The regional study area includes the west side communities adjacent to Provincial Road 955 extending from Green Lake to Cluff Lake, which are affected by the socio-economic implications of the project. Figure 5.2 identifies the location of each community. Each of these communities has some interaction with the mine, mostly in the form of business and employment linkages. Most of these communities are represented on the Environmental Quality Committee (EQC).

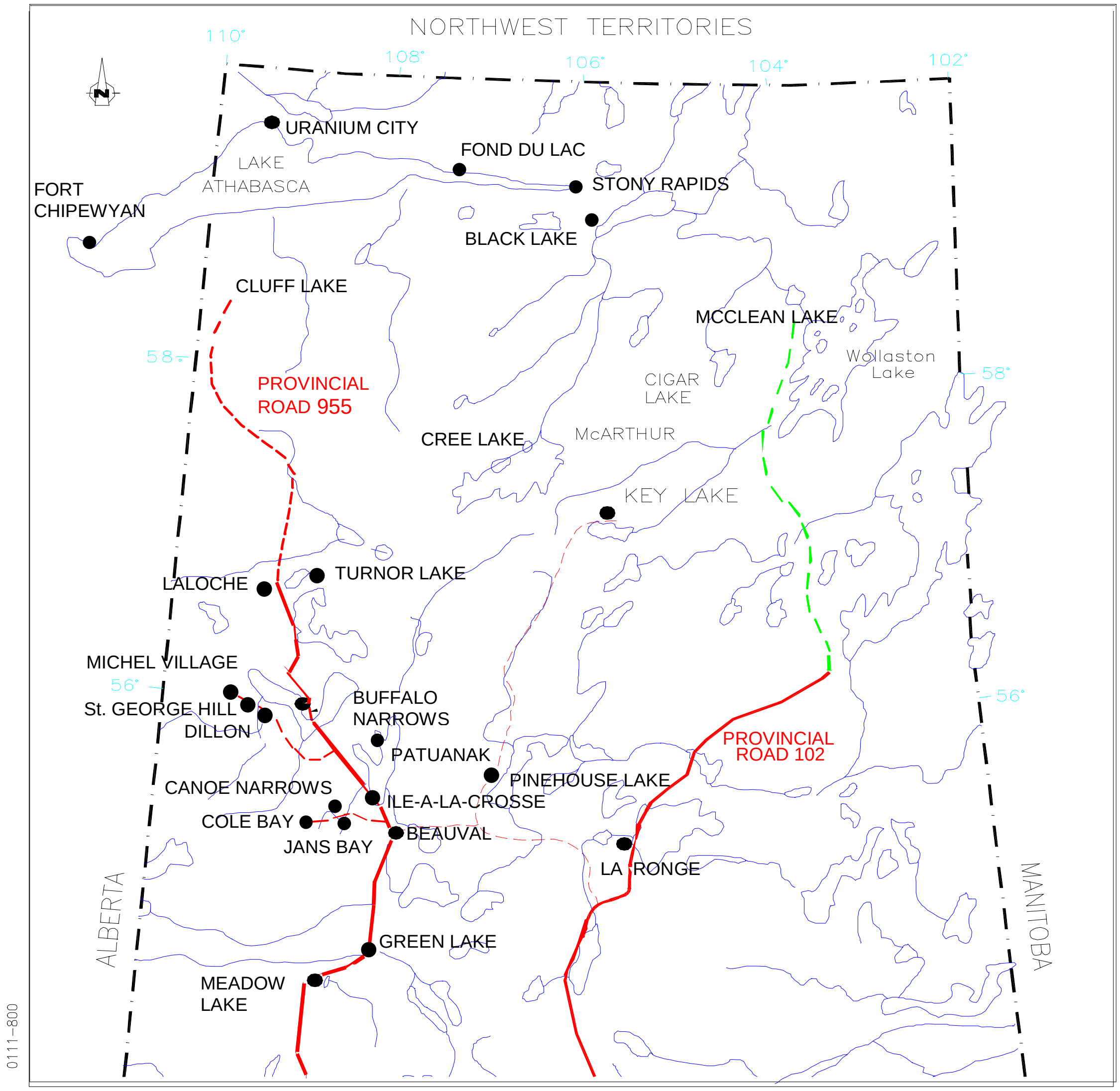
Figure 5.1
Local Study Area



West side communities, which have the closest ties with the mine site, are expected to be most directly affected (COGEMA, 2000e, Appendix E), and include:

Beauval
Buffalo Narrows
Canoe Narrows
Dillon
Green Lake
Ile-a-la-Crosse
Jans Bay
La Loche
Michel Village
Patuanak
St. George Hill
Turnor Lake

Figure 5.2
Location of Communities in Northern Saskatchewan



In addition, given their participation in local trapping activities, the Fort Chipewyan representatives have also been included in discussions about future land use.

5.2.2 Study Boundaries – Temporal

This study considers baseline information gathered at the start of the Cluff Lake Project in the 1970s, existing environmental conditions and effects resulting from past operations, and examines potential environmental effects (project and cumulative) over the long term. Modeling of impacts on groundwater and surface water quality extends hundreds and even thousands of years into the future to capture the influence of long contaminant flow paths and contaminant source depletion. Generally, the vast majority of the effects of the project will have dissipated within the first 200-300 years after decommissioning, and this time period is the focus of the most detailed analysis.

5.2.3 Assessment Process

The first step in assessing the environmental impacts of the Cluff Lake decommissioning project was to identify all contaminant sources on the project site and the existing environmental conditions and effects. These are discussed in section 6.

Next, the valued ecosystem components (VECs) and the decommissioning objectives were established.

Valued Ecosystem Components

A VEC can be defined as an environmental attribute or component perceived as important for social, cultural, economic or ecological reasons, and identified through consultation with affected people and through scientific opinion. The VECs used in this assessment are the components of the environment that are important to northern Saskatchewan's local residents, as well as those components of the environment that are ecologically significant.

The identification of VECs was developed through consultation. The local communities were involved in consultation on valued species during the Panel discussions in the early 1990s and up to recent workshops specific to the decommissioning project. The Environmental Quality Committee and the Athabasca Working Group have been active during the operational period and continue to provide a forum for ongoing consultation. The VECs used for this assessment are described in further detail in section 6.2.14.

Decommissioning Objectives

The objectives of the decommissioning activities to be conducted at Cluff Lake are to ensure that:

- the environment is safe for non-human biota and human use;
- long-term adverse effects are minimized;
- all constructed structures are removed or stabilized;
- the reclaimed landscape is self-sustaining; and
- restrictions on future land use are minimized.

Achievement of these qualitative decommissioning objectives was defined in relation to existing Provincial and Federal environmental quality objectives and where objectives are not available, site-specific benchmarks were derived (COGEMA 2000a; 2001, 2002a; 2002b). Any restrictions on land use are associated with land planning activities and should not limit traditional land use by aboriginal and non-aboriginal peoples. Section 7 provides a more complete description of the decommissioning objectives.

In consultation with Provincial and Federal Authorities, these objectives, and the appropriate locations and timeframes to achieve the objectives, were established through consideration of spatial-temporal relationships of the identified contaminant sources.

Review of Alternatives

The project site was then broken down into logical discrete areas and a variety of alternative methods (refer to section 8.1) of minimizing the environmental effects of potential contaminant sources were identified for each area.

Once the initial options were identified, contaminant source terms were quantified, and a modeling framework was used to identify potential environmental effects. Groundwater and surface water quality modeling was a primary focus of this level of assessment, as long-term water quality was identified as the environmental component most likely to be affected by the project. The main activities of decommissioning include: moving waste rock, flooding or infilling pits, salvaging, demolishing and disposing of buildings and equipment, covering or disposing of contaminated rocks or soils, and revegetation. Most of these activities are expected to have only a minor and short-term impact on air quality, ambient radiological levels, geology, and terrestrial ecology. However, such activities may have longer-term effects on groundwater and surface water quality, and therefore on aquatic ecology, terrestrial wildlife, human health, and potential land use.

Selection and Evaluation of Preferred Options

After the alternatives and mitigation measures were modeled and assessed against the decommissioning objectives, a preferred option was chosen for each area and more detailed modeling and risk assessment was performed to predict long-term environmental effects. The model results were used as inputs into a pathways analysis to evaluate potential long-term ecological effects and potential effects on human health. The modeling approach is described in greater detail in subsection 5.2.4.

Follow-up Monitoring Program

Finally, the results of all analyses, and in particular, the uncertainties in the modeling predictions, were used to identify the follow-up monitoring requirements for the project and to identify any contingency measures if the monitoring indicates that the decommissioning objectives may not be achieved, or there are potentially significant environmental effects.

5.2.4 Modeling Approach to Evaluate Post-Decommissioning Effects

As described above, the post-decommissioning environment was modeled based on a variety of alternative decommissioning options; the results used to evaluate the effects of those options. To evaluate potential effects, a number of models were employed.

Contaminant transport from the TMA was modeled with and without a soil cover:

- Infiltration through a cover was predicted with the use of a soil cover model. The model Soil Cover is described in COGEMA 2000b, Appendix C.
- Source term definitions for long term solute transport modeling were determined from historical monitoring data from the liquids pond, lower solids pond, Snake Lake, monitoring wells, as well as laboratory testing programs on tailings samples (COGEMA 2000b, Appendix B).
- Contaminant transport modeling was used to predict the movement of contaminants through groundwater and into the downstream surface water environment (i.e. Snake Lake). MODFLOW (COGEMA 2000b, Appendix C) was used, with input parameters for the preferred options, to develop a regional groundwater flow model. This was then used as the basis for evaluating solute transport.
- The results of the solute transport model were input to the pathways analysis to compare against decommissioning objectives and evaluate the risk to VECs.

Potential contaminant sources in the Cluff Lake mining areas include the open pits, underground mines, and waste rock piles. Decommissioning alternatives included flooding or infilling pits, moving or covering piles, and flooding or pumping underground mines. These options were modeled as follows:

- Infiltration through an engineered soil cover into the Claude Waste Rock pile was calculated (COGEMA 2000c, Section 4.2, Appendix D).
- Geochemical modeling, using PHREEQC, developed from an extensive program of collection and laboratory analyses of waste rock samples, and existing historical data, were used to determine the Claude waste rock source term (COGEMA 2000c, Section 3.4, Appendix B).
- Mass loadings of constituents from the D and DJ Pits were calculated. The approach used to calculate loadings was based on available data, and the nature of the source term environment. The source term of the flooded DJX Pit was estimated based on values observed when DJN Pit was flooded (COGEMA 2000c Section 3.2, Appendix B).
- The source term of flooded waste rock was then estimated from humidity cell/column test results (COGEMA 2000c, Section 3.4, Appendix B).
- The source term from flooded underground mines was estimated based on D-Pit results. (COGEMA 2000c Section 3.3, Appendix B).
- Contaminant transport through the groundwater from all sources to surface water receptors was modeled for the baseline and various options, and loading and peak surface water concentrations calculated. The numerical codes MODFLOW, MODPATH and ZONEBUDGET were used to simulate groundwater flow (MODFLOW), determine travel times and advective pathlines for solute transport to the nearest receptor (MODPATH) and to calculate water balance within specified regions of the numerical grid (ZONEBUDGET). See COGEMA 2000c, Sections 4.0 and 5.0, Appendix C, for descriptions of the models.
- The surface water system between each surface water receptor and Cluff Lake was considered, and the resulting peak concentration at each downstream location calculated. See COGEMA 2000c, Sections 6.0 to 10.0, Appendix C, for the results.

- A comprehensive review of the source terms and flow rates was undertaken and the scenarios for backfilling versus flooding of the DJX pit were remodeled using the revised parameters (COGEMA 2002a).
- The results of these models were used in the environmental pathways analysis and the ecological risk assessment.

Pathways Analysis (COGEMA 2000d; COGEMA 2001)

- Air, water and sediment quality were evaluated as described above. Air quality modeling of the operations and decommissioning scenarios provided estimates of radon levels. Source emissions and characteristics and meteorological data provided input to the U.S. EPA Industrial Source Complex (ISCST3) dispersion model.
- For the aquatic environment, both radioactive and non-radioactive contaminants, were predicted with the INTAKE model, which has the capability to model watersheds with variable characteristics. It was applied to both the Island Creek and Cluff Lake drainage basins.
- Surface water modeling was conducted for 10,000 years to assess the movement of major ions, radionuclides, and metals from the Cluff Lake site in the receiving environment. Estimated source terms and an estimate of discharge to Island Lake were combined in the INTAKE model, to provide an overall assessment of impacts. The INTAKE model is embedded in a probabilistic framework.

Ecological Risk Assessment (COGEMA 2000d)

- Predicted air, water, and sediment quality models were used as inputs to the ecological risk assessment. Model simulations were carried out for a period of 10,000 years covering the continuing operation, the decommissioning period, the post-closure monitoring period, and the post-decommissioning period. The model was run probabilistically.
- The model was run 100 times in yearly time steps to produce a distribution of predicted concentrations for each modeled contaminant. In total, predictions were made for sixteen individual contaminants including eight metals, four radionuclides, and four major water quality species.
- The approach to the ecological risk assessment is described in COGEMA 2000d, Sub-Appendix B3. The predicted concentrations in the water were compared to SSWQOs for aquatic life, and to site-specific objectives. The predicted sediment concentrations were compared to the *Canadian Sediment Quality Guidelines* (CSQG), and literature based benchmarks. The effects on biota was considered by looking at selected VEC receptors. Absorbed dose rates to selected species of animals and plants were estimated for beta and gamma exposures from radioactivity in the surrounding water and sediment, and for alpha, beta and gamma exposures from radioactivity incorporated into the plant or animal tissue. The potential effects were evaluated by obtaining EC_{20} values for quickly reproducing populations, and the No Observable Adverse Effects Level in the slower reproducing populations. Exposure estimates used conservative assumptions based on the behaviour of specific receptors.

Human Health Assessment

Hypothetical human receptors were selected for the purpose of estimating natural background doses and incremental radiation doses from the decommissioned site to members of potential critical groups living in the vicinity of the Cluff Lake site. The selection of critical groups took into account pre-mining land uses which include traditional trapping, hunting and fishing.

The human receptor model converts radionuclide intake by the human receptors from inhalation of air and ingestion of drinking water, vegetables, fruits and meat into a dose. The dose conversion factors used in the model are based on the values provided by the International Commission on Radiological Protection (ICRP 1996). The predictions of total annual incremental dose to each receptor were modeled over a 10,000 year time period, in one-year incremental time steps.

Cumulative Effects Assessment

Cumulative environmental effects are defined as:

> *"the effects on the environment, over a certain period of time and distance, resulting from effects of a project when combined with those of other past, existing, and imminent projects and activities."*

The only past and existing projects located in the same part of the province are the siting, construction and operation of the Cluff Lake mine. There are no permanent communities or industrial activities in the local study area and no major industrial activities in the regional study area that might impact on the project. Thus, the cumulative environmental effects are associated with current environmental effects resulting from operations and any additional effects resulting from the proposed decommissioning project.

5.2.5 Follow-up and Monitoring

In the context of the CEAA, follow-up programs are intended to verify the accuracy of the environmental assessment of projects, and to determine how effective mitigation measures have been in reducing adverse effects. Follow-up should assist in determining if and when mitigation measures require adjustment.

Follow-up programs may also be used to:

- address public concerns raised during the consultation process;
- verify the accuracy of the models used in the EA;
- verify the accuracy of the predictions of environmental effects and the conclusions made in the EA; and
- continue pertinent research to more fully understand the physical and natural processes involved.

The follow-up program for the Cluff Lake Decommissioning Project will be designed to address all of these considerations, including continued communication with the public and inclusion of stakeholders throughout the decommissioning process; methods of comparing actual change with predicted change; verification of the efficacy of the decommissioning activities; and the development and/or continuation of research programs to improve understanding of physical and natural systems. Section 10 discusses the follow-up program and provides the details of each of these components.

6 SITE DESCRIPTION AND EXISTING ENVIRONMENT

This section provides an overview of the current facilities and site components, the environmental effects resulting from operations and a review of the existing environmental conditions on the site prior to the final decommissioning phase. Section 6.1 provides a description of the current site facilities and components, and an overview of the environmental effects resulting from the approved operations in these areas. Section 6.2 describes the existing environment and provides more details on the environmental effects resulting from operations. Finally, section 6.3 summarizes the environmental effects and compares them to the predicted impacts from previous environmental assessments.

The proposed plans for final site remediation and decommissioning, to achieve the decommissioning objectives, are summarized in section 8.

6.1 Site Description: Site Components and Current Status

An outline of significant site components at Cluff Lake is provided in Figure 2.2. Additional details of the mine area are illustrated in Figure 2.3. Figure 2.4 provides additional details of the mill and TMA. A more extensive detailed description is provided elsewhere (COGEMA 2000a, 2000b and 2000c).

In general, surface sumps were located at all surface facilities where there existed a potential for surface radiological contamination from mining/milling activities. The sumps collect surface runoff which, prior to the cessation of milling operations, was directed to the mill for process use. All minewater pumped from the pits and underground mines was also collected and pumped to the mill for process use. All mill process water was then pumped to the TMA where it was treated in the primary (PTS) and secondary (STS) treatment systems prior to final discharge to the environment.

With the cessation of milling, any potentially contaminated waters are still being collected and treated, as required, prior to discharge to the environment.

6.1.1 The D Mine Area

Description

D-Pit was the first orebody mined at the Cluff Lake Project. Mining began in 1979 and was completed in 1981. The D ore body contained the highest grade uranium ore at Cluff Lake and significant gold reserves.

The D-Pit and the associated D waste rock pile comprise an area of approximately 3.0 ha. During the development of D-Pit, Boulder Creek was diverted past the open pit by means of an upstream dam and diversion flume. At the completion of mining, the D-Pit had a maximum depth of about 28 m. Post-mining clean-up and reclamation activities included the removal of surface facilities, breaching of the Boulder Creek diversion dam, and removal of the half culvert diversion flume. The Boulder Creek stream channel was re-established adjacent to the D-Pit.

During the 1983 spring thaw, an ice dam formed in Boulder Creek, causing the creek to overflow and flood D-Pit. In response, a dyke was constructed between Boulder Creek and the pit. The pit has remained flooded and isolated from Boulder Creek over the intervening years.

The D waste rock pile, located immediately adjacent to the pit, is comprised entirely of D-Pit waste, has an area of about 2.3 ha, and a volume of about 150,000 m^3. Subsequent to the removal of the D mine area surface facilities, the D waste rock pile and surrounding area disturbed during development were resloped and revegetated between 1983 and 1985. An investigation by COGEMA on the waste rock pile indicated that future acid generation potential is minimal and low metal leaching values would be anticipated (COGEMA 2001, Response to Regulatory Comments).

Operational Impacts

Operational effects in the D mine area include the flooded open pit, the disruption of the Boulder Creek channel from its original location, the development of a waste rock pile, and the surface disturbance associated with development.

D-Pit water quality has been monitored on a monthly basis since 1992 at the near-surface, 5 m, 10 m, 15 m and 20 m depth intervals (COGEMA, 2000c, Appendix E). The flooded water column exhibits a stable chemocline which fluctuates between 13 m and 17 m depths (maximum pit depth - 22 m). Water quality in the upper water column (above 10 m) has met SSWQO values for all monitored parameters with the exception of iron. D-Pit is fed only by surface runoff and groundwater and, during dry periods, iron content in the groundwater has raised iron levels in the upper water column as high as 7 mg/L. Uranium values have also been variable and these fluctuations have been correlated with heavy precipitation/runoff events which appear to flush uranium into the pit from the adjacent waste rock pile. In 1998, following two consecutive years of heavy precipitation, uranium concentrations near surface peaked at 0.45 mg/L. By 2002, concentrations had returned to pre-1992 concentrations of less than 0.1 mg/L.

Since flooding in 1983, the D-Pit has remained isolated from Boulder Creek. Recent monitoring in Boulder Creek indicates that D-Pit has had negligible influence on Boulder Creek water quality. Similarly, local groundwater monitoring has not detected any significant influence of D-Pit on groundwater quality. An evaluation of the differential between the equilibrium surface water elevation in the pit and the minimum elevation of the dyke separating D-Pit from Boulder Creek indicates that the probability of Boulder Creek connecting to D-Pit is low.

The revegetation efforts in reclamation areas are generally viewed as successful, with native plants colonizing the areas where agronomic species were initially used to stabilize disturbed surfaces.

6.1.2 Claude Mine Area

Description

The Claude mine area consists of the Claude open pit and associated infrastructure, and the Claude waste rock pile (Figure 6.1). Claude mine area infrastructure included a mine dry (shower facilities), administrative building, fueling station, ore pad, scanner building, Claude Pit water pumping system, runoff collection sump, and a maintenance shop. Of the original infrastructure, only the Claude maintenance shop, the runoff collection sumps and the Claude Pit water pumping system remain.

The other structures were removed in 2000 and 2001. As with the other operating areas on the site, the area is graded so as to direct potentially contaminated runoff to a collection sump which is routinely pumped out.

The Claude open pit was the largest open pit developed at the site and was mined from 1982 through to 1989. During exploration activities in the 1970s, the surface water elevation of Claude Lake was drawn down to aid delineation of the Claude ore reserves. To allow development of the open pit mine, two nested berms were extended into Claude Lake along its eastern shore (Figure 2.3).

The adjacent Claude pile, comprised of Claude Pit waste rock, was constructed between 1982 and 1989. At the time of waste rock placement, no attempt was made to segregate the Claude waste by chemical composition. The pile is approximately 30 m high, and covers an area of 29.5 ha. The pile contains roughly 8.59 Mt (million tonnes) of waste rock or approximately 4.91 Mm^3 (million cubic metres), assuming a dry density of 1750 kg/m^3.

The pile was developed by end dumping waste rock in a series of lifts. The pile contains well-developed traffic surfaces between lifts of placed material. It was contoured in 1993 to reduce the side slopes to a ratio of 2H:1V or less. In 2001 and 2002, resloping and compaction tests were conducted on a portion of the Claude waste rock pile to evaluate constructability and waste rock cover performance to support the final cover design.

Since 1989, Claude Pit has been approved and used as a repository for various wastes generated at the site including waste rock, scrap steel, contaminated materials, demolition wastes and non-combustibles such as plastic piping and tires. The waste rock placed in Claude Pit includes DJX waste rock, and special waste rock from the DJX Pit (material classified with a uranium concentration between ore and clean waste, 0.03% < uranium < 0.1%). DJ underground waste rock (<0.1% uranium) and OP/DP underground waste (surface stockpiled waste) were also deposited in the pit. A small amount of low grade ore (approximately 0.13% uranium) from DJX Pit was also disposed of within Claude Pit following a determination that this material was not economic to mill and that its placement in Claude Pit would have a negligible impact on the existing contaminant loadings in the pit.

Since the cessation of mining and the curtailment of pit dewatering, the Claude Pit has partially flooded as a result of surface water runoff and groundwater inflow. Intermittent pumping maintained the Claude Pit water elevation below the Claude Lake surface water elevation of 339 meters above sea level.

More recent activities include the continued placement of waste materials and the pumping of water from the pit to provide additional storage capacity in anticipation of future decommissioning activities. Water is pumped to the DJX Pit prior to final pumping and treatment at the mill and the TMA. The maintenance shop remains available for storage of equipment and possible use during decommissioning.

Operational Impacts

Operational effects in the Claude mine area include: the lowered surface water elevation in Claude Lake, the extension of two berms into the lake to facilitate mining of the ore body, surface disturbance associated with the development of the mine, infrastructure, the Claude waste rock pile, and dust and atmospheric emissions associated with mining activities and disturbed surfaces. Of most significance are the partially backfilled and flooded Claude Pit waste repository and the adjacent Claude waste rock pile, both of which contain appreciable inventories of radiological and non-radiological contaminants.

A comprehensive waste rock characterization program was initiated in 1999. The program determined the waste rock acid generation potential, and assessed physical stability characteristics of the waste rock regarding its suitability for cover construction (COGEMA 2000c). The physical tests indicated a relatively high rate of mechanical weathering and alteration within the waste rock. Geochemical testing concluded that acid generating potential existed in the Claude waste rock with low NP/AP ratios in over half of the Claude pile samples.

Groundwater quality monitoring immediately adjacent to the Claude waste rock pile has identified a shallow acidic plume (pH < 4), containing elevated levels of contaminants including nickel (> 10 mg/L) and uranium (> 100 mg/L), migrating to the south and east of the waste rock pile. The plume is concentrated along a small fringe around the perimeter of the waste rock pile. Further details can be found in the reference, COGEMA 2000c.

The Claude Pit water quality is impacted by the emplaced waste materials, runoff and possibly leachate from the adjacent Claude waste rock pile. In 2002, mean concentrations of sulphate, total dissolved solids (TDS), uranium, nickel, arsenic, and radium-226 (Ra^{226}) were 1126 mg/L, 1950 mg/L, 6.8 mg/L, 0.17 mg/L, 9.3 mg/L and 1.3 Bq/L, respectively. As previously noted, the pit water level remains below the adjacent lake surface elevation through occasional pumping and the water inventory continues to be reduced in preparation for the proposed final backfill. The maintenance of this differential water level promotes continuous groundwater movement into the pit and currently prevents contaminant transport to the surrounding environment.

6.1.3 OP/DP Mine Area

Description

The OP/DP mine area consisted of the OP/DP underground access ramp, the OP/DP waste rock pile and mine support facilities including a materials laydown area, maintenance shop, mine dry, scanner building, administrative building, sewage system, shotcrete plant, an ore pad, and a runoff collection sump (Figure 6.2). Stripping and construction of ramps for the DP mine began in 1983 and production commenced in 1985.

Underground Mining Method

The ore extraction or stoping method used in underground operations at Cluff Lake was known as undercut-and-fill mining. This method was used because of poor rock conditions in the ore zone, where the openings created during the mining activity cannot stay unsupported, even with the use of support systems such as roof-bolts, screening, and strapping. The method involved the placement, into the mining voids, of cemented, slurried backfill, which was pumped into place. The voids were either completely filled (known as tight fill), or partially filled (known as slab fill). After an initial opening was made along the strike of the orebody, with a nominal cross-section of 2.5 m wide x 3.5 m high, the void created was partially filled by a 1.5 m thick cemented-backfill slab. After a period of a few days, the cement slab was sufficiently strong to allow mining to proceed underneath the slab. The strength of the cemented backfill is in the order of 8 MPa. The slab not only gives strength to the stope walls, but also made it safe for miners to work underneath a more secure roof (known as the back). Tight fills were constructed when multiple ore panels were being mined on the same horizon. The combination of cemented fill, shotcreting (cement sprayed on to the rock), and mechanical ground support systems, produced long-term competent and stable rock conditions adjacent to and above the stoping area.

Current Status

With the cessation and closeout of underground mining in 1999, the OP/DP mine began flooding with groundwater inflow. As of August 2002, all underground workings were flooded. The OP/DP fresh air and exhaust raises were partially backfilled in 2000. In 2002, raise backfilling was completed and each raise capped with reinforced concrete. The underground access portal was backfilled approximately 176 m down the ramp and a concrete plug poured at the portal opening.

The top of the DP fresh air raise is at the lowest elevation of all the raises. There is a potential for contaminated minewater surfacing at this location, should the final water elevation be above the collar of the DP fresh air raise. It has, therefore, been equipped with a water collection system and pumping capabilities to allow for water handling and treatment should minewater surface at this location.

The OP/DP waste rock pile was relocated to Claude Pit between 1998 and 2000. Most mine support facilities were removed between 2000 and early 2003. The laydown area north of the OP/DP mine area was cleaned up and reclaimed in 2001.

At the time of writing, the fueling station and surface water runoff collection sump were the only remaining surface facilities. The removal of these redundant facilities is included in existing approved operational plans.

Operational Impacts

Operational effects associated with the OP/DP area include surface disturbance from the construction of surface facilities including all facilities near the mine decline, a number of ventilation raises located at various locations on the property, the materials and equipment laydown area, and the footprint from the former OP/DP waste rock pile. Dust and atmospheric emissions associated with mining activities have resulted in small localized impacts. The flooded underground workings represent a source for groundwater contamination and potentially surface water contamination.

A sewage system for grey water from the mine maintenance and dry has released water through a set of tiles immediately adjacent to the mine. The fueling station is a potential source of soil and groundwater contamination which will be verified and mitigated as required when the fueling station is removed.

The mine is currently flooded. The water quality in the mine currently exhibits elevated levels of key contaminants with uranium being the element of most concern with concentrations of about 1.2 mg/L. Pumping capabilities are currently maintained to provide short-term mitigation if minewater surfaces at the DP Fresh Air Raise.

6.1.4 DJ Mine Area

Description

The DJ mine area consists of the DJN and DJX open pits, the DJ underground mine access ramp, the DJ overburden pile, the DJN waste rock pile, the DJ Pods, and the associated infrastructure including the DJ ore pad and support facilities (Figure 6.3).

Pits

The DJN and DJX open pits are located south of the Claude mine area and adjacent to the north end of Cluff Lake. They are two adjacent pits; the DJN Pit is the original pit that came into production in 1989 and continued through to 1991. Mining of the DJX Pit occurred from 1994 through to 1997.

To allow development of the initial DJN Pit, it was necessary to divert Claude Creek, which originally reported to Cluff Lake, around the pit and into the nearby Peter River. The creek has intermittent flow, which is more prevalent during spring runoff and after major precipitation events. The creek is not deemed to be fish bearing due to the intermittent flow and the shallow water depth. The embankments are stable and well vegetated as a result of natural encroachment by native species.

Overburden was stripped from the mining area prior to pit development. DJN overburden was stored with the DJN waste rock while DJX overburden was stockpiled to the west of the pit as shown in Figure 6.3. Post excavation, the DJN Pit was allowed to partially flood. The DJN Pit was subsequently drained and used as a waste rock repository for clean waste rock (< 0.03% uranium) from the DJX Pit. Other DJX waste rock (0.03% < uranium < 0.1%) was hauled and placed in Claude Pit.

During underground mining, DJX Pit was routinely pumped to keep the water elevations very low and eliminate any potential for flooding of the underground workings. In more recent years, the pit was used as a temporary sump for underground minewater which was later used in the mill as process water. Since the cessation of mining, the DJX Pit has begun to flood with groundwater and runoff inflows. It is currently being used to store minewater from Claude Pit dewatering prior to pumping and treatment at the mill and the TMA.

DJN Pile

The DJN waste rock pile was developed by end dumping waste rock in a series of lifts. As a result, the waste rock pile contains well-developed traffic surfaces between the lifts of placed material. Some special waste (0.03% < uranium < 0.1%) was segregated within the pile and encapsulated by clean waste. The DJN waste rock pile is up to 16 m high and covers an area of 14.1 ha.. It contains roughly 1.846 Mt of waste rock. The estimated volume of the waste rock is approximately 1.055 Mm^3 assuming a dry density of 1750 kg/m^3.

DJ Underground Mine

The DJ underground mine was developed in 1994. It operated until May of 2002, at which time the mine began to flood. Mine flooding was initially augmented with water pumped from the DJX Pit. In 2002, the fresh air and exhaust raises and the underground access ramp were backfilled and capped with reinforced concrete. In addition, several support buildings and the DJ ore pad were removed. The water handling infrastructure and the fueling station remain as support facilities for the decommissioning project.

DJ Pods

The DJ Pods were developed to test a jet boring type mining technology. The pod platform was constructed on the inside and adjacent to the northwest shore area of Cluff Lake (Figure 2.3). The facility included a freeze plant, an ore storage pad, a series of sumps located adjacent to DJX Pit, and a series of drill holes into the underlying bedrock to allow for ground freezing and ore removal by jet boring. The mining method was tested in 1996. The clean-up and revegetation of the area was undertaken in 2000 with the removal of the freeze plant, cleaning and covering of the ore pad, removal of sumps, and sealing and covering of the drill holes. The area was scanned for radiological contamination and revegetated with native shrubs and trees.

The shoreline disruption is the subject of a habitat compensation agreement between the proponent and Fisheries and Oceans Canada. Habitat compensation has consisted of enhancement to the shoreline and construction of shallow ponds to encourage reproduction by native fish.

Operational Impacts

Operational effects associated with the DJ mine area include the Claude Creek diversion, the encroachment of the DJ pods into the near shore area of Cluff Lake, and the surface disturbance associated with the DJN/DJX Pits, the DJ underground and supporting infrastructure, one instance of surface subsidence, the DJN waste rock pile, and dust and atmospheric emissions associated with mining activities and disturbed surfaces.

DJ Underground Mine

There has been one surface subsidence incident attributable to mining activities that occurred in the form of a 10 m diameter and 5 m deep sink-hole on February 28, 1999 in the sub-outcrop area of the DJ underground mine between the DJX Pit and Cluff Lake.

The reason for the formation of the sink-hole is believed to be due to the collapse of mineralized support pillars in the mined-out ore zone immediately below the surface pillar. The pillars were composed of incompetent rock which were weakened by surrounding mining activities. The collapse of one pillar into the partially filled stope void, weakened another pillar above, thus creating a domino effect, which eventually reached surface.

The problem was rectified by pouring massive amounts of cemented backfill into, and around, the stoping block and constructing bulkheads in the openings of the adjacent stope. This effectively filled and sealed off the collapsed area and reduced the potential for surface water inflow.

The underground mine is currently in the process of flooding and final water elevations have not yet been established. Minewater quality exhibits similar properties to those found in the flooded OP/DP mine with the exception of arsenic which is more prevalent in DJ minewater (170 µg/L in DJ vs. 5 µg/L in DP). The DJ exhaust raise is a potential source of near-surface contaminated minewater, however, its proximity to the DJX Pit and the local topography is such that any minewater which might surface at the DJ exhaust raise would immediately report to the isolated pit.

DJN/DJX Pits and DJN Pile

The dewatering of the DJX Pit and the operation of the surface collection sump has contained contaminated waters preventing release of contaminated surface or groundwater to the neighboring environment. DJX Pit water quality is affected by the addition of minewater from the DJ underground mine and more recently from Claude Pit. Prior to the addition of these waters, DJX Pit waters contained appreciably lower concentrations of uranium (mean of 0.7 mg/L) in 1999 when compared to Claude Pit water quality (mean of 6.6. mg/L in 1999). Nickel concentrations, however, were appreciably higher (mean of 0.38 in 1999) when compared to Claude Pit water quality (mean of 0.04 mg/L in 1999). Current water quality is now reflective of Claude Pit water as a result of recent additions to the pit.

A comprehensive waste rock characterization test program was conducted on the DJN waste rock pile and the DJX waste material placed in the backfilled DJN Pit to determine acid generation potential and physical stability with regard to suitability for cover construction. The waste rock in the DJN Pit has demonstrated an elevated potential for acid generation, however, the inventory of leachable materials remains low. Further details are available in COGEMA 2000c. Any contaminated water released from the pile is contained within the DJN and the DJX Pits.

DJN pile contains more elevated concentrations of contaminant, than the DJX waste rock but lower acid generating potential. Monitoring results indicate the groundwater contains elevated levels of some contaminants, but at concentrations much lower than those found near the Claude waste rock pile (COGEMA 2000c).

6.1.5 The Mill Complex and Support Facilities

Description

The Mill Complex consists of the mill and associated offices, the powerhouse, warehouse, heavy duty shop, and associated support buildings and site infrastructure (Figure 6.4).

The mill, designed with a series of concrete sumps to provide secondary containment, went through two main phases of operation. Phase I mill operations, from 1980 to 1983, consisted of milling of ore from the 'D’ ore body. A gravimetric separation process was used to produce a high grade concentrate (average 29.3% U), which was then processed through grinding and acid leaching. The leach tails were stored in concrete cylindrical vaults. Neutralized tailings from processing of the leach filtrate were transferred to the TMA. The gravimetric tails (1 to 3% U) generated during Phase I were subsequently reprocessed in 1983 to 1984 through the Phase II mill which had been modified/expanded to accommodate the lower grade ores from the Claude, OP, and DP orebodies. In 1985 to 1986, a gold recovery plant was added to the Mill Complex. This allowed reprocessing the approximately 6500 tonnes of Phase I leach tails to recover approximately 58 g/t gold, and, by subsequently combining the reprocessed tailings with low grade ore leach feed in the mill, the additional recovery of 0.3% to 1% residual uranium from the Phase I tailings. The circuit configuration of the Phase II mill, consisting of primary and secondary crushing, grinding, acid leaching, counter-current decantation, solvent extraction, and yellowcake precipitation and drying, was maintained until cessation of milling in December 2002. The milling operation for Phase II is briefly described below.

Milling Operation – Phase II

Ore was delivered from the mine in 50- tonne trucks to an ore pad located near the crushing building. Ore was fed to a stationary grizzly to initially break down the ore. Using a number of conveyor belts, the ore was transported to a series of crushers and grinding mills to reduce the ore to less than 0.5 mm diameter, producing 58% solids slurry.

The solids slurry was processed through a series of tanks, where sulfuric acid, sodium chlorate, and steam were used to extract the uranium from the solids slurry. The average leaching efficiency was 98.5%.

The uranium-bearing solution from the counter-current decantation (CCD) circuit was directed to the solvent extraction (SX) plant for purification. In the extraction step, the dissolved uranium was transferred from the feed solution into the organic phase. Next, the stripping step recovered the uranium into a sodium chloride aqueous phase after which the barren organic was recycled to the extraction cells.

The organic was regularly scrubbed by a sodium carbonate solution in a regeneration cell to remove trace impurities. The average efficiency of the SX circuit was 99.9%.

The high-grade “pregnant” strip solution from SX was advanced to the next stage where magnesia slurry was added to precipitate magnesium diuranate. The yellow cake precipitate was thickened in a series of precipitation tanks and forwarded to a belt filter for water extraction. The resulting filter cake was washed with ammonium sulfate solution to remove impurities, and then fed to a dryer maintained at 200°C. The dried yellow cake was roll-crushed and packed into 220 litre steel drums for shipment to customers.

The solids underflow from CCD was treated with lime to raise the pH. Barium chloride was then added to precipitate out most of the radium (Ra^{226}). Finally, the slurry passed through a “high-density” thickener to increase the density to over 50% solids by weight. The thickened tailings were then pumped to the TMA for final disposal while the raffinate was pumped to the TMA for further treatment in the PTS and STS prior to discharge to the environment.

The mill exhaust systems, in particular, those associated with crushing, grinding, and yellowcake drying and packaging circuits were equipped with wet scrubbers to reduce dust emissions.

From 1983 to 2002, the mill processed approximately 3 Mt of ore at an average grade of 0.6% U generating nearly 2.4 Mm^3 of solid tailings. Over recent years, roughly 1.2 Mm^3/yr of process water was used in the mill. At least 50% of this volume was comprised of mine dewatering water, which was temporarily stored in a lined minewater holding pond and the powerhouse cooling water. Freshwater makeup for the Mill Complex was provided from Cluff Lake via the Cluff Lake Pumphouse.

In recent years, the Mill Complex infrastructure and support facilities that were no longer required for continued operation of the mill were removed as part of the approved operating plans. In 1999, clean-up of the fuel storage area, north of the mill, was completed. In 2000, the gold plant and ore storage bins were demolished and the minewater holding pond removed. In 2002, management, administration, and support staff were transferred to offices in the mill building and the main administration building taken out of service and demolished.

Mill Mothballing

In January 2003, activities to mothball the mill began with the remaining qualified staff. The objectives were to minimize potential environment, health and safety hazards from chemical reagents and potential radioactive sources: and to prepare the various mill circuits for future demolition which can be undertaken subject to regulatory review and approval.

Mothballing activities generally included the removal, cleaning, and disposal of tanks representing a potentially significant radiological hazard. The radioactive material contained in these tanks was disposed of in the TMA; the tanks were then disposed of in the Claude Pit. Tanks remaining in the mill were cleaned to remove the bulk of the radiological contamination and left in place. Equipment was shutdown, gearboxes and reservoirs drained of oil, and cleaned in situ or removed for disposal.

The dust collection and ventilation systems were cleaned and walls, support beams and trusses were washed down. All floors were washed and water systems drained. All sumps were then pumped out and cleaned.

The furnaces were shut down and the main propane lines turned off at the valve for each furnace. The overhead cranes were parked at the service platforms. The Motor Control Centers (MCC) were disabled and the power locked out to prevent inadvertent operation. The control rooms were cleaned with key records archived for future reference. Building entrances and openings were secured to prevent inadvertent access.

Used oil was shipped off-site for recycling. Sealed source Cs^{137} density gauges were removed from various lines and placed in secured storage while awaiting recycling or off-site disposal at a licensed facility. Stored items, including oxygen-acetylene, welding rods, welders, paint, report sheets, bolts, grease, shovels, slings, ladders, and wheelbarrows were removed.

Residual contamination exists in tanks and equipment left in situ, in all of the concrete floors, metal clad walls, and all wood floors of the galley ways. With the exception of the leach tanks and a few pieces of equipment, the major sources of gamma radiation and radon gas have been removed. Water lines have been drained, but are available to provide service when required. The roof and wall fans remain ready for restart if required.

The tailings neutralization and lime addition circuits within the former mill were retained and are currently used for the treatment of contaminated minewater pumped from the Claude and DJX Pits. The warehouse continues to be used for receiving and shipping of all materials and equipment. The heavy-duty shop is used for maintenance and upkeep of all vehicles and most heavy equipment on site. The Powerhouse, the primary location of power generation at site, continues to supply primary power for the site utilizing a combination of diesel generators. A back-up power supply consisting of diesel generators remains available for TMA operations (i.e. PTS and/or STS), and Germaine Camp. A series of outbuildings, which may be utilized in support of the decommissioning project, have also been maintained.

Operational Impacts

Operational effects associated with the development and operation of the Mill Complex and associated infrastructure include the surface disturbance associated with site and infrastructure development, aerial emissions associated with stockpiling and milling of ore, consumption of significant quantities of mill reagents. The generation of tailings and contaminated water, which can also be attributed to milling operations, are the subject of the next section.

Airborne emissions from the exhaust vents from the ore crushing and grinding circuits, and from the yellowcake packaging and drying stacks have resulted in localized impacts in the immediate area of the Mill Complex. There is appreciable surface contamination in the immediate area of the mill as a result of these airborne emissions and more significantly, as result of the spread of contamination from ore haulage and the operation of surface equipment on and near the ore pad.

In its current mothballed state, some areas of the mill (mainly the leaching circuit) remain as a source of radon gas, radon progeny, long-lived radioactive dust, and gamma radiation. These do not pose an immediate hazard as the mill is secured and access is controlled. The management of these residual radiological hazards will be important when demolishing the mill.

There may be soil and groundwater contamination from hydrocarbons near fuel handling facilities and the heavy duty shop. Established provincial and federal guidelines are in place to ensure effective clean-up during final reclamation.

The most significant operational impacts are associated with the large quantities of tailings and contaminated water which were generated as a result of milling operations. These are discussed in more detail in the section that follows.

6.1.6 The Tailings Management Area and Effluent Treatment Systems

Description

During the operational life of the Cluff Lake mines and mill, all tailings and contaminated water generated at the site were transferred to the TMA for disposal and treatment. The TMA is located southwest of the mill and upstream of Snake Lake and the Island Lake drainage basin. The TMA is comprised of the following major components: a solids containment area, a tailings water decantation area, the primary and secondary water treatment systems, and the freshwater diversion ditches (Figure 6.5).

The containment and decantation areas are located in a topographic low, where tailings solids and liquids are retained behind a main dam. The main dam, which is approximately 1.24 km long and a maximum of 6.5 metres high, crosses the Mill Creek Valley and defines the southern extent of the TMA. Previous geotechnical evaluations of the dam have determined that it is stable, structurally sound and fully meets all design specifications.

The containment and decantation areas were divided into various ponds by using internal berms and dykes. These ponds were used to separate coarse and fine tailings, increase storage capacity and facilitate decantation. Further details on these structures can be found in COGEMA 2000a.

During milling operations, tailings were discharged into the Upper Solids, Lower Solids, and Lower Solids Decant areas. Tailings decant liquid, mill tailings thickener raffinate, and minewater were fed to the Primary Treatment Plant for Ra^{226} precipitation, by barium chloride and ferric sulphate addition, and retention in two settling ponds prior to decant to the Liquids Pond. When required, pH adjustment was accomplished using soda ash that was added to the spillway between the last settling pond and the Liquids Pond. The PTS remains in use for treatment of radiologically-contaminated water.

The Liquids Pond provides retention to increase precipitate settling prior to final polishing in the STS. The Liquids Pond also provides sufficient storage capacity for tailings storage area runoff during precipitation events. The treated water in the Liquids Pond is fed to the STS treatment plant for final treatment and discharged to lined settling ponds prior to final discharge to Snake Creek at the outlet of Snake Lake. Snake Lake, located upstream of the STS discharge, receives no direct effluent discharge. It is subject to seepage of partially-treated tailings water from the liquids pond and to seepage of tailings porewater under the main dam.

The tailings storage area contains approximately 2.6 Mm^3 of tailings.

In 1999, two of the four STS settling ponds were removed from service and partially reclaimed. The South Diversion Ditch and the North Diversion Ditch were constructed in 1999 and 2000, respectively, to divert uncontaminated water around the TMA to Snake Lake and minimize water entry to the TMA. The diversion ditches were designed to ensure that area runoff from a major precipitation event, i.e. a Probable Maximum Precipitation (PMP) event would safely be diverted around the TMA.

In 2001 and 2003, a 1 m till leveling course was placed over the tailings storage areas to minimize radiological hazards, dust emissions, and to promote tailings consolidation.

Operational Impacts

The TMA is a significant waste repository in both quantity and quality for the Cluff Lake site. Considerable information exists on the geochemical and physical characteristics of the Cluff Lake tailings and is provided in supporting documents (COGEMA 1998b, 2000a and 2000b).

Mean values for key contaminants in tailings from 1993 to 1999 were: 42 µg/g arsenic, 76 µg/g molybdenum, 53 µg/g nickel, 82 Bq/g Ra^{226}, 68 Bq/g Th^{230}, and 136 µg/g uranium. More recent samples from tailings, generated in 2001 and 2002, indicate increased concentrations of all contaminants as a result of the processing of higher ore grades (approximately 2.3% or about four times the mean grade). These recent tailings represent about 4% of the total tailings volume in the TMA.

In 1990, Ra^{226} measurements were taken on upwards of 100 solids samples, comprised of Phase 2 thickened, Phase 2 unthickened, and Phase 1 tailings. The Phase 2 tailings samples obtained *in situ* contained between 20 and 140 Bq/g Ra^{226}, having a mean value of 65 Bq/g, with the lowest values typically in the 'sandy unthickened tails'. Empirical data gathered from annual reports document values for Ra^{226} ranging between 6 Bq/g and 450 Bq/g. The most frequently reported values were around 100 Bq/g for all solids reporting to the TMA.

Tailings from the re-processing of Phase 1 gravimetric tails (refer to section 6.1.5), generally referred to as the "Ra^{226} enriched tailings", were believed to contain higher Ra^{226} concentrations due to the high original ore grade. These tailings resulted from the milling of gravimetric tails (original ore grade up to 30% U) from Phase 1 combined with the lower grade ore at the beginning of Phase 2 for a resulting feed grade of approximately 1%. Since, in general, the feed grades to the mill have been less then 1%, the Ra^{226} concentrations in the "Ra^{226} enriched" tailings are expected to be a little higher then the mean concentration for all tailings in the TMA. Chemical analyses of tailings collected during routine monitoring and field investigations confirm that the Ra^{226} concentration in these tailings is not significantly higher than the other tailings in the Cluff Lake TMA (COGEMA 2000b).

The slimes solids contain higher concentrations of metals than the bulk tailings because the slimes are comprised mainly of fine grained mineral precipitates. It was found that the fine fraction of bulk tailings contained the majority of the total metals mass, with the coarser fractions almost exclusively comprised of quartz.

Tailings Porewater Chemistry

In addition to routine internal monitoring, analytical data on tailings porewater chemistry has been accumulated over the years by consultants and researchers. Chemical analyses of *in situ* tailings piezometers, toe berm drainage, and Lower Solids Pond liquids were reviewed in order to assist in establishing source terms for various parameters that were used in contaminant transport modelling.

Toe sump water and piezometers from the base of the tailings and immediately downgradient are considered to be the best representation of in situ tailings pore fluid conditions. Several piezometers were chosen as providing representative tailings pore water quality which could be used in contaminant transport modeling (COGEMA 2000b). The tailings porewater can be generally characterized as follows: Ra^{226} = 2.0 Bq/L, uranium = 0.02 mg/L, sulphate = 2,000 mg/L, chloride = 1,250 mg/L, arsenic = 0.019 mg/L and nickel = 0.002 mg/L.

In 2000, sampling of porewaters in the liquids pond identified a Ra^{226} concentration of 0.2 Bq/L. This lower concentration may be attributed to the limited availability of Ra^{226} in solution resulting from the addition of $BaCl_2$ and $Fe_2(SO_4)_3$ in the Primary Treatment System (PTS) and the subsequent precipitation of Ra^{226} in the PTS settling ponds and the Liquids Pond. Therefore the source term for the Liquids Pond area assumes a Ra^{226} concentration of 0.2 Bq/L. All other parameter concentrations are assumed to be the same as those presented above.

Other operational effects associated with the TMA include the surface disturbance associated with development of the TMA and associated infrastructure, water treatment facilities and diversion ditches, and aerial emissions. Additional operational effects are associated with changes in the hydrological regime in the immediate area of the TMA and related to the discharge of treated effluent into Snake Creek, contaminant loadings to Snake Lake as a result of seepage from the tailings area and liquids pond, and contaminant loadings to Snake Creek and Island Lake from 20 years of treated effluent discharge.

The groundwater between the TMA and Snake Lake has been impacted as a result of seepage from the tailings area and liquids pond. Increases in major ions, trace metals, and radionuclides have been observed and are within the design parameters of the constructed structure. A comparison of recent water quality to pre-operational data indicates increased major ion concentrations in Snake Lake water quality. Changes in groundwater and surface water quality downstream of the TMA are discussed in greater detail in section 6.2.

While Snake Lake has experienced an increase in Ra^{226} concentration as a result of seepage from the TMA, a further appreciable increase was observed in 1997 and 1998. The increase was attributable to the inadvertent use of a contaminated pipeline for the diversion of freshwater around the TMA, which was later corrected. Since then, Ra^{226} concentrations have gradually returned to pre-1997 conditions.

The 20-years of treated effluent release and the associated reagent and contaminant loadings to Island Lake have resulted in adverse effects on water and sediment quality, and on the aquatic ecology. In Island Lake, changes in the zooplankton, benthic macroinvertebrate and fish communities have been observed. This is discussed further in section 6.2.

6.1.7 Ancillary Buildings and Services

Germaine Camp Area

The permanent camp for the Cluff Lake operations is located adjacent to Germaine Lake near the southwest end of Cluff Lake (Figure 6.6). It is comprised of residential buildings, bunkhouses, a kitchen/dining facility, a gymnasium, a recreational hall, a licensed lounge, a curling rink, a pump house with domestic water treatment facilities, a sewage treatment building, and a standby generator. As staffing levels were reduced, redundant bunkhouses and residential buildings were shutdown and/or removed in 2001 and 2002.

Operational impacts include surface disturbance and minor impacts on Germaine Lake resulting from seepage from the sewage treatment facility.

Cluff Center

Cluff Center was the original mine maintenance and support area when the D orebody was mined. It consisted of a mine maintenance shop and several storage buildings. More recently, COGEMA's Exploration Department used the Cluff Center area for core logging and storage. It is comprised of two trailers used by exploration staff for core logging and a few larger storage buildings for materials, equipment and drill cores. In addition, the mine maintenance building and a few storage buildings continue to be used for storage of operating materials and equipment.

With the reduction of the exploration program and the decision to decommission, several of these buildings became redundant and were removed in 2002. An exploration office has been set up at the Mill Complex to accommodate any future needs. All drill cores continue to be stored at Cluff Centre.

Operational impacts in this area are generally limited to surface disturbance. The remaining drill cores pose a minor radiological hazard as some of the cores contain elevated concentrations of uranium.

Southgate Entrance

The Southgate Entrance is a security building and gate located at the south end of the site property on the main access road. It is the primary location for controlling site access. In December 2002, a camera was set up at Southgate Entrance to allow for remote monitoring and recording of activities; the monitor is located in the mill powerhouse.

Operational impacts are limited to land disturbance.

Batch Plant

This area included the batch plant that provides concrete for mining operations, an A-frame, a pump house at Earl Creek, the cement and fly ash silos, and borrow areas. Part of the borrow areas was recontoured in 2002. All surface facilities were removed in 2003 leaving a concrete foundation. Remaining reclamation includes removal or covering of the concrete foundation, recontouring and site revegetation.

Operational impacts are limited to land disturbance.

Cluff Lake Pumphouse

The Cluff Lake Pumphouse and associated pipeline to the mill is used to meet all water needs for the mill complex. This includes domestic water, process water (where minewater is insufficient), firewater, and cooling water for diesel generators. With the cessation of milling operations, the water demand and consumption has been significantly reduced.

The Pumphouse, the primary source of water for site operations, diverted about 1 Mm^3 of water from Cluff Lake to the mill during milling operations. This represents less than 1% of the estimated flow through Cluff Lake. This volume has been significantly reduced since milling operations closed.

Airstrip

The airstrip consists of a runway, an above ground aviation fuel storage tank, and two small buildings. Impacts in this area are generally limited to surface disturbance from the establishment of the airstrip.

Site Roads

Several roads were established to move personnel, materials and equipment, and to access the various facilities on site. These include several roads for mining and milling operations on-site, the road to Germaine Camp, and Highway Road 955, which provides access to the Cluff Lake site.

The impacts from the roads are generally associated with surface disturbance. There are some areas with surface contamination resulting from ore spillage on haul roads. These are generally very limited and localized and are easily identified using ground gamma surveys. The ore haulage road from the Claude mining area is graded such that any surface water runoff is collected and directed to the DJX Pit.

There are some stream crossings, the most significant being the crossing at Peter River, Boulder Creek, and at the outlet of Cluff Lake. Stream crossings are well established and stable with no evidence of excessive erosion or carryover of fines into the stream bed.

Fuel Storage Facilities

Fuel storage facilities include gasoline and diesel fuel storage facilities and propane tanks. Fuel storage tanks are on surface and are within lined berms to collect any potential leaks. Concrete pads and sumps were recently constructed at all fueling stations to contain any spillage from pumping stations.

As part of site clean-up and reclamation, redundant tanks and fuel storage facilities have been removed. There is some evidence of contamination of underlying soils at the fuel pumping stations as a result of past practices prior to the establishment of the containment pads and sumps. Removal and clean-up of the facilities and any contaminated soils is done in accordance with any applicable federal and provincial guidelines.

Contaminated and Treated Effluent Pipelines

Surface pipelines, which have transported minewater, tailings slurry, or raffinate, are located adjacent to the site roads. A series of pipelines between Claude Pit, DJX Pit, mill, and the TMA continue to be used for the management of water from Claude and DJX Pits.

Operational impacts from the pipelines are associated with a number of minor pipeline leaks and spills over the operational history. Spills and leaks have been of limited volume, concentration, and impact. Spill response has resulted in the immediate remediation at the time of occurrence, and areas where radiological spills had arisen were scanned following clean-up to verify the effectiveness of clean-up.

Borrow Areas

There are several borrow areas on the Cluff Lake site. The most significant is the borrow area near the concrete batch plant and the borrow area southwest of the TMA. The borrow area next to the Batch Plant is in the process of being reclaimed while all other non-operating borrow areas have been reclaimed. Reclamation consists of regrading and resloping to minimize erosion and minimize water ponding. Wherever possible, surface vegetation removed during the establishment of the borrow area is spread over the reclaimed area to provide an organic base and seed source to facilitate revegetation. Where this is not possible, revegetation with native shrubs and trees is undertaken. The borrow area at the TMA is the only active borrow area at this time.

Solid Waste Landfills

There are currently three active landfill sites: Claude Pit, the industrial landfill, and the domestic landfill sites. There are also a number of landfills which have been previously reclaimed.

The industrial landfill is located on the eastside of the Upper Solids Pond. This facility is a disposal area for industrial wastes that are potentially radiologically contaminated. Material in the industrial landfill includes items such as pipes, wood pallets, waste wood from mine areas, waste packaging, reagent bags, and vent tubing.

The domestic landfill is located between the Mill Complex and Germaine Camp. The domestic landfill has been used to dispose of domestic wastes originating from the camp and administration office areas. These wastes generally consist of highly biodegradable materials that will have a negligible effect on soil and groundwater.

There are three other known historical waste disposal areas on the Cluff Lake site. These are an old landfill near Cluff Center, an old landfill just south of the mill, and an old drum disposal area south of the TMA. These landfills were used for non-hazardous industrial wastes (wood, metal, concrete) and domestic wastes.

A series of monitoring wells were installed around the various landfills in 2001. These will be used to help verify and confirm that the landfills are not having any downstream impacts.

6.2 Description of the Existing Environment

6.2.1 Introduction

This section provides a description of the environment prior to mining operations and near the end of the operational phase of the Cluff Lake Project, and provides an assessment of the overall environmental impacts over the operational phase.

To assess the significance of changes in environmental monitoring components during the operational phase, environmental impact predictions that were made in various environmental assessments conducted during the development of the Cluff Lake Project were used as a framework for comparison. Three environmental assessments were undertaken during the Cluff Lake Project Development, including the initial assessment (Bayda 1978), the Phase II assessment (Cluff Mining 1982) and the DJX Assessment (Amok 1992). The DJX environmental assessment provides the most recent and quantitative impact predictions, which were subjected to regulatory and public review, and thus provides the focus for this assessment of monitored changes to the environment from project development. The environmental significance of operational effects was also assessed by comparison with relevant provincial and federal environmental quality objectives or site-specific benchmarks.

Environmental baseline and monitoring data describing the Cluff Lake environment has been compiled over the last 25 years. A description of environmental components that have been characterized and monitored, including climate and atmospheric emissions, geology, hydrogeology and surface water hydrology, and aquatic and terrestrial ecology is summarized below, as well as an outline of the identified valued ecosystem components that form an integral part of the environmental assessment framework.

Extensive discussions regarding the existing environment, with supporting data, are contained in COGEMA 2000d, Appendix A.

6.2.2 General

The Cluff Lake Project is located approximately 55 km south of Lake Athabasca, within a ring-type geological feature known as the Carswell structure. The project lies within the Athabasca Plain ecoregion within the boreal shield ecozone. This ecoregion extends south from Lake Athabasca to Cree Lake, in northwestern Saskatchewan, and is roughly coincident with the flat-lying Proterozoic sandstones.

The ecoregion forms part of the continuous coniferous boreal forest that extends from northwestern Ontario to Great Slave Lake in the Northwest Territories. Stands of jack pine with an understory of shrubs and lichen are dominant. Some paper birch, white spruce, black spruce, balsam fir, and trembling aspen occur on warmer, south-facing sites. Forest fires are common in this ecoregion and most coniferous stands tend to be young and stunted. Bedrock exposures have few trees and are covered with lichens.

Permafrost occurs sporadically throughout the ecoregion. The plain is covered with undulating to ridged fluvioglacial deposits and sandy, acidic till. Wildlife includes moose, black bear, woodland caribou, lynx, wolf, beaver, muskrat, snowshoe hare, waterfowl (including ducks, geese, pelicans, and sandhill cranes), grouse, and other birds.

Within the Cluff Lake Project area, Cluff Lake forms a head water lake, receiving drainage at its north end from Beaver Creek, Boulder Creek, Earl Creek, Peter River, and Claude Creek. Cluff Creek drains southward to the Douglas River which flows to Sandy Lake and ultimately to Lake Athabasca. Sandy Lake is also the confluence of the Island Creek drainage, a relatively small drainage, which subdivides at Agnes Lake into the Bridle Creek system and the Snake Lake-Island Lake system.

6.2.3 Climate

Climatic conditions at Cluff Lake have been monitored since 1981. Until 1999, temperature, wind direction and velocity, snow depth, precipitation and evaporation records were maintained from a wind anemometer, a weather observation station, an evaporation station, and a snow survey station. In January of 1999, these stations were replaced with a single weather station, located at the airstrip, that digitally records weather observations and evaporation.

The climate in the Cluff Lake region consists of short, cool summers with an average frost-free period of less than 90 days and a mean daily temperature ranging from 14.7^{o}C to 17.0^{o}C. Average winter temperatures range from -17.5^{o}C to -20.3^{o}C. Extreme temperatures range from a maximum of 36.0^{o}C in the summer, to as low as -49.0^{o}C in the winter.

Average annual total precipitation is 451 mm, with more than half occurring from June through to September. Snowfall usually occurs from October to May, with the largest amounts from January to April. Annual evaporation exceeds annual precipitation. The prevailing annual wind direction at Cluff Lake is from the southeast (COGEMA 2000d, Section 2.0).

6.2.4 Air Quality

The ambient air quality monitoring program at Cluff Lake includes measurements of suspended particulate matter (TSP), radon levels, and metals and radionuclides in lichen.

Background total suspended particulate (TSP) levels in the Cluff Lake area were measured in 1975 (Stearns-Roger Incorporated 1976). Levels ranged from 1 to 27 $\mu g/m^3$, with a mean of 12.8 $\mu g/m^3$ and a geometric mean of 10.1 $\mu g/m^3$. With regard to radiological content, the only relevant data measured prior to commencement of mining were gross alpha and gross beta in TSP. Gross alpha levels in TSP measured at Cluff Lake for pre-mining conditions range from 5×10^{-5} to 6×10^{-4} Bq/m^3, with an average of 3.2×10^{-4} Bq/m^3. Gross beta levels in TSP measured prior to mining at Cluff Lake ranged from 1.2×10^{-3} Bq/m^3 to 5×10^{-3} Bq/m^3, with an average of 3.2×10^{-3} Bq/m^3.

TSP is currently monitored at three high volume air sampling (HVAS) monitoring stations located at the mill, Germaine Lake, and Cluff Centre. Particulate matter chemical composition is determined on a semi-annual basis from composites of the monthly TSP samples at each of these locations. Median TSP concentrations during 1999 were 5 μg/m^3 at Germaine Lake, 6 μg/m^3 at Cluff Centre, and 19 μg/m^3 at the mill site, while more recent data for 2002 indicate median concentrations of 14 μg/m^3, 10 μg/m^3 and 13 μg/m^3 for each respective area. These median concentrations are similar to pre-operational values and are well below the allowable annual geometric mean (for lognormal data, the median approximates the geometric mean) of 70 μg/m^3 specified in the *Saskatchewan Clean Air Regulations*.

A review of the median annual concentrations of radioactivity for 2002 in the suspended dust shows that the highest uranium concentration of 0.024 μg/m^3 was measured at the mill location. This is somewhat higher than the regional background levels of 0.001 μg/m^3 to 0.005 μg/m^3. The highest concentrations of Th^{230} and Ra^{226} were also found at this location and these levels are relatively consistent with the uranium concentrations since equilibrium with the uranium would predict Th^{230} and Ra^{226} concentrations of about 0.1 mBq/m^3 or about twice the measured uranium values.

The concentrations of Pb^{210} and Po^{210}, (maximum 2.3 mBq/m^3) (maximum 0.6 mBq/m^3) are somewhat higher than concentrations of Ra^{226} due to contributions arising from the decay of Rn^{222} in ambient air as well as contributions from local suspended particulate.

Ambient radon levels are measured using track-etch detectors deployed quarterly. Summary statistics on the ambient radon measurements collected between 1994 and 2002 indicate typical levels (i.e. median levels) ranging from about 15 to 160 Bq/m^3 with most locations having median levels lower than 40 Bq/m^3. While no pre-mining data is available for Cluff Lake, these values fall within the range of regional background values measured in the Wollaston Lake region on the east side of the province, where uranium mining has also been conducted.

When mining and milling was still underway and prior to the placement of the leveling course in the TMA, the highest radon concentrations were measured in the vicinity of the tailings areas and near the mill. The lowest concentrations were measured to the south and east of the tailings and mill facility; specifically at the Germaine Camp where typical levels (median) were about 15 Bq/m^3. The relatively higher radon concentrations near the TMA were likely associated with radon emissions from the tailings and radium precipitate in the Liquids Pond. The levels at the mill were likely associated with emissions from processing ore at the mill and radon from nearby stockpiles. Other relatively elevated radon concentrations could be associated with radon from the underground workings.

The above airborne concentrations of radon gas can be conservatively converted in airborne concentrations of radon progeny by assuming an equilibrium factor of 0.1 or less between radon and its progeny. [For a typical low windspeed of 3 m/s, it takes about 2.8 minutes for radon to move a distance of 500 m, thus leading to an equilibrium factor of about $0.06 \approx 0.023\ (2.8)^{0.85}$ based on Evans' (1969) formula.] On this basis, radon concentrations of 15 and 160 Bq/m^3 convert to radon progeny concentrations of about 0.0002 and 0.0024 WL. Radon progeny measurements taken at the TMA in the fall of 2000, prior to the placement of the leveling course, ranged from 0.0005 to 0.0032 WL.

With the cessation of mining and the backfilling and capping of all mine openings, the airborne concentrations of radiological contaminants in the mining areas have returned to near background levels. Similarly, the cessation of milling operations and the placement of a leveling course over the exposed tailings is likely to have significantly reduced airborne concentrations of radiological contaminants near the mill and TMA.

In 1990, Cluff Lake initiated a revised monitoring program for the chemical and radiological analysis of lichen. Table 6.1 summarizes mean levels of radionuclides and heavy metals in lichen based on 1991, 1995 and 1999 data. The next sampling campaign is scheduled for 2004.

There is a trend of decreasing concentrations away from the mill. The closest station to the mill (LCH1000T) typically has higher concentrations than the next closest station (LCH2000T), with concentrations at Cluff Centre (LCH4000T) being the lowest. The last column in Table 6.1 shows the ratio between the average concentration for data from the mill locations (LCH1000T and LCH2000T) and the background locations (LCH3000T and LCH3100T). Uranium, Th^{230} and Ra^{226} levels around the mill area showed the greatest increase over background levels (29.4, 4.7 and 7.4 times, respectively). Pb^{210}, Po^{210}, and metals levels around the mill ranged from background to two times background levels.

Table 6.1

Mean Concentrations (dry weight basis) in Lichens at Cluff Lake*

Analyte	Units	Locations Near Mill			Background Locations		
		LCH1000T 300 m east of mill	LCH2000T 1000 m SE of mill	LCH4000T Cluff Centre	LCH3000T Saskatoon Lake	LCH3100T Agnes Lake	Ratio of Mill to Background
U	µg/g	4.9	3.627	1.23	0.095	0.244	29.4
Th^{230}	Bq/g	<0.019	<0.008	0.017	0.002	0.004	4.7
Ra^{226}	Bq/g	0.057	0.017	0.015	0.006	0.004	7.4
Po^{210}	Bq/g	0.183	0.223	0.24	0.165	0.17	1.2
Pb^{210}	Bq/g	0.21	0.303	0.34	0.275	0.18	1.1
As	µg/g	0.2	<0.167	< 0.1	< 0.1		1.8
Cd	µg/g	0.05	< 0.05	< 0.05		< 0.05	1.0
Cu	µg/g	1.3	0.8	0.9		0.6	1.8
Ni	µg/g	<0.433	<0.367	0.4	< 0.4	0.2	1.2
Pb	µg/g	2.533	<0.967	0.8	< 1.1	0.3	2.1
Zn	µg/g	10	12	9.8		10	1.1

* reported values are the means of the 1991, 1995 and 1999 data.

Annual metals and radionuclide data, summarized in Table 6.2, do not show any notable variation among years, with the exception of uranium and Ra^{226}, and possibly lead. For these analytes, levels around the mill in 1991 were higher than levels reported in later years.

Table 6.2
Table of Measured Lichen Concentrations (dry weight basis)

Analyte	Units	Mill(1) 1991	Mill(1) 1995	Mill(1) 1999	Mill(2) 1991	Mill(2) 1995	Mill(2) 1999	Background 1991	Background 1995	Background (new) 1999
U	µg/g	8.3	3.4	3	7.5	1.4	1.98	0.1	0.09	0.244
Th^{230}	Bq/g	<0.001	0.025	0.03	<0.001	0.01	0.014	8.00E-04	0.003	0.004
Ra^{226}	Bq/g	0.075	0.05	0.046	0.03	0.015	0.006	0.001	0.011	0.004
Po^{210}	Bq/g	0.12	0.2	0.23	0.2	0.3	0.17	0.13	0.2	0.17
Pb^{210}	Bq/g	0.3	0.04	0.29	0.3	0.4	0.21	0.3	0.25	0.18
As	µg/g	0.2	0.3	0.1	0.1	0.3	<0.1	<0.1	0.1	
Cd	µg/g			0.05			<0.05			<0.05
Cu	µg/g			1.3			0.8			0.6
Ni	µg/g	<0.5	0.4	0.4	<0.5	0.4	0.2	<0.5	0.3	0.2
Pb	µg/g	6	0.6	1	<2	0.5	0.4	<2	0.2	0.3
Zn	µg/g			10			12			10

Notes:

Mill(1) is LCH1000T station - Mill(2) is LCH2000T station.

Background is LCH3000T station - Background(new) for 1999 is LCH3100T station at Agnes Lake.

Summary of Air Quality Impacts

The Environmental Impact Statement for the Dominique-Janine Extension (Amok 1992) predicted changes in air quality due to emissions of Total Suspended Particulates (TSP), standard pollutants, radioactive dust, and radon. The impacts of the predicted changes was assessed to be minor, which was characterized as a temporary deterioration in air quality but the maintenance of compliance with environmental standards.

The comparison of pre-operational air quality monitoring data with operational monitoring data indicates that operational air quality impacts have been minor. With the exception of somewhat elevated air quality parameters near the mill, mine developments, and tailings area, air quality in the vicinity of the Cluff Lake Project has reflected background conditions. The actual air quality impacts are therefore consistent with the impact predictions presented during the development of the Cluff Lake Project. Although some adverse changes in air quality have occurred, compliance with environmental standards has ensured that this adverse effect is not significant.

6.2.5 Gamma Radiation Levels

Ground gamma survey of the Cluff Lake site, prior to the commencement of mining, were used to identify potential orebodies and are of limited value in determining the lower ranges of background values.

In 1999, a comprehensive environmental gamma radiation survey was conducted in the vicinity of the Cluff Lake site using a combination of aerial and ground survey techniques. The aerial survey provided average gamma radiation levels with a spatial resolution in the order of 50 m by 50 m. This information was supplemented by a ground level survey on accessible areas (mainly roads and developed areas) where the measurements reflect spatial resolution over a few metres.

The natural background gamma exposure levels, in areas unimpacted by operations measured, at 1 m above ground, range from 0.01 to 0.5 µSv/h over most of the site. The low natural background radiation levels essentially correspond to water and low-lying areas, presumably saturated with water or areas with thick layers of unmineralized overburden. In the drier areas, or areas with exposed bedrock with some mineralization, natural background levels generally range from about 0.1 to 0.5 µSv/h. Values approaching 1 µSv/h have been observed to the south of D-Pit where the natural presence of mineralized rocks generate more elevated gamma levels.

The highest gamma radiation levels, some exceeding 5 µSv/h, were observed at the TMA with above-background levels also observed near the mill and the ore storage areas.

Summary of Surface Impacts Resulting from Gamma Radiation

The gamma survey conducted in 1999 indicates gamma radiation at the Cluff Lake site was appreciably above-background levels in the vicinity of the TMA, mill, and ore storage areas. While more recent ground gamma radiation surveys have not been conducted to confirm it, the placement of the leveling course on the TMA and the site clean-up and reclamation activities around the mining areas are expected to have significantly reduced these levels. The current environmental effects can be classified as adverse, however, due to the limited spacial extent and the operational controls to ensure human exposure is minimized, the effect is not classified as significant. However, some additional remediation is required to ensure the long term protection of humans and non-human biota.

6.2.6 Geology

There have been extensive investigations to characterize the geology at Cluff Lake both in support of exploration and operations activities. These investigations are described in (COGEMA, 2000b; COGEMA, 2000c).

The Cluff Lake area has been subjected to several episodes of continental glaciation all of which have been characterized by the dominance of glacial erosion of the substrata over which the ice advanced. Glacial erosion has sculpted the major elements of the landscape.

The following is a summary of the geology of the Cluff Lake site.

Mining Area

The Cluff Lake uranium deposits are clustered within the Carswell Structure located on the west side of the Athabasca sedimentary basin. The Carswell Structure is probably one of the most conspicuous, large diameter ring-type geological structures in Canada. The Athabasca basin overlays the Canadian Shield basement rock in Northern Saskatchewan. 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 which turned upside down. The origin of this structure is thought to be a meteorite impact which occurred during Ordovician time.

The local basement rock is composed of two different gneisses. The relationship between both types of gneisses was not well understood until the discovery of the Dominique-Peter ore body in 1980. Occurrence of uranium mineralization in the basement rock appears to be related to the stratigraphic contact between aluminous and quartzo-feldspathic gneisses around the Dominique-Peter Dome. Most of the uranium deposits at Cluff Lake are intimately related to the basement rock and its past tectonic history.

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. Other uranium mineralization similar to those discovered east of the Athabasca basin are of the unconformity type. Only chunks of such deposits have been found close to the faulty boundary of the structure and are interpreted as remnants of formerly large accumulations of uranium. Beyond the limit of the structure, it is believed that major uranium unconformity deposits may still be discovered. The Dominique-Janine deposit was located on the southwestern flank of the Dominique-Peter Dome, close to the south edge of the Carswell Structure.

The surficial geology of the waste rock area at the Cluff Lake Project consists of a continuous cover of permeable, drumlinized sandy till that is 2 to 7 m thick and interspersed with glaciofluvial and glaciolacustrine deposits. Surficial deposits are up to 20 m thick in the Peter River valley.

Underlying the overburden are the low permeability basement gneisses; the Peter River, Earl Creek and transition zone gneisses. The upper 10 m of all bedrock materials is thought to be weathered and thus have a somewhat higher permeability than the deeper, unweathered bedrock. The higher permeabilities are partly attributed to paleoweathering prior to the deposition of the Athabasca Basin sediments, paleoweathering before the Quaternary and weathering and fracturing during Pleistocene glaciation.

TMA

The overburden stratigraphy on the uplands adjacent to the TMA typically consists of sandy glacial till directly overlying the bedrock. Within the TMA the overburden stratigraphy reflects a glaciofluvial origin, comprised of peat deposits that range from 0.1 m to 3 m thick, underlain by sand deposits that range from 0.5 m to 10 m thick, which in turn are underlain by a sandy glacial till that ranges from 0.4 m to 9 m thick. The till directly overlies the bedrock. The thickest deposits of sand are found along a narrow strip approximately 300 m wide which extends from the Liquids Pond to Snake Lake.

There are two significant lithologic features associated with the TMA; tectonized sandstone and pelitic sandstone.

Sandstone underlies most of the area downstream of the Main Dam. It is typically medium grained with lesser coarse grained and fine grained sandstone beds intersected in drill core. The sandstone is invariably tectonized in the area immediately downstream of the Main Dam. The tectonization is defined by the development of tectonic brecciation which varies from mild to intense. Virtually all bore holes between the Main Dam and Snake Lake exhibit some degree of tectonization.

Secondary hematization and bleaching typically accompanies the tectonization. Dark purple hematization is typical of early hematization found throughout the Athabasca basin. This is not related to the tectonic brecciation. Reddish-brown hematization, both concentrated along fracture planes and pervasive through some core sections appears related to the tectonic brecciation and the implacement of "Cluff Breccia" found throughout the Cluff Lake region. Where hematization is not associated with the tectonic breccia, bleaching and kaolinization of the breccia is common. This results in a white coloration. The brecciation often results in poor core recovery and rock quality designation; however, the presence of abundant silt and clay size particles associated with the alteration results in generally tight fracture systems within the rock.

An interlayered assemblage comprised of fine grained sandstone, siltstone and pelite is present in numerous bore holes upstream of the Main Dam. These units have been grouped into the pelitic sandstone assemblage. The fine sandstone varies from reddish-brown to white while the siltstone and pelite are typically reddish-brown or light green coloured and comprised of clay and silt. Bedding is typically well defined within the assemblage. Tectonic brecciation may be present, but it is typically not as intense or widespread as in the sandstone unit.

Core recovery and rock quality designation of the pelitic sandstone unit is typically higher than that of the tectonized sandstone. Fractures are tight and often coated with clay and silt.

6.2.7 Hydrogeology

Numerous field investigations have been completed at the Cluff Lake site to characterize the hydraulic properties of the geological strata (COGEMA 2000d, Section 6.0 and COGEMA, 1998a). This data was used to develop a regional groundwater model for the Cluff Lake region to facilitate contaminant transport modeling.

Following is a summary of the hydrogeologic conditions at the Cluff Lake site.

Regional Hydrogeology

Deep regional 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.

Relative hydraulic conductivity contrasts are expected between the Archean basement, sandstone, the sandstone within the regional fault systems and the Douglas-Carswell Formations. The Archean basement and the Douglas Formation siltstone (pelitic sandstone) are estimated to have the lowest relative hydraulic conductivities based on their lithology. 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 conductivity properties due to intense silicification along parts of the contact zone and lack of secondary silicification in other parts of the zone.

Piezometric Conditions

A regional scale numerical investigation was completed to establish an approximation of the regional groundwater flow regime at the Cluff Lake site. The regional phreatic surface varies from approximately 350 masl (meters above sea level) in the topographic high region north of Claude Lake, to a low of approximately 313 masl in the vicinity of Island Lake.

Major Hydrostratigraphic Units

Numerous field investigations have been completed at the Cluff Lake site to characterize the hydraulic properties of the geological strata. The major investigation involved over 137 hydraulic conductivity tests completed on 66 piezometers and 71 packer tests completed on eight deep bore holes. The piezometers were installed in overburden or shallow bedrock (<30 m deep). The packer system was used to test bedrock up to a depth of 200 m.

All tests were grouped according to depth and lithology to determine statistical variation of the hydraulic conductivity within each group. The lithologic units and hydraulic conductivity parameters are listed in Table 6.3.

Table 6.3
Summary of the Major Hydrostratigraphic Units

MATERIAL	DEPTH (M)	MEASURED HYDRAULIC CONDUCTIVITY STATISTICS (M/S)		
		Minimum	Median	Maximum
Overburden		8.1×10^{-8}	4.0×10^{-6}	6.5×10^{-5}
Sandstone	0-5	1.7×10^{-7}	3.2×10^{-7}	8.4×10^{-6}
Sandstone	5-15	4.5×10^{-8}	2.9×10^{-7}	1.1×10^{-6}
Sandstone	15-65	4.3×10^{-9}	5.2×10^{-8}	4.2×10^{-6}
Sandstone	>65	3.6×10^{-9}	3.8×10^{-8}	3.6×10^{-7}
Pelite	0-15	Untested		
Pelite	>15	2.7×10^{-9}	3.0×10^{-8}	2.9×10^{-7}

TMA Hydrogeology

The pelitic sandstone unit, which underlies two 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 also immediately south of the pelitic sandstone contact and in the Liquids Pond area. The recharge downstream of the contact is due in part to the hydraulic conductivity contrast between the pelitic sandstone and the tectonized sandstone and in part to the presence of the Main Dam cut-off wall and Liquids Pond. Discharge conditions exist further south from the pelitic sandstone contact and the Main Dam adjacent to the Liquids Pond and Lower Solids Pond.

The well cemented nature of the rock and the estimated low matrix porosity suggests that fracture flow predominates throughout the deeper parts of the flow system (i.e. >5 m into bedrock), while flow in the overburden and upper 5 m of sandstone approximates flow through a porous medium.

Piezometric Conditions

Snake Lake and the TMA lie within the Island Lake drainage basin. Snake Lake forms a major groundwater discharge for the watershed. Groundwater flow within the basin is radial toward the TMA and Snake Lake. Horizontal hydraulic head gradients are typically less than 1 m in 50 m on the uplands and in the lowlands below the TMA. Horizontal hydraulic head gradients on the slopes leading down to TMA are typically 2 m to 3 m in 50 m. Horizontal hydraulic head gradients between the Main Dam and piezometers immediately downstream from the dam are high. The highest hydraulic head gradient was 4.5 m in 50 m across the Main Dam between the Liquids Pond and the area downstream.

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. At the south-east extension of the Main Dam and along the east side of the TMA, the vertical gradient is downward.

Hydrostratigraphy

Based on hydraulic conductivity tests, five hydrostratigraphic units are defined within the TMA area. They include:

- overburden;
- the upper 15 m of tectonized sandstone which is typically more weathered;
- tectonized sandstone at depths between 15 and 65 m;
- tectonized sandstone at depths greater than 65 m; and,
- the pelitic sandstone.

All overburden piezometers tested downstream of the Main Dam exhibited hydraulic conductivities higher than 1×10^{-7} m/s. The minimum value of 8.1×10^{-8} m/s is from piezometer HYD98-36a, located on the berm between the Upper and Lower Solids Pond. All the sandstone tested was tectonized to varying degrees. The hydraulic conductivity within the tectonized sandstone generally decreases with depth.

The pelitic sandstone assemblage has a distinctly lower hydraulic conductivity than the tectonized sandstone and the conductivity does not decrease with depth. Although no pelitic sandstone was tested in the 0 m to15 m depth range, the shallowest tests in this unit were 5×10^{-9} and 2.8×10^{-8} m/s at 25 m and 20 m, respectively. Ninety percent of the tests in the pelitic sandstone were in the 10×10^{-8} and 10×10^{-9} m/s range.

The hydraulic conductivity of the tailings has been defined by previous investigations as ranging from 1×10^{-9} to 2×10^{-4} m/s.

Mining Area Hydrogeology

The regional and local groundwater flow regime in the vicinity of Cluff Lake is governed by topography. Groundwater recharges the flow system throughout most of the Cluff Lake drainage basin area that is not occupied by the larger and deeper lakes. Groundwater moves downwards and laterally through the overburden and shallow bedrock, ultimately discharging locally in low-lying areas or regionally into the bottom or along the shoreline of major lakes and streams.

Table 6.4 lists the range of saturated hydraulic conductivities for each of the hydrostratigraphic units in the mining area (COGEMA, 2000c, Appendix C).

Table 6.4
Estimated Ranges of Saturated Hydraulic Conductivity

Hydrostratigraphic Unit	Saturated Hydraulic Conductivity (m/s)
Waste Rock	$1x10^{-2} – 4x10^{-7}$
Backfill	$1x10^{-5} – 2x10^{-7}$
Sandy Till	$3x10^{-4} – 3x10^{-7}$
Transition Zone	$1x10^{-5}$ - $5x10^{-8}$
Regolith	$1.1x10^{-6} – 4.3x10^{-9}$
Peter River Gneiss	$5x10^{-6} – 1x10^{-8}$
Earl Creek Complex	$5x10^{-6} – 1x10^{-8}$

Surface drainage features, topography, and bedrock structure control shallow groundwater flow in the study area. The most important surface water body, Cluff Lake, is the ultimate receptor for all groundwater and surface water flows in the region of interest. The important lakes in the area include Claude Lake and Cluff Lake. Shallow groundwater flow discharges into various streams in the area, such as Beaver Creek, Boulder Creek and Claude Creek, as well as Earl Creek and Peter River.

6.2.8 Groundwater Chemistry

This section characterizes baseline groundwater chemistry and operational impacts to groundwater quality in the areas of the TMA, and the Claude and DJ mines. Further details are provided in (COGEMA, 2000a and COGEMA 2000b).

Methodology

The groundwater chemistry of samples collected from control stations (up gradient of TMA with respect to groundwater flow) and exposure stations (down gradient of TMA with respect to groundwater flow) surrounding the TMA were compared, for a suite of 30 analytical parameters, using a principal components analysis (PCA) (COGEMA 2000d). This was done as an initial screening to determine which parameters show the largest change within the data set and which areas demonstrate similar chemistry results.

Based on the results of the PCA, parameters at exposure stations showing significant variations, with respect to the data set, were plotted against baseline concentrations. Instances of change from baseline conditions are discussed in the following sections.

In the Claude and DJ mine area, an initial screening was not warranted, due to the limited number of monitoring stations present. All available historical data were plotted against baseline concentrations. Instances of changes from baseline conditions are discussed in the following sections.

TMA Area

Monitoring wells situated in several general areas up gradient of the TMA were used to establish baseline conditions. The areas include: the area immediately north northeast of the TMA, the uplands north northeast of the TMA, those areas east and southeast of the TMA; and the area northwest of the STS.

Based on the results of the principal components analysis, the areas of greatest impact from the operation of the TMA are discussed in the following sections. Impact values represent maximum impacts observed, based on emerging trends in parameter concentrations, down gradient of the TMA. While no groundwater quality objectives exist in Saskatchewan, the groundwater concentrations were compared to SSWQO values for irrigation and Saskatchewan Drinking Water Quality Standards and Objectives (SDWQSO) to help in qualifying the groundwater impacts.

pH and Major Ions

The greatest change in pH of groundwater is noted in the area down gradient of the liquids pond. Values for samples collected from stations in this area are depressed with respect to base line conditions (5th percentile of 5.36 units) and range to approximately 3.5 units.

The greatest concentrations of major ions correspond to monitoring stations located down gradient of the lower solids pond. Major ion concentrations encountered in this area are summarised in Table 6.5, below.

Table 6.5
Groundwater Concentrations Down Gradient of TMA
Baseline vs. Exposure – Major Ions

Parameter	Baseline Concentration	Exposure Concentration	SDWQSO
bicarbonate (mg/L)	116.5	3000	na
magnesium (mg/L)	12.5	250	200
potassium (mg/L)	4.0	40	na
sodium (mg/L)	11.6	1000	300
calcium (mg/L)	21.2	600	na
chloride (mg/L)	38.5	1000	250
sulphate (mg/L)	9.9	2000	500

na = Not available

SSWQO values for irrigation applicable to sodium and chloride are 100 mg/L each. The SDWQSO values for the noted parameters are not standards but objectives which are generally associated with aesthetics. As can be seen, the exposure concentrations are elevated when compared to SSWQO and SDWQSO.

Trace Metals and Radionuclides

The greatest change from baseline concentrations of arsenic, cobalt, manganese, and molybdenum correspond to monitoring stations located down gradient of the lower solids pond, while those for iron, lead, and vanadium correspond to monitoring stations located down gradient of the liquids pond.

The greatest change from baseline concentrations of nickel are observed down gradient of the STS and were found to be marginally above baseline concentrations. Concentrations of the above trace metals detected in these areas are summarised in Table 6.6, below. The exposure concentration presented for arsenic is based on observed trends in water chemistry down gradient of the lower solids pond.

Table 6.6
Groundwater Concentration Down Gradient of TMA
Baseline vs. Exposure – Trace Metals

Parameter	Baseline Concentration	Exposure Concentration	SSWQO for Irrigation	SDWQSO (Note 1)
arsenic (mg/L)	0.0016	0.003	0.1	0.025
cobalt (mg/L)	0.003	0.020	0.05	na
iron (mg/L)	136.1	200	5	0.3
lead(mg/L)	0.017	0.070	0.2	0.01
manganese (mg/L)	1.057	2	0.2	0.05
molybdenum (mg/L)	0.017	1	0.01	na
nickel (mg/L)	0.011	0.020	0.2	na
Pb^{210} (Bq/L)	0.037	0.300	na	0.1
Po2^{10} (Bq/L)	0.034	0.080	na	0.11
Ra^{226} (Bq/L)	0.086	0.2	na	0.1
uranium (μg/L)	13.6	30	10	20
vanadium (mg/L)	0.044	0.1	0.1	na

Note 1: The SDWQSO for iron and manganese are objectives while the other values are standards. The standards are derived to safeguard health on the basis of life long consumption. Objectives are generally associated with aesthetic requirements, however, concentrations above these levels may pose a health risk to some people. SDWQSO for radio-isotopes is 0.1 Bq/L for gross alpha and 0.11 Bq/L for gross beta.

As shown, iron, manganese, and molybdenum are elevated relative to the SSWQO for irrigation. These same elements in addition to lead exceed the SDWQSO. Note, however, that baseline concentrations for these same elements are also elevated relative to the objectives and standards.

The greatest concentrations of radionuclides correspond to monitoring stations located immediately adjacent to or within the lower solids pond. These concentrations are considered indicative of tailings pore water chemistry, due to their proximity to the TMA, and not downstream groundwater quality. These values were used to validate source term concentrations derived for the TMA, but were not considered in evaluating radionuclide impact to groundwater down gradient of the TMA.

Values presented in Table 6.6 represent an upper bound for observed concentrations of parameters in groundwater at representative locations down gradient of the TMA.

As shown, all exposure concentrations are elevated when compared with SSWQO for irrigation and SDWQSO.

Claude & DJ Areas

Baseline Conditions

Groundwater monitoring locations in the Claude and DJ areas are relatively limited and focus primarily on areas immediately down gradient of the waste rock piles and ore bodies. Based on an examination of available groundwater chemistry data for the Claude and DJ area, it was determined that one monitoring station, located east of the Claude waste rock pile, near the Peter River, has not been impacted by mining activities, and is thus indicative of baseline groundwater conditions up gradient of the mine areas.

The areas, surrounding the Claude and DJ waste piles, indicating the greatest impact to groundwater quality are discussed in the following sections. Impact values discussed represent maximum impacts observed, based on emerging trends in parameter concentrations, in the Claude and DJ mine areas.

pH and Major Ions

The greatest change in pH of groundwater is noted in the area immediately east of the Claude waste pile. Values for samples collected from stations in this area are depressed with respect to base line conditions (5th percentile 6.80 units) and range to approximately 3.8 units.

Bicarbonate concentrations are depressed at exposure stations, with respect to baseline conditions. All remaining major ion concentrations are elevated relative to baseline conditions. The greatest concentrations correspond to monitoring stations located immediately east and south of the Claude waste pile.

Major ion concentrations encountered in these areas, demonstrating the greatest impact, are summarised in Table 6.7, below.

Table 6.7
Groundwater Concentrations Down Gradient of Claude Waste Pile
Baseline vs. Exposure – Major Ions

Parameter	Baseline Concentration	Exposure Concentration	SDWQSO
bicarbonate (mg/L)	156.8	1	na
magnesium (mg/L)	14.8	2 000	200
potassium (mg/L)	1.6	20	na
sodium (mg/L)	5.4	500	300
calcium (mg/L)	30.2	600	na
chloride (mg/L)	6.4	30	250
sulphate (mg/L)	4.1	6 000	500

The SDWQSO values listed in this table are all objectives and not standards.

The sodium exposure concentration is elevated when compared to the SSWQO for irrigation of 100 mg/L. Magnesium, sodium, and sulphate concentrations are elevated when compared to SDWQSO.

Trace Metals

With the exception of iron, the greatest concentrations of trace metals correspond to monitoring stations located immediately east and south of the Claude waste pile.

Iron concentrations are highest, and have been increasing over time, in groundwater collected from between the Claude and DJ waste piles. This area appears to be only marginally impacted with respect to other metals. Iron concentrations are generally depressed from background levels at those locations demonstrating a greater impact to groundwater chemistry with respect to other metals.

Concentrations of the above trace metals detected in these areas are summarized in Table 6.8, below.

Table 6.8
Groundwater Concentrations Down Gradient of Claude Waste Pile
Baseline vs. Exposure – Trace Metals

Parameter	Baseline Concentration	Exposure Concentration	SSWQO for Irrigation	SDWQSO (Note 1)
arsenic (mg/L)	0.0015	0.100	0.1	0.025
copper (mg/L)	0.017	1	0.2	na
iron (mg/L)	9.5	30[1] / 0.2 [2]	5	0.3
lead(mg/L)	0.008	0.1	0.2	0.01
manganese (mg/L)	0.272	300	0.2	0.05
molybdenum (mg/L)	0.003	0.04	0.01	Na
nickel (mg/L)	0.024	30	0.2	Na
zinc (mg/L)	0.128	6	1	5

1. Data from station HYD321
2. Data from remaining stations

As shown, both the baseline and exposure concentrations for iron and manganese are high relative to the SSWQO for irrigation and the SDWQSO. The manganese exposure concentrations are notably higher. The arsenic, lead and zinc exposure concentrations are high when compared to SDWQSO, while arsenic, copper, molybdenum, nickel, and zinc are at or above the SSWQO for irrigation.

Radionuclides

The greatest concentrations of Ra^{226} and uranium correspond to monitoring stations located immediately east and south of the Claude waste pile. Ra^{226} concentrations are approximately 0.2 Bq/L as compared to a baseline concentration of 0.025 Bq/L. Uranium is detected, at stations located at the base of the Claude waste pile, at mean concentrations up to approximately 150 mg/L; as compared with baseline concentrations of 0.055 mg/L. Both these values are elevated when compared with either SSWQO for irrigation or SDWQSO.

Summary of Groundwater Impacts

Localized groundwater impacts have been observed at both the TMA and adjacent to the waste rock piles.

Groundwater impacts in the TMA are concentrated downstream between the main dam and Snake Lake. Due to the proximity of the TMA and Snake Lake, the spacial extent is very limited.

As previously noted, groundwater monitoring has confirmed groundwater impacts at the perimeter of the Claude Waste rock pile. While elevated concentrations of both nickel and uranium are present, the spacial extent is also currently limited. Groundwater contamination in other areas of the site has been limited as result of maintaining dewatered conditions in both open pits and underground mines.

The groundwater may pose a risk to human and non-human biota if it is accessed for human consumption and use. The installation and use of wells for potable water use, irrigation or livestock watering is unlikely given the abundance of surface water in the local study area and the relative isolation of the site. Current site controls and the proposed institutional controls to prevent inappropriate use of contaminated groundwaters within the impacted areas, will further mitigate these risks.

On this basis, the environmental effects on groundwater resulting from operations are classified as adverse but not significant.

6.2.9 Morphology, Hydrology and Limnology

The Environmental Impact Statement for the Dominique-Janine Extension (Amok 1992) did not specifically predict the impacts of the project on the surface hydrology of the Cluff Lake Project area. It was, however, recognized that releases of treated effluent would result in increased flow within the Island Lake drainage, which would be most noticeable in the upper sections of the drainage.

Annual average daily flows from the STS were expected to be about 3500 m^3/day. It was acknowledged that such flows would result in a more uniform annual hydrograph within the drainage than under natural flow conditions. It was estimated that these flows would have little influence on lake elevation, which was estimated to increase by less than 2 cm at both Island Lake and Sandy Lake.

Actual discharges from the STS to Snake Creek above Island Lake averaged less than 3500 m^3/day over the operational period. However, it was noted that in the years prior to 1992, Island Lake surface water elevation had appeared to increase by approximately 20 cm due to an apparent increase in the wetland vegetation in certain areas of the fen immediately downstream of Island Lake. This lead to the development of a second channel between Island Lake and Agnes Lake, which is located immediately downstream of the fen.

The following sections provide an overview of the lake morphology and limnology and surface hydrology within the Cluff Lake Project area. Detailed data are presented in (COGEMA 2000d, Section 7.0).

Lake Morphology

The morphological characteristics of a lake have a significant influence on its physical, chemical, and biological parameters. These include the quality and quantity of habitat available to the fish resource.

Cluff Lake Drainage

Cluff Lake is the largest lake investigated within the study area (341 ha) and has the greatest maximum and mean depth with values of 52 m and 19.9 m, respectively. The large mean depth of Cluff Lake indicates that it is deep over a large portion of the lake.

By comparison, First to Fourth lakes are much smaller, ranging in size from 18.2 ha (Second Lake) to 42.2 ha (Fourth Lake). First Lake is the deepest of these lakes (21 m), followed by Third Lake (20 m). Mean depths of these lakes are comparable, varying from 4.92 m for Second Lake to 6.74 m for Third Lake.

Island Lake Drainage

Snake Lake is the smallest lake for which morphometric data are available (19.6 ha). Snake Lake has a maximum and mean depth of 2 and 1.8 m, respectively, indicating it has a uniform shallow and relatively flat bottom.

Island Lake is the second largest lake surveyed (181 ha). It has a maximum and mean depth of 2.2 and 1.5 m, respectively, indicating the lake is uniformly shallow and has a flat bottom.

Limnology

Limnological measurements have been taken from selected lakes in the Cluff Lake area at varying intervals from 1978 to 1999 (Tones 1979; Amok 1992; TAEM 1993; TAEM 1994; Appendix A).

Within the Cluff Lake drainage, Cluff Lake maintains high oxygen levels throughout its water column. First, Third, and Fourth lakes all develop low oxygen to anoxic conditions in their deeper regions during the summer months. Specific conductivity in the lakes in the Cluff Lake drainage has been low (as is typical for the region) through both the pre-operational and operational periods.

The Island Lake drainage, being the main receiving body of effluent release, has experienced the greatest change in conductivity from pre-operational to operational periods. There has been a marked increase in the specific conductivity in both Snake Lake (6.8 fold) and Island Lake (28 fold). There is some change in oxygen levels in this drainage during pre-operational to operational periods. While oxygen levels are typically high during the open-water period and reduced during ice cover, winter oxygen levels are believed to have remained relatively high up until recently as a result of continuous effluent releases from the STS.

Hydrology

A streamflow monitoring program was initiated in August 1997 to supplement the hydrological information for the site. The study area included the Cluff Creek drainage and the Island Creek drainage. Streamflow monitoring stations were installed in the Island Creek drainage and in the Cluff Creek drainage. Staff gauges were also established at several lakes in both drainage areas. Stage-discharge rating curves were developed and, in order to gain an understanding of long-term flow patterns, streamflow records were extended using the long-term record from the Douglas River streamflow monitoring location managed by the Water Survey of Canada. A summary of streamflow in the Cluff Lake region is provided below.

Streamflow

A review of streamflow monitoring data shows a difference in the peak and timeline when comparing the Cluff Lake and Island Lake drainage basin. Peak flows at Cluff Creek downstream of Cluff Lake are slightly delayed and do not recede as quickly as those occurring at Island Creek below Island Lake. This is likely a function of the larger drainage area associated with Cluff Creek and also the attenuating effect of Cluff Lake. When peak flows are standardized on a unit area basis, runoff rates were similar for the Douglas River, Cluff Creek, and Island Creek during that time. Once all available storage within the watersheds has been filled, runoff volumes become more a function of precipitation and drainage area.

The long-term annual mean discharge for Island Creek is estimated at 0.235 m^3/s, while the data indicates that the long-term annual mean flow for Cluff Creek below Cluff Lake is 0.612 m^3/s. On a unit area yield basis, this translates to 0.0028 $m^3/s/km^2$ and 0.0035 $m^3/s/km^2$ for Island Creek and Cluff Creek, respectively. The different runoff rates for the two adjacent drainages are summarized in Table 6.9, below.

Table 6.9
Unit Area Runoff Estimates at Various Locations within the Cluff Lake Project Area

Branch Description	Unit Area Runoff ($m^3/s/km^2$)	Unit Area Runoff as Precipitation (mm/yr)
Island Creek Drainage		
Snake Lake Outlet	0.0028	88
Island Lake Inlet	0.0028	88
Island Lake Outlet	0.0028	88
Agnes Lake Inlet	0.0016	51
Agnes Lake Outlet	0.0023	74
Island Creek Outlet at Sandy Lake	0.0028	88
Cluff Creek Drainage		
Outlet of Claude Lake	0.0031	98
Claude Creek Upstream of Peter River Confluence	0.0031	98
Peter River at Claude Creek	0.0031	98
Earl Creek Upstream of Peter River	0.0025	79
Boulder Creek at Inlet to Cluff Lake	0.0019	59
Cluff Creek at Cluff Lake Outlet	0.0035	110
Cluff Creek Outlet to Douglas River	0.0035	110
Douglas River Drainage		
Sandy Lake Inlet from Douglas River	0.0059	186
Sandy Lake Outlet	0.0059	186

Summary of Hydrological Impacts

The DJX environmental assessment (Amok 1992) did not specifically predict the impacts of the project on the surface hydrology of the Cluff Lake Project area. It was, however, recognized that releases of treated effluent would result in increased flow within the Island Lake drainage, which would be most noticeable in the upper sections of the drainage. Annual average daily flows from the STS were expected to be about 3500 m^3/day. It was acknowledged that such flows would result in a more uniform annual hydrograph within the drainage than under natural flow conditions and a slight increase in water elevation.

Average discharge from the STS over the period 1993 to 1999 was 3190 m^3/day. The average discharge has decreased since then. The effluent discharges are slightly lower than the 3500 m^3/day predicted in the DJX environmental assessment. A more uniform hydrograph within Island Creek did result from this discharge until most recently when the gradual reduction in operations lead to reductions in water consumption and more intermittent operation of the STS. This had an effect on both water levels and dissolved oxygen concentrations. As noted earlier, the Island Lake water elevation increased above the predicted elevation likely as a result of increases in wetland vegetation at the outlet of the lake leading to some restrictions in flow and subsequently increases in elevation. The continuous discharge also helped to maintain elevated oxygen concentrations through the winter months. This assisted in the overwintering of fish and reduced the potential for winter fish-kills throughout most of the operation up until recently.

In the Cluff Lake watershed, the physical disruption of the hydrologic regime is associated with the diversion of Boulder Creek and Claude Creek and the loss of surface flow associated with the maintenance of dewatered conditions in the mining area and mill freshwater utilization. These disruptions to the hydrologic regime are minor, relative to the variability in the natural flow regime, and are generally reversible on cessation of operations including the reflooding of the mines and pits to re-establish the water table and the reduction (and eventual cessation) of freshwater utilization at the mill.

The hydrological changes in both the Cluff Lake and Island Lake watershed have limited magnitude and spatial extent. The changes are generally reversible on cessation of operations when the dewatering activities in the mining area cease and the diversion of water from Cluff Lake to support the operations and decommissioning activities will also cease. On the application of criteria recommended in the Canadian Environmental Assessment Agency guidance documents, the environmental effects on hydrology during the operational period would be classified as adverse but not significant.

6.2.10 Surface Water Quality

Surface water samples have been collected at a number of monitoring stations in receiving waters potentially impacted by Cluff Lake mining operations and flooded pits. Pit water quality has already been addressed in section 6.1.1 and in more detail in COGEMA 2000e, Appendix E.

Changes in water quality in the Cluff Lake Project surface waterbodies have been periodically evaluated in the Status of the Environment (SOE) reports. Three such reports have been completed for the Cluff Lake Project (Swanson 1991; TAEM and Senes 1995; COGEMA 2000f). This section builds on the assessment of recent data presented in COGEMA 2000a and COGEMA 2000d by providing comparisons to original pre-operational baseline data, where available, and to water quality predictions made within environmental impact assessments of Cluff Lake Project developments. The Saskatchewan Surface Water Quality Objectives are also utilized to assess the current water quality within the Project Area.

Cluff Lake Drainage Basin

The DJX environmental assessment (Amok 1992) predicted moderate water quality impacts to Cluff Lake. The DJX development proposal included the construction of a berm in Cluff Lake to facilitate access to the ore deposit. Water quality issues related to the proposed development included siltation and contaminant leaching from berm construction materials. During the licensing phase, the proposed development plan was modified, approved, and the requirement to build a berm structure in Cluff Lake was no longer required.

Within the Cluff Lake drainage basin, potentially impacted streams include the Claude Creek, Peter River, Earl Creek and Boulder Creek flow into Cluff Lake. These streams do not receive any direct effluent or minewater discharge. However, they are adjacent to both open-pit and underground mines, waste rock piles, and access roads. Surface water quality monitoring is conducted in these waterbodies to identify potential groundwater or seepage impacts from mining operations. The D-Pit mine is located upstream of Cluff Lake adjacent to Boulder Creek. D-Pit is flooded but not connected to Boulder Creek.

Boulder Creek

Boulder Creek water quality monitoring has occurred upstream and downstream of the D-Pit development. The comparison of upstream and downstream water quality, and pre-operational baseline water quality indicates the current influence of mining activity in the drainage is negligible, with current water quality typical of background conditions. SSWQO exceedences for iron occurred at both upstream and downstream monitoring locations, indicating iron concentrations tend to be naturally elevated, and that the exceedences are not related to mining activity. With the exception of the occasional exceedence of iron concentrations, water quality in Boulder Creek is well within SSWQOs and typical of pre-operational water quality.

Peter River

Peter River water quality monitoring has occurred upstream and downstream of the mine related activities, including the D-P underground and waste rock areas. The comparison of upstream and downstream water quality and pre-operational baseline water quality indicates the influence of mining activities within this drainage is minor, with current water quality generally typical of background conditions. There were no exceedences of SSWQO over the 1995 to 2002 period. Relative to upstream and baseline water quality, elevated sulphate concentrations were apparent at the downstream monitoring location in the Peter River. It was previously postulated that this difference was a measurable indication of acidic drainage, presumably, from waste rock piles draining into the Peter River (TAEM and Senes 1995). The current influence on water quality, although adverse, is not considered significant.

Earl Creek

Earl Creek water quality monitoring has occurred upstream and downstream of mining activities, including the cement batch plant. The comparison of upstream and downstream water quality and pre-operational baseline water quality indicates the influence of mining activities within the drainage is negligible; with current water quality generally typical of background conditions. Some increased concentrations of calcium, bicarbonate, magnesium, and associated increases in total alkalinity, total hardness, total dissolved solids, and specific conductivity were noted between upstream and downstream monitoring locations. Iron concentrations occasionally exceeded the SSWQO for iron of 1 mg/L, however, such exceedences typically occur upstream of the area impacted by the project, and thus appear to represent natural background conditions.

The noted upstream/downstream differences are similar to those reported by Swanson (1991) and TAEM and Senes (1995) in which disturbances due to the operation of a cement batch plant and runoff from the plant site were cited as possible contributors to the differences in water quality. Despite the noted differences between upstream and downstream water quality, concentrations are still generally within the range of background for the area.

Claude Creek

Claude Creek water quality monitoring has occurred at Claude Lake outlet. Claude Creek water quality is typical of pre-operational conditions and meets the SSWQO with the exception of iron which is naturally high. This is consistent with the previous findings of Swanson (1991) and TAEM and Senes (1995) which reported there were no indications of any changes from pre-operational water quality in Claude Creek.

Cluff Lake

Cluff Lake water quality monitoring has occurred at Cluff Lake outlet. Statistical analysis identified a slight increase in sulphate during the 1990 to 1999 monitoring period. More recent monitoring indicates stable concentrations similar to those observed in 1999. Sulphate levels are still considered low and although they represent an adverse effect, this effect is not significant.

Summary of Surface Water Quality Impacts in the Cluff Lake Drainage

Due to the modification of DJX project development, actual water quality impacts within the Cluff Lake drainage are substantially less than those predicted in the DJX Environmental Impact Statement. This was largely due to the modification of the project development plan which negated the need for a berm structure in Cluff Lake. The water quality changes noted do not represent significant water quality impacts from mining operations within the Cluff Lake drainage. The moderate impacts predicted in the DJX environmental assessment were not realized during the operational period.

The increase in sulfate concentrations in both the Peter River and Cluff Lake are well below any level of concern. These operational effects are therefore considered adverse but not significant.

Island Creek Drainage Basin

The DJX project development environmental assessment classified the predicted water quality impacts within the Island Lake drainage as moderate. In Snake Lake, average annual TDS, sulphate, and chloride levels were predicted to be 3,610 mg/L, 1,560 mg/L, and 820 mg/L, respectively. In Island Lake, average annual TDS, sulphate, and chloride levels were expected to be 5,470 mg/L, 2,380 mg/L, and 1,250 mg/L, respectively. Heavy metals and radionuclides concentrations were expected to be less than the MMLER regulatory limits applicable to effluent releases (Swanson, 1991). Changes in water quality in Sandy Lake were predicted to be minor. In the Douglas River, downstream of Sandy Lake, predicted average annual concentrations of TDS, sulphate, and chloride were 135 mg/L, 10 mg/L and 40 mg/L, respectively.

Snake Lake

Snake Lake is located upstream of the secondary treatment system (STS) discharge and receives no direct effluent discharge. It is subject to seepage of partially-treated tailings water from the liquids pond and to seepage of tailings porewater under the main dam, both of which were predicted and assessed under the design operational conditions.

A comparison of recent (1994-99) water quality to pre-operational data indicates increased major ion concentrations in Snake Lake water. Over the 1995 to 1999 period, there was a slight increase in the average annual concentration of most major ions, TDS and conductivity. A similar trend was noted for data covering the 1989 to 1994 period (TAEM and Senes 1995). Average annual concentrations of these parameters in 1999 were similar to 1995 levels with the years 1996 to 1998 showing slightly lower average annual concentrations. In 1999, the mean annual concentrations of TDS, sulphate, and chloride were 718 mg/L, 235 mg/L, and 174 mg/L, respectively. More recent data for 2002 shows similar mean concentrations of TDS, sulphate, and chloride; which were 691 mg/L, 243 mg/L, and 168 mg/L, respectively.

Snake Lake also experienced a temporary increase in Ra^{226} concentration due to the inadvertent use of a contaminated pipeline in 1997 and 1998 for the diversion of freshwater around the TMA. Total Ra^{226} concentration began rising at the outlet of Snake Lake (Station ISL2000S) in May 1997, reaching a maximum value of 0.15 Bq/L in February 1998. Historically Ra^{226} concentrations at the outlet were in the range of 0.02 to 0.04 Bq/L. The Saskatchewan Surface Water Quality Objective (SSWQO) for Ra^{226} is 0.11 Bq/L.

As a follow-up to this incident, the potential impacts of Ra^{226} on the biota of Snake Lake and the Island Lake drainage system were evaluated by calculating the dose for both Ra^{226} alone and for Ra^{226} in association with Pb^{210} and Po^{210}. Those estimates were compared to the dose level below which populations effects to aquatic biota would not be anticipated. It was concluded that elevated Ra^{226} levels in Snake Lake would not result in adverse impact on aquatic biota within Snake Lake or in the Island Lake drainage system.

With the extraneous source of Ra^{226} terminated, the water quality in Snake Lake has returned to near pre-1997 levels with the mean Ra^{226} concentration in 2002 being 0.05 Bq/L.

Island Lake

Island Lake is the first water body downstream of the STS effluent discharge point. Final effluent from STS is discharged to Snake Creek, which flows into Island Lake. As such, Island Lake is the most adversely affected surface waterbody at Cluff Lake.

As predicted, contaminant concentrations in Island Lake increased appreciably from pre-mining conditions. Sulphate, chloride, calcium, sodium, uranium, and TDS all increased substantially from pre-mining conditions. Baseline concentrations for TDS, sulphate, and chloride were 77 mg/L, 1.2 mg/L, and 5 mg/L, respectively. In 1999, the mean annual concentrations of TDS, sulphate, and chloride in Island Lake were 2868 mg/L, 1157 mg/L, and 641 mg/L, respectively. By 2002, TDS, sulphate, and chloride values had increased to 3333 mg/L, 1289 mg/L, and 875 mg/L, respectively. Effluent discharges from the STS lead to considerable salts loading to the Snake Creek and downstream Island Lake. These changes have resulted in appreciable increases in salinity of the lake which may have affected the ecology of the lake.

Uranium increased from < 1 μg/L baseline to a mean concentration of 248 μg/L in 2002. However, the hardness level also increased substantially (baseline of 34 mg/L vs. mean of 1207 mg/L in 2002) which is believed to reduce uranium toxicity. This relationship was used in establishing the decommissioning water quality objectives discussed in section 7 and is also a key component of the follow-up monitoring program presented in section 10.

Of most concern is molybdenum, which increased from baseline values of 0.005 mg/L to current values of 1.2 mg/L. While there is no SSWQO value for molybdenum and no effluent discharge limits for molybdenum, more recent research suggests that currently measured molybdenum concentrations may have contributed to some of the observed changes in the aquatic biota in Island Lake. This is discussed further in section 6.2.14 and has been considered in the establishing the long term water quality objectives as noted in section 7.

There were also slight increases in Total Kjeldahl Nitrogen (TKN), total calculated nitrogen, and total phosphorus. These increases are not statistically significant and are indicative of the conditions in Island Lake over the past 15 years (TAEM and Senes 1995).

Sandy Lake

Sandy Lake is the confluence of the Island Creek drainage system and the Douglas River. Water samples are collected at the inlet of Sandy Lake where the Douglas River enters and at the outlet of Sandy Lake where the Douglas River exits. By comparing the water quality in the Douglas River upstream and downstream of Sandy Lake, any changes associated with flows from the Island Creek drainage system can be assessed.

No statistically significant differences in water quality were apparent between locations upstream and downstream of Douglas River. Differences between current and pre-operational water quality generally tend to fall within the range of background variability. Relative to pre-operational water quality, slightly elevated concentrations of TDS (113 mg/L), sulphate (6.2 mg/L), and chloride (31 mg/L) were apparent at the Sandy Lake outlet in 2002. All parameters measured, both upstream and downstream, were below the respective SSWQO.

Summary of Surface Water Quality Impacts for Island Creek Drainage

Within the Island Creek watershed, water quality impacts were predicted to be moderate, consisting of increased concentrations of major ions and trace elements. The current TDS, sulphate, and chloride concentrations are less than the predicted concentrations, while trace element concentrations are well below the historic MMLER guidelines applicable to effluents, which were presented as maximum predicted concentrations within the watershed. Thus, observed water quality impacts in the Island Creek drainage during the operational period are consistent with, or less than the impacts predicted during project development environmental assessments overseen by the Regulatory Agencies.

The surface water quality impacts are concentrated in Island Lake with limited migration further downstream. With the eventual cessation of effluent discharges, water quality is expected to improve. Concentrations fall within the SSWQO values with some concern due to elevated concentrations of uranium and molybdenum. Due to the limited spatial extent and magnitude, the environmental effects, due to operations, to surface water quality in Island Lake are considered adverse but not significant.

6.2.11 Sediment Quality

A number of sediment sampling programs have been completed in the Cluff Lake project area during both the pre-operational and operational phases. The technical supporting document (COGEMA 2000) can be consulted for a detailed review of the results for all of the waterbodies and sampling periods. Discussions, herein, will be limited to the primary waterbodies of interest, Cluff Lake, Snake Lake, Island Lake, and Sandy Lake.

The most recent comprehensive sediment sampling program was completed in 1998. This data was considered to adequately reflect present conditions in the Cluff Lake drainage due to the low sedimentation rate and the lack of any significant operational contaminant releases to this drainage. The 1998 data was not considered adequate for the Island Lake drainage as a substantial volume of treated mill effluent has been released since 1998. To account for this, the additional sediment accumulation was modeled (see COGEMA 2001). Hence, for the Island Lake drainage, the sediment concentrations discussed in this section of the CSR are the peak concentrations predicted to occur up to the end of the operational phase of the facility (i.e. 2002).

The environmental significance of changes in sediment quality will be assessed using the available sediment guidelines. In this manner, the sediments can be classified with respect to specific metal contaminants and their potential for effects on benthic organisms. These general guidelines provide a range from low contaminant concentrations to high (Table 7.2). Sediments with concentrations below the lower range (e.g., LEL, TEL, ERL, NOEC) are considered to require no further assessment. Sediments exceeding the upper boundaries represent sediments that would be considered to be highly contaminated.

It is not unusual for natural sediments in the Canadian Shield, especially those associated with commercial ore bodies to exceed the lower guideline levels. Hence, sediments exceeding the lower guideline ranges are compared to available regional baseline data and their position relative to the lower and upper guideline boundaries. At present, there are no guidelines for molybdenum, or uranium; however, recent studies (Thompson et al., 2003; Long et al., 1995) provide toxicity benchmarks which can be used to assess these metals. Radionuclides are not discussed within this section as sediment quality is best assessed by calculating overall radiation dose from the combined exposure to multiple radionuclides rather than through the use of individual contaminant sediment quality guidelines. This assessment was completed for the post-decommissioning stage and is provided in section 9.2.5 and 9.2.6.

Cluff Lake

Cluff Lake sediments have elevated concentrations of arsenic, lead, nickel, zinc, uranium, and Ra^{226} when compared to local and regional reference locations. A comparison to documented pre-operational concentrations indicates the nickel, Ra^{226}, and uranium concentrations are natural (Dunn 1980). The documented lead and nickel concentrations were near or below the available lower effects threshold guideline concentrations and hence, are of no significant concern.

The 1998 arsenic concentrations are slightly greater than local baseline concentrations, exceeds the CCME upper threshold (PEL) guideline, and is similar to the Ontario MOE upper threshold. However, the upper range in natural regional arsenic concentrations also exceed these upper threshold guidelines indicating they may not be applicable to this region. The peak recorded arsenic concentrations fall in the lower range of concentrations proposed for uranium bearing regions (Thompson et al 2003), indicating they are likely not a major concern. In addition, the lack of any activities within the Cluff Lake drainage that would be capable of substantially increasing arsenic concentrations suggests the measured concentrations are indicative of natural spatial heterogeneity rather than the influence of Cluff Lake Project development. Hence, the available data shows that Cluff Lake sediments have not been impacted by operational activities.

Island Lake Drainage

Snake Lake

The only sediment contaminants to have increased during the operational period in this waterbody were uranium and Ra^{226}. The most recent analyses (1998) documented mean uranium and Ra^{226} concentrations of 36 µg/g (SD=14.5) and 0.608 Bq/g (SD=0.3), respectively. While uranium may have increased in the sediments, values are well below the low effects guideline (Table 7.2) and are unlikely to pose a threat to benthic organisms. Ra^{226} concentrations remained relatively constant up to the 1993 sampling period. The present elevated Ra^{226} levels are primarily the result of a "spill event" involving the use of a tailings contaminated pipe in the years prior to the 1998 sampling. Follow-up investigations including radiation dose calculations indicated that the increased radionuclide levels posed no risk to benthic invertebrates (COGEMA 2000a).

Island Lake

As previously mentioned, the 1998 sampling was not considered to be representative of the sediment quality to be expected immediately prior to decommissioning due to the continuation of operations between 1998 and 2002. The additional contaminant accumulation was modeled to include the effects of the remaining operational releases of effluent and the recovery predicted to occur after decommissioning and the associated cessation of effluent releases. Since the majority of this modeling involves the post-decommissioning period, the associated figures and tables are provided in section 9. In Island Lake, the peak contaminant concentrations are predicted to occur at the end of the operational period (pre-decommissioning) and decrease post-decommissioning, as shown in Figure 9.6. The environmental state discussed in the following paragraphs covers the pre-decommissioning period.

As predicted within the original EIS, operational releases to Island Lake have resulted in the accumulation of contaminants within sediment. At the end of the operational period the predicted levels of arsenic, copper, lead and zinc are near or below their respective low threshold guidelines (Table 7.2) for both the 50th and 95th percentiles. Hence, in Island Lake, these contaminants are not considered to be contaminants of potential concern (COPC).

In contrast, predicted molybdenum, nickel, selenium and uranium levels exceed benchmark values. Of these three contaminants, predicted 50th percentile concentrations for all but selenium are well below upper threshold guidelines. Based on these results, effects on the benthic community would be expected though significant effects would not be expected. This conclusion is supported by benthic macroinvertebrate data for Island Lake (COGEMA 2000f). These data indicate near-normal total abundance; however, there has been a substantial shift in the benthic species towards metal-tolerant chironomids. Discussions relating to sediment selenium toxicity are presented in section 6.2.14 as selenium concerns are primarily related to fishes and are best assessed using tissue rather than sediment guidelines.

Sandy Lake

Of the monitored metals and radionuclides, only uranium and Ra^{226} exhibit measurable sediment accumulation. The mean uranium concentration (9.5 µg/g) is slightly elevated relative to pre-operational levels (0.96 µg/g), but is within the range of values measured in First through Fourth Lakes. It is well below the low effects level guideline of 104 µg/g (see Table 7.2) and would not be expected to harm resident biota. Sediment Ra^{226} levels were slightly elevated in 1998 (0.46 Bq/g) compared to the pre-operational period (0.36 Bq/g). Given that there have been no measurable changes in surface water quality in Sandy Lake over the operating period, the sediment quality results for Sandy Lake are likely representative of the natural spatial heterogeneity. These levels pose no radiation risk to resident biota (see section 9.2.6).

Summary of Sediment Quality Impacts

Based on the monitoring data, changes in sediment quality are apparent within the Island Lake drainage. These adverse changes are most evident in Island Lake and Snake Lake. Sediment quality is generally within the range of sediment quality predicted in the Dominique-Janine extension EA (TAEM and Senes 1995) with the exception of sediment arsenic and nickel concentrations in Island Lake, which are somewhat elevated relative to those predicted. The significance of these effects is discussed in further detail in section 6.2.14 and section 9.

6.2.12 Ecological Field Studies

Aquatic Communities

Over the operational history of the facility, several aspects of aquatic ecology have been studied including phytoplankton, aquatic macrophytes, zooplankton, benthic macroinvertebrates, fisheries resources, and fish habitat. The results of these field studies are summarized in the following paragraphs. More details can be found in Swanson 1991; TAEM and SENES 1995; COGEMA 2000f.

Fish and benthic invertebrate communities in Island Lake and Cluff Lake have been the primary focus of monitoring activities. Island Lake and Agnes Lake support a very simple fish community consisting of northern pike and white sucker. The fish community of Cluff Lake is somewhat more diverse consisting of ten species. The Sandy Lake fish community is comprised of eight species. Northern pike and white sucker are species common to all of these lakes and throughout northern Saskatchewan. Lake whitefish is found in Cluff Lake and Sandy Lake.

Monitoring indicates the aquatic macrophyte communities in the Island Lake drainage basin have been moderately affected during the operational phase, as demonstrated by changes in species composition and evidence of uranium, Se, and Ra^{226} bioaccumulation. The species composition of zooplankton communities in Island Lake have also changed. Island Lake benthic communities, while maintaining similar total abundance to reference study areas, exhibit a substantial shift in community composition to fewer taxa consisting of more metal-tolerant species. Snake Lake benthic invertebrate communities have also illustrated some changes in species composition. Sediment toxicity tests indicate low toxicity. Invertebrate trace metal and radionuclide levels have not shown any significant bioaccumulation. In Cluff Lake, benthic macroinvertebrate communities do not appear to have been affected by mining activities. These effects are consistent with environmental assessment impact predictions.

Monitoring of fish communities has consisted of measurements of abundance, community composition and relative biomass, and trace metal and radionuclide accumulation in muscle and bone. The monitoring results suggest a shift in Island Lake fish community composition from a community dominated by northern pike, to one dominated by white sucker. Monitoring has also illustrated some evidence of the bioaccumulation of some trace elements, in particular selenium, in fish tissue in Island Lake.

Terrestrial Ecology

The development of the Cluff Lake Project has resulted in approximately 418 ha of land disturbance, but sensitive habitats identified as supporting rare plants have remained undisturbed. Wildlife utilization outside of the immediate development area appears to be similar to that which existed prior to project development.

Monitoring of soil has indicated some bioaccumulation of radionuclides and trace metals in the soil east and southeast of the mill, but levels in vegetation samples are within the range for plants collected from unimpacted areas in northern Saskatchewan. No bioaccumulation was evident in limited small mammal studies.

Summary of Ecological Impacts

The ecological impacts are limited to Island Lake and Snake Lake where adverse effects on species composition and evidence of bio-accumulation have been observed. The significance of these effects are discussed in further detail in section 6.2.14 and section 9.

6.2.13 Valued Ecosystem Components

A Valued Ecosystem Component (VEC) is defined as “an environmental attribute or component perceived as important for social, cultural, economic or ecological reasons, and identified through consultation with affected people and through scientific opinion” (Lee et al., 1992). The VECs to conduct this EA were chosen based on their expected presence in the Cluff Lake surroundings, and their ecological and cultural significance to the area.

These valued ecosystem components were used in the risk assessment to characterize potential effects from current operations and the decommissioning project. Tables 6.10 and 6.11 provide the aquatic and terrestrial VECs used in the risk assessment. Details of the risk assessment are discussed in the following section and section 9.

Table 6.10
Summary of the VECs for Specific Aquatic Habitats

Lake	Aquatic Environment VEC						
	Pond Weed	Phyto-plankton	Benthic Invertebrate	Zoo-plankton	Northern Pike	Lake Whitefish	White Sucker
Snake Lake	X	X	X	X	X		X
Island Lake	X	X	X	X	X		X
Fen	X	X	X				
Agnes Lake	X	X	X	X	X		X
Sandy Lake	X	X	X	X	X	X	X
Cluff Lake	X	X	X	X	X	X	X

Table 6.11
Summary of the Selected VECs for the Terrestrial Environment

HERBIVORE
- Woodland caribou
- Moose
- Ptarmigan
- Snowshoe hare

OMNIVORE
- Black bear
- Muskrat
- Ducks
  - Scaup
  - Mallard
  - Merganser

CARNIVORE
- Wolf
- Bald Eagle
- Otter

6.2.14 Traditional and Recent Land Use

The Cluff Lake site, as a result of its remote location, has limited access. The establishment of the mine site, the construction of the onsite airstrip and the upgrades to Highway 955, while facilitating site access, has not lead to major increases in public access to the site.

Traditionally, the site was seasonally accessed by an aboriginal trapper who maintained a commercial trap line in the local study area. The trapper also hunted and fished for personal consumption. There is no evidence of any other site activities by aboriginal or non-aboriginal peoples prior to site development. Throughout the Cluff Lake project history, this same trapper has continued to trap within the Cluff Lake site. The trapper has maintained cabins at both Cluff Lake and Sandy Lake. In addition, more recently, an outfitter also established a fishing/hunting lodge on the shore of Carswell Lake, approximately 20 km north of the site. While some fishing has occurred on Cluff Lake, limitations on both fish species and abundance of fish, has resulted in most fishing being concentrated on the nearby Sandy and Carswell lakes. Gathering and consumption of locally available low bush cranberries, blueberries and mushrooms has also been conducted throughout the project history.

While no hunting is permitted on site, access through the site has been permitted for visitors seeking to access the Sandy Lake area in the fall during the moose hunting season.

6.2.15 Island Lake Post-Operation Risk Assessment

Of all the natural waterbodies associated with the Cluff Lake facility, Island Lake and the associated fen and riparian habitats are the only areas to have accumulated contaminants over the operational period to levels of potential concern to aquatic and terrestrial biota. For this reason an ecological risk assessment (ERA) was completed for Island Lake to assess the existing risk to aquatic and terrestrial biota (VECs) at the end of the operation (pre-decommissioning). This establishes the baseline conditions against which recovery or any additional impacts associated with decommissioning activities are measured. The overall ERA for assessing potential decommissioning options and the long-term recovery of the environment is documented in section 9. Rather than duplicating the tables and figures this section will refer to the tables and figures in section 9.

For interpretation of the pattern of declining risk through time, screening indices were calculated for current conditions resulting from operational activities (approximate year 2000) and for conditions at two post-decommissioning time intervals (2009, 2050) for aquatic and terrestrial VECs. An additional set of screening indices (year 2100) were calculated for terrestrial VECs. This section addresses the current conditions at the end of operations and prior to decommissioning. The results of the post decommissioning assessment are presented in section 9. The assessment was completed using the probabilistic method; hence the results are presented as the 50th and 95th percentile predicted risks. Chapter 9 of this document and the technical supporting documents (COGEMA, 2000d, Appendix B, and COGEMA, 2002b) present additional details on the modeling and a more comprehensive discussion of the most sensitive model parameters.

Aquatic Biota

The aquatic VECs in this assessment consisted of simplified representatives of several trophic levels in a typical lake ecosystem. They included primary producers (algae and aquatic macrophytes), primary consumer (zooplankton), detritivores (benthic invertebrates), and secondary consumers (northern pike and white sucker). Risks to aquatic biota from water-borne contaminants are addressed in this section. The risks to biota from exposure to sediment-bound contaminants have been presented in section 6.2.11. Aquatic mammals and birds are included in the terrestrial biota assessment.

The results of the calculations for Island Lake are presented in Table 9.7 in the form of screening indices consisting of the ratio of the predicted peak exposure concentration (i.e., water) to the benchmark value. Screening indices above 1 indicate a potential for an impact to an individual or population. No risk quotients exceeded 1 for the following contaminants: ammonia, arsenic, cobalt, lead, selenium, and zinc.

Hence, these water-borne contaminants are considered to pose no risk to aquatic organisms in Island Lake. Dose modeling also indicated that there was no radiation risk from radionuclides accumulated in Island Lake. Please see section 9.2.6.1 for additional information on the calculation of radiation dose.

The screening indices for the 95th percentile concentration of copper indicate the potential for impacts to primary producers and fishes. However, it is evident from the indices calculated for regional background copper concentrations, that copper levels in these lakes are naturally above the toxicity benchmarks for these VECs. This conclusion is supported by baseline work in the Cigar Lake and McArthur River mine areas where natural copper concentrations ranged up to 0.005 and 0.008 mg/L respectively (CLMC 1995). These concentrations substantially exceed the modeled peak 50th percentile with the McArthur value exceeding the 95th percentile (0.0074 mg/L) exposure assessment. Hence, copper exposures are unlikely to pose a threat to the native aquatic biota.

The risk assessment indicates that Island Lake nickel concentrations pose a risk to phytoplankton. However, this risk quotient is primarily a result of the use of a conservative toxicity benchmark (0.005 mg/L). The similarity between the risk quotients for background and exposure lakes and the fact that modeled exposure concentrations are less than the CCME water quality guideline of 0.025 mg/L (CCME guidelines are considered to be protective of aquatic life in general), suggests the assessment was overly conservative and that nickel concentrations pose little risk.

Screening index values based on predicted peak (50th and 95th percentile) uranium concentrations are above 1 for primary producers, zooplankton and white sucker (Table 9.7). The uranium screening indices were calculated without considering the ameliorating effects of hardness on uranium toxicity (See section 7.1.2). Incorporating natural hardness into the toxicity benchmark would remove white sucker from the potential effect list. The screening indices for plankton would be substantially lower, but would continue to exceed one. This assessment is supported by the previously discussed operational environmental monitoring data which concluded that there had been a shift in plankton community composition in Island Lake.

Molybdenum is the other effluent constituant that may have contributed to the documented shifts in the aquatic community of Island Lake. Both the 50th and 95th percentile predicted peak concentrations pose a risk to zooplankton and northern pike (Table 9.7). The monitoring program supports the risk calculations as Island Lake has seen a shift in zooplankton species composition and an apparent decrease in northern pike abundance (section 6.2.12).

As previously mentioned, the risk modeling indicates that water-borne selenium poses no risk to aquatic biota in Island Lake (Table 9.7). However, it is well recognized that water based selenium toxicity benchmarks are a poor means of assessing risks from selenium (Sappington 2002). The sediment data indicate that elevated selenium concentrations are present in Island Lake. Fish tissues, the preferred means of assessing potential risks from selenium, show bioaccumulation above levels of potential concern in fish collected from Island Lake and Snake Lake (COGEMA 2001).

Fish flesh concentrations in northern pike and white sucker collected from Island Lake in 1999 showed mean selenium concentrations of 27.45 µg/g and 16.82 µg/g on a dry weight basis. Fish flesh concentrations in northern pike and white sucker collected from Snake Lake in 1999 showed mean selenium concentrations of 12.55 µg/g and 7.62 µg/g dry weight. These values fall within or above the range of values (6-12 µg/g dry weight) considered by Lemly (1998) to be biological effects thresholds.

The elevated soft tissue selenium concentrations in Island Lake northern pike and white sucker indicate that selenium is a contaminant of concern in the treated water effluent. In 2002, the mean selenium concentration in effluent discharge from the STS was 0.031 mg/L. The elevated selenium concentrations in Snake Lake northern pike and white sucker soft tissues is somewhat surprising given that recent monitoring indicates both water and sediment selenium concentrations in Snake Lake are at their respective detection limits (0.001 mg/L and 0.5 µg/g dw, respectively). It is assumed that the release of treated effluent into Snake Creek just below the Snake Lake discharge and the movement of fish between Snake Lake and Island Lake accounts for the Snake Lake fish tissue levels.

In order to properly assess the impacts to fish populations, Lemly (1998) recommends that studies of teratogenic deformities in fish early life stages be undertaken. COGEMA has initiated specific studies to evaluate the potential risks to fish from selenium. These involve the collection of gametes from Island Lake fish for fertilization and laboratory rearing to directly measure the rate, if any, of teratogenic deformities. These special investigations will be incorporated into the follow-up program as outlined in section 10.

Terrestrial Biota

The following paragraphs address the results of a Tier 2 assessment of impacts from non-radionuclides and radionuclides on terrestrial VECs exposed to contaminants in Island Lake and the surrounding fen and riparian habitats. This analysis quantified the risk to wildlife drinking water, foraging for food, and ingesting soil/sediment, calculated from predicted pre-decommissioning contaminant concentrations in water, prey items, vegetation, sediment or soil. For wide-ranging or migratory species, diets were adjusted for expected use of the impacted areas (e.g. waterfowl were assumed to be exposed for six months of the year, COGEMA 2000d, Sub-Appendix B3). As only limited site-specific data were available for most parameters (especially for specifying probability distributions), wildlife risk estimates were highly dependent on modeled water and soil/sediment concentrations, and their associated diet transfer factors.

At Island Lake, screening indices were all below one for current and future conditions for arsenic, cobalt, copper, lead, nickel, and zinc (Table 9.10). Slightly elevated risk quotients were determined for a few species (mallard, scaup, muskrat, otter) due to exposure to selenium.

Extreme screening indices were found initially in the Tier I analysis for molybdenum and uranium at Island Lake (COGEMA, 2001) for several species. In the realistic Tier 2 analysis (Table 9.10), screening indices for both elements dropped by orders of magnitude, and hence, only a few risk estimates for molybdenum (mallard, scaup, muskrat, otter) remained above one for the pre-decommissioning conditions. The differences between Tier 1 and Tier 2 results for these two important elements and their interpretation are discussed in detail in section 9.

6.3 Summary of Operational Impacts

The predicted operational impacts as originally presented and classified in the environmental assessment documentation are summarized by environmental component in Table 6.12. For each predicted impact, the available operational monitoring results were examined and the actual impacts summarized and classified. As illustrated by this comparison, actual impacts are generally similar, or less than those predicted at the time the developments were originally assessed.

The most important impact, as predicted, occurred in Island Lake, where the twenty some years of effluent discharge has resulted in accumulation of contaminants well above natural background concentrations in the aquatic system and the associated terrestrial habitats such as the surrounding riparian habitat and the Island Lake fen. The pre-decommissioning risk assessment for Island Lake indicates that the operational releases have resulted in the accumulation of contaminants to levels that pose some risk to resident aquatic and terrestrial biota. The conclusions of the risk assessment are substantiated by the observed effects identified in the aquatic community monitoring program. Terrestrial monitoring has been too limited to substantiate the risks identified by the terrestrial ERA. Uranium, molybdenum and selenium are the primary contaminants of concern for both the aquatic and associated terrestrial systems. These environmental effects are classified as adverse, however, based on the risk assessment, the limited magnitude and the spatial extent of these effects, they would not be considered significant.

7 DECOMMISSIONING OBJECTIVES

The objectives of decommissioning activities are to remove, minimize, and control potential contaminant sources and thereby minimizing the adverse environmental effects associated with the decommissioned property. The decommissioning project is designed to achieve an end-state property that will be safe for non-human biota and human use, stable, allow utilization for traditional purposes, and that minimizes potential constraints on future land use planning decisions. The decommissioning project is designed to minimize the need for care and maintenance activities and long-term institutional control taking into consideration socio-economic factors.

7.1 Decommissioning Objectives

The decommissioning objectives, described above, and appropriate locations and timeframes for their achievement were established in consultation with federal and provincial authorities and through the proponent’s public consultation process.

Where relevant, achievement of these qualitative decommissioning objectives was defined in relation to existing federal and provincial guidelines and taking into consideration site specific conditions. For identified contaminants of potential concern, where federal or provincial guidelines were not available, information obtained from the scientific literature and site specific conditions were evaluated to derive benchmarks for inclusion as decommissioning objectives.

7.1.1 Locations for the Achievement of Decommissioning Objectives

Locations chosen to meet the water quality decommissioning objectives for key surface waterbodies were identified by the consideration of the locations, and the distances of potential contaminant sources in relation to potentially impacted natural surface waterbodies, and in consultation with federal and provincial authorities. The selected locations are listed in Table 7.1.

7.1.2 Water Quality Decommissioning Objectives

Water quality objectives generally represent contaminant concentrations below which significant adverse effects on aquatic organisms are unlikely. Therefore, water quality that meets or exceeds such objectives will ensure that waterbodies on the Cluff Lake site can support a healthy aquatic community.

The SSWQO for “General” and “Protection of Aquatic Life and Wildlife” were adopted as decommissioning water quality objectives, with the exception of iron. There are no Saskatchewan or national water quality guidelines for uranium, molybdenum or cobalt.

For iron, uranium, molybdenum, and cobalt, site-specific decommissioning water quality objectives were developed based on site-specific conditions, the consideration of past, interim, and current guidelines from other jurisdictions, and experimental toxicity data published in the literature.

There is presently a Regional Water and Sediment Quality Working Group (RW&SQWG), consisting of representatives of Government (provincial and federal), University (University of Saskatchewan), and the uranium mining industry, formed to contribute to further research toward confirming or, for some parameters, developing appropriate regional objectives for Northern Saskatchewan.

Water Quality Objectives for Flooded Pits

Because of their geometry and isolation from natural freshwater ecosystems, flooded mined out pits do not generally represent good aquatic habitat. Experience in northern Saskatchewan and elsewhere has shown that mined out flooded pits may become colonized with aquatic organisms and may be occasionally used by wildlife and waterfowl. For this reason, water quality decommissioning objectives have been set for flooded pits at the Cluff Lake site.

The decommissioning water quality objectives for flooded pits are set for the portion of the water column above an expected chemocline. This approach requires achievement of better quality water in the upper portion of the water column. However, poorer water quality is expected at the bottom of the pits where the basement rock is the lowest permeability and biological activity is minimal. Groundwater transport from the bottom of the pit to downstream surface waters will be reduced in comparison to the larger flows of better quality water moving through overburden.

The decommissioning water quality objectives were further refined to apply to a minimum 50% upper water column which represents approximately 80% of the pit water volume. Wildlife and waterfowl use of flooded pits is expected to be infrequent and restricted to the upper water column, well above this depth objective.

Site Specific Water Quality Objective for Iron

In the Athabasca Basin, many small lakes, wetlands and creeks exhibit naturally elevated concentrations of iron in their waters. Measured iron concentrations in surface waters within the local study area, which are unimpacted by mining and milling activity, are up to 13.0 mg/L. This is appreciably greater than the SSWQO for iron of 1 mg/L. Therefore, a site-specific decommissioning objective for iron was adopted based on the natural background variability observed in surface water iron concentrations. For a particular watershed, the site-specific values chosen represent the 95th percentile of the observed iron concentrations recorded since 1992 at reference locations within that watershed. The decommissioning objective to be achieved in the upper water column of flooded pits represents the highest 95th percentile iron concentration measured in the watersheds.

Site Specific Water Quality Decommissioning Objective for Uranium

To develop a uranium surface water decommissioning objective, the scientific literature describing uranium toxicity to freshwater organisms was reviewed. The review suggested that, like several metals (e.g. cadmium, copper, nickel, zinc), uranium bioavailability is reduced with increasing water hardness.

To assess the relationship between uranium bioavailability and water hardness, the scientific literature describing uranium acute and chronic toxicity was compiled in conjunction with the water hardness under which each test was conducted. The data was classified into two toxicity test types: acute and chronic, and three classes of organisms: fish, invertebrates and algae. The majority of available data consists of two categories: fish acute toxicity tests (n=19) and invertebrate acute toxicity tests. For these two categories of data, linear regression was used to evaluate the relationship between uranium toxicity, as represented by toxicity test LC50 concentrations, and water hardness. Invertebrates were the more sensitive of the two groups. For invertebrates, the regression relationship was LC50 [mg/L]=0.20 times the water hardness [mg/L]. Since this relationship was derived from acute toxicity tests, a safety factor of 100 was applied to this relationship to derive a suitably protective benchmark. The hardness dependent site specific surface water decommissioning objective for uranium (mg/L) is therefore 0.002 times the water hardness (mg/L).

Refinement of this uranium toxicity hardness function is presently the primary objective for the previously mentioned RW&SQWG. COGEMA's participation in this group, as well as the completion of uranium toxicity tests on Cluff Lake waters, are components of the follow-up program described in section 11.

Site Specific Water Quality Decommissioning Objective for Molybdenum

Two water quality objectives were selected for molybdenum. The more stringent objective of 0.073 mg/L was adopted for Snake Lake and the Cluff Lake watershed as these waterbodies have not been negatively influenced by operational activities. This is the interim *Canadian Water Quality Objective* (CWQO) [adopted from the Ontario Ministry of Environment (MOE) guideline objective] for the protection of aquatic life and is based on chronic effects on eyed eggs of rainbow trout (0.73 mg/L) with a safety factor of 10 (standard for objectives based on chronic tests).

Island Lake molybdenum concentrations are substantially elevated as a result of past operations. The molybdenum decommissioning objective for Island Lake has been set at 0.5 mg/L. This value is not likely to adversely affect aquatic life as it is below all of the chronic response levels used in the development of the interim CWQO and also corresponds to the value recommended for the protection of wildlife.

The molybdenum objective set for the flooded pits is also 0.5 mg/L. This value is considered acceptable as the pits will remain isolated from natural waterbodies. There will be no surface water interchange between the flooded pits and local lakes and streams. Protection based on wildlife use of water for drinking is therefore appropriate.

Site Specific Water Quality Objective for Cobalt

The literature was reviewed in the development of a suitable cobalt objective (COGEMA 2001, Response to Regulatory Comments). Based on the available information, a dissolved (filtration through a 0.45 micron filter) water quality decommissioning objective of 0.020 mg/L was adopted. This value was derived from the Lowest Observable Effect Concentration (LOEC) derived for a species present in the region. This value falls below all values for acute toxicity and most values for chronic toxicity in a data set collated by the Ontario MOE and, therefore, is deemed a suitably protective benchmark.

In summary, decommissioning objectives for water quality for key watercourses, following the completion of decommissioning, are identified in Table 7.1.

Table 7.1
Summary of Surface Water Quality Objectives
(Total Concentrations Unless Otherwise Specified)

		SSWQO	Snake	Island	Claude Lake	Claude Creek	Peter River	Earl Creek	Cluff Lake	Flooded Pits*
As	µg/L	50	50	50	50	50	50	50	50	50
Ba	mg/L	1	1	1	1	1	1	1	1	1
Cd	µg/L	1	1	1	1	1	1	1	1	1
Cr	µg/L	20	20	20	20	20	20	20	20	20
Cu	µg/L	10	10	10	10	10	10	10	10	10
Fe##	mg/L	1	3.2	1	7.3	7.3	1	5.2	1	7.3
Pb	µg/L	20	20	20	20	20	20	20	20	20
Hg	µg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ni ***	µg/L	***	***	***	***	***	***	***	***	***
Se	µg/L	10	10	10	10	10	10	10	10	10
Ag	µg/L	10	10	10	10	10	10	10	10	10
Zn	µg/L	50	50	50	50	50	50	50	50	50
Ra^{226}	Bq/L	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
U **	mg/L	--	**	**	**	**	**	**	**	**
Mo##	µg/L	--	73	500	73	73	73	73	73	500
Co#	µg/L	--	20	20	20	20	20	20	20	20

* Flooded Pits – Objectives apply to upper 50% of the water column only

** Uranium is calculated as 0.002 [Hardness in mg/L] at the site in question

*** Nickel values are also hardness related; values are 25 µg/L when [Hardness] <100 mg/L and 100 µg/L when [Hardness] >100 mg/L at the site in question

\# Cobalt objective value to be applied to a dissolved concentration

\## Fe and Mo are waterbody specific.

7.1.3 Decommissioning Sediment Quality Assessment Guidelines

The *Canadian Sediment Quality Guidelines* (CSQG) were used to assess the suitability of predicted post-decommissioning sediment quality to support a healthy benthic invertebrate community. For Snake Lake, Island Lake, and Cluff Lake, the CSQG classifies sediment quality with respect to specific contaminants and their potential for effects on benthic organisms. These general guidelines provide a range from low to high contaminant concentrations (Table 7.2). No sediment quality guideline exists for nickel (under review), uranium or molybdenum. A review of the scientific literature was undertaken to derive decommissioning benchmarks. Recent studies show a large range of benchmark toxicity values for uranium, molybdenum, and nickel, indicating that factors affecting chronic toxicity levels are not well understood and additional study is necessary. These benchmarks are used in the ecological risk assessment to gauge potential adverse effects. Additional discussion on the application of these guidelines is provided in section 9.2.5.

Table 7.2
Sediment Quality Benchmark Values

	CCME		Ontario MOE		Thompson et al., 2003[2]		Long et al., 1995	
Metal (µg/g)	TEL	PEL	LEL	SEL	LEL	SEL	ERL	ERM
Arsenic	5.9	17	6	33	9.3-9.8	346-5874	8.2	70
Copper	35.7	197	16	110	12-22	200-269	34	270
Lead	35	91.3	31	250	28-37	380-412	46.7	218
Molybdenum	-	-	-	-	8-14	540-1239	-	-
Nickel	18[1]	35.9[1]	16	75	21-23	170-484	20.9	51.6
Selenium					0.9-1.9	4.7-16.1		
Uranium	-	-	-	-	32-104.4	3410-5874	-	-
Zinc	123	315	120	820	-	-	150	410

<u>Note</u>:

-	no data available
TEL	threshold effects level
PEL	probable effect level
LEL	lowest effect level
SEL	severe effect level
ERL	effects range low
ERM	effects range medium
1	guideline under review by CCME.
2	due to the sensitivity of the calculations to the statistical estimation method the LEL and SEL values consist of ranges obtained through the use of two different estimation procedures (“weighted” and “closest observation method”).

7.1.4 Decommissioning Radiological Objectives

The decommissioning radiological objectives are based on a need to keep radiation doses to nuclear workers and the general public below the regulatory limits and as low as reasonably achievable (ALARA), through the final decommissioning and post-decommissioning phases.

Workers

The limits on effective dose to nuclear energy workers (NEW) under the *Radiation Protection Regulations* (RPR) are 50 mSv in any year and 100 mSv in any five-year period (an average of 20 mSv per year). The regulations specify that the limit includes committed doses from external sources, inhalation of radon progeny, and ingestion and inhalation of radioactivity according to the applicable sum rule provided in Section 13 of the RPR.

Given the remaining radiological hazards and the radiation protection program already in place at the licensed facility, meeting the regulatory limits will be fairly straightforward. The objective will therefore primarily focus on the application of ALARA. The attainment of this objective will be assured by an evaluation of potential doses from gamma, LLRD and RnP exposures and the establishment of effective controls to keep these exposures ALARA.

Members of the Public

The limit on annual effective dose to a member of the public under the CNSC's RPR is 1 mSv. The regulations specify that the proposed limit includes contributions from external sources, inhalation of radon progeny, and ingestion and inhalation of radioactivity according to the sum rule provided [subsection 13(4) of the RPR]. Pathways analyses will be used to verify that exposures to members of the public, under a variety of potential land use scenarios, will be well below this limit both during and after the completion of decommissioning activities.

The decommissioning radiological objectives were derived on the basis of achieving a safe, stable property that would allow utilization of the area for traditional purposes or occasional access. This assumes casual access with no individuals spending greater than 1000 hrs in a given area at this isolated, remote location.

Radon progeny and Long Lived Radioactive Dust levels (LLRD) will be reduced through removal of source material or by covering with clean soil material. Sufficient cover materials will be applied to eliminate LLRD, and to reduce radon progeny levels to near background conditions where source terms exist. Post-decommissioning LLRD and RnP levels are, therefore, expected to be near background and will not require specific decommissioning objectives. The potential exposure to gamma radiation is assumed to be the primary exposure pathway.

For gamma exposures, gamma surveys, conducted at a height of one meter above ground surface, will be undertaken in disturbed areas that are potentially contaminated. Areas illustrating average dose rates from gamma exposure in excess of 1 μSv/h above background (averaged over a 100 m x 100 m surface, or a 10,000 m^2 surface), or with a maximum spot dose in excess of 2.5 μSv/h above background, will be remediated. In most areas, dose rates from gamma exposure are expected to be about 0.1 μSv/h above background. It is expected that remediation will achieve gamma exposure rates in the order of 0.1 to 0.5 μSv/h.

Following decommissioning, a site-wide comprehensive gamma survey will be conducted to ensure that all surficial radiation sources, associated with the operation of the Cluff Lake uranium mines and mill, is within the specified objectives and ALARA, and are unlikely to change.

7.1.5 Care and Maintenance and Long-term Institutional Controls

In the post-decommissioning or abandonment phase, institutional controls will be necessary, but will be minimized as much as feasible, taking into account socio-economic factors. It is expected that some provincial land use restrictions, including restrictions on groundwater use and development on major impacted areas (i.e. waste rock piles, backfilled pits, tailings), will be necessary. However, traditional land use consisting of seasonal access for camping, trapping, hunting and fishing should not be restricted. The need for long-term care and maintenance shall be minimized. Long-term monitoring requirements should be infrequent and limited as the site should be in a relatively stable, self-sustaining state.

8 PROJECT DESCRIPTION

8.1 Alternatives

The selection of the preferred decommissioning approach for each area (see Table 8.1) was conducted by COGEMA through an evaluation of alternative strategies for site decommissioning weighed against the decommissioning objectives described in section 7.

The initial identification of potential alternatives was constrained to those that met the following criteria:

- reliance on institutional control in the long term should be limited to a simple confirmation monitoring function and minor maintenance activities.
- passive maintenance features, either natural or engineered, should be encouraged while options requiring frequent maintenance should be avoided. Long-term care and maintenance requirements are to be minimized or eliminated.

Using these criteria, several potential methods of decommissioning were identified. At least two alternatives, and as many as six, existed for each area in the Cluff Lake Project site. Each of these possible alternatives was then evaluated based on a number of factors including:

- minimizing the disturbance of new areas;
- minimizing adverse environmental effects, focusing predominantly on water and sediment quality in surface waterbodies;
- protection of human and non-human biota in the long term;
- feasibility and practicality of implementation, based on currently available technology; and
- economic feasibility versus environmental benefit.

Evaluation of environmental effects was the first step, as only those options that meet the decommissioning objectives described in section 7 were seriously considered. For each alternative that provided acceptable environmental effects in both the short and long-term, feasibility (technical and economic) was then considered. Finally, for areas where more than one option was both environmentally acceptable and technically/economically feasible, the cost versus environmental benefit of the options was analyzed.

Regional, local, and site specific factors were considered in selecting the most appropriate options, and sources of uncertainty received focused technical analysis. This evaluation process allowed the systematic elimination of alternatives based on one or more of the above criteria (COGEMA 2000b, 2000c and 2002).

Generally, alternatives were considered by application of a two-step process. Primary alternatives were assessed to define the overall concept for decommissioning. For example, the tailings in the TMA could be decommissioned in the current location, by reprocessing to selectively remove the worst contaminants or by relocating them to a different area entirely. Once the option of in situ decommissioning was selected, the secondary alternatives for how the tailings would be decommissioned in place (i.e. various forms of dry covers or a water cover) were identified and evaluated. The preferred option was then selected based on environmental merit (e.g. achievement of decommissioning water and sediment quality objectives described in section 7), economic, and engineering feasibility.

The decommissioning options considered for the Cluff Lake facilities, including the preferred option proposed by COGEMA, are described in Table 8.1.

Table 8.1
Decommissioning Alternatives Considered

	Preferred Option	Other Options				
D-Pit and Waste Rock Pile	No further action - flooded pit and revegetated waste rock pile	Backfill pit with waste rock from adjacent pile; revegetate waste rock pile area				
Claude Pit: Primary Alternatives	Backfill Pit entirely with waste rock, cap with compacted till, revegetate	Regrade waste in pit to below overburden/ bedrock interface, cap with 1 m compacted till, flood	Cap waste at current elevation with 0.3 m compacted till, flood	Cap waste at current elevation with 0.3 m compacted till, flood, install surface gravity drain		
Claude Pit: Secondary Alternatives	Backfill pit mainly with waste rock from DJN waste rock pile, some DJX waste rock from the DJN Pit, and demolition wastes/waste rock from the Claude waste rock pile.	Backfill pit with waste rock from the Claude waste rock pile.				
Claude Waste Rock Pile: Primary Alternatives	Decrease contaminant releases by reducing the rate of infiltration and acid generation through placement of a dry cover.	Deplete sulphides by increasing the rate of acid generation though active leaching	Relocate pile to more suitable above ground location	Minimize the volume of waste rock on surface by backfilling Claude Pit and DJX pit.		
Claude Waste Rock Pile: Secondary Alternatives	Placement of engineered composite cover system consisting of 1 m of sandy till over compacted waste rock	Placement of a simple till cover	Placement of engineered composite cover system combined with perimeter drain collection and in-pit treatment	Placement of engineered composite cover system combined with an adit under-drain collection system and in-pit treatment		
DJX/DJN Pit	Move material above groundwater equilibrium level from DJN to Claude Pit, cap remaining material with 0.3 m compacted till, flood both pits to create a single water body	Move material above groundwater equilibrium level from DJN to DJX, cap with 0.3 m compacted till, flood both pits	Move DJN waste above ground-water equilibrium level, and DJN rock pile, to DJX; flood both pits	Allow both pits to flood.	Backfill entire pit from DJN and Claude waste rock piles	
DJN Waste Rock Pile	Relocate pile to Claude Pit as back fill, re- vegetate site using native trees and shrubs.	Relocate pile to DJX pit	Relocate special waste to DJX pit; place engineered cover with drainage	Regrade, vegetation cover	Regrade, till cover	Regrade; composite engineered cover and engineered drainage system

	Preferred Option	**Other Options**		
DP Underground Mine	Flood to natural water levels. Seal off surface openings.	Hydraulic containment with small capacity pump.		
DJ Underground Mine	Flood to natural water levels. Seal off surface openings.	Hydraulic containment with small capacity pump.		
Temporal Mill Area	Demolition as soon as practical.	Keep mothballed mill pending results of exploration.		
Mill Area Facilities	Recycle and re-use buildings and equipment subject to contamination limitations, after considering expense of decontaminating and overall condition. Assess on a case by case basis.	Dispose of all buildings and equipment into the Claude Pit.		
Germaine Camp	Retain; modify facilities to hold administrative centre during post-closure period, then complete final camp decommissioning	Remove camp and house post closure workforce at accommodations constructed at City Hall.		
TMA: Primary Alternatives	Decommission tailings in-situ	Reprocess tailings	Relocate tailings to a more suitable site	
TMA: Secondary Alternatives	Recontour surface and place till cover	No cover	Water cover	Zoned cover
Island Lake Recovery	“Do Nothing”. Natural recovery of water and sediment quality following cessation of effluent discharge	Dredging of sediments to the TMA	Covering of sediments using clean fill material	
Industrial Landfill	Cover wastes in place, revegetate	Relocate wastes to Claude Pit		

8.1.1 Mining Area

D-Pit

The preferred option for the D-Pit is to leave the currently flooded pit and revegetated waste rock pile as they are, and undertake no further decommissioning activities. Monitoring shows that the flooded pit is chemically stratified, and water quality in the upper 50% of the water column (above the chemocline) meets SSWQO with the exception of iron, with periodic fluctuations in uranium content. The waste rock pile has been successfully revegetated and colonization by native plant varieties is well advanced.

Table 8.2
D-Pit and Waste Rock Pile Alternatives Considered

	Preferred Option	**Other**
D-Pit and Waste Rock Pile Alternatives	No further decommissioning actions – leave flooded pit and revegetated waste rock pile as they currently exist.	Backfill pit with waste rock from adjacent pile; revegetate waste rock pile area

The backfill option is not deemed necessary or appropriate given the water quality and stability of the revegetated waste rock pile, which are expected to only improve over time.

Claude Pit

Initial assessment of the Claude Pit decommissioning options considered partial backfilling and flooding of the remaining pit volume. The waste rock pile would remain in the current location but would be resloped to 4:1 side slopes, the top surface compacted and a 1 m till layer placed on the surface. In the initial modeling (COGEMA 2000c, Appendix C) conducted to quantify the residual effects of this decommissioning strategy, it was evident that water quality in the flooded Claude Pit was above current guideline values for protection of aquatic resources and wildlife. Furthermore, a passive mitigative strategy could not be guaranteed and downstream water quality in the small Claude Lake/Claude Creek watershed may have exceeded decommissioning objectives.

As a result, the decommissioning strategy was revised to completely backfill Claude Pit with waste rock. Secondary options include different possible sources for materials for backfilling the pit. The preferred option is to use the DJN waste rock pile, and a portion of the Claude waste rock pile to backfill the pit. Contaminant transport modeling (COGEMA 2000c, Appendix C) demonstrates that relocating the DJN waste rock pile into the pit will lead to a significant reduction in the predicted peak concentrations of uranium and nickel in Claude Creek and downstream in Cluff Lake.

Relocation of the Claude pile, while improving predicted water quality in Claude Lake, did not produce the same level of benefit on Claude Creek and Cluff Lake as that presented by relocating the DJN pile, based on the assumptions used in the modeling. This is predominantly the result of the location of the DJN waste rock pile which is immediately above both Claude Creek, which has very limited flow, and the

Peter River. In addition, while the entire DJN pile could be accommodated in Claude Pit, only a portion of the Claude pile could be similarly accommodated.

Table 8.3
Primary Claude Pit Alternatives Considered

	Preferred Option	**Other**		
Claude Pit	Backfill Pit entirely with waste rock, cap with compacted till, revegetate	Regrade waste in pit to below overburden/ bedrock interface, cap with 1 m compacted till, flood	Cap waste at current elevation with 0.3 m compacted till, flood	Cap waste at current elevation with 0.3 m compacted till, flood, install surface gravity drain

Table 8.4
Secondary Claude Pit Alternatives Considered

	Preferred Option	**Other**
Claude Pit	Backfill pit mainly with waste rock from DJN waste rock pile, some DJX waste rock from the DJN Pit, and demolition wastes/waste rock from the Claude waste rock pile.	Backfill pit with waste rock from the Claude waste rock pile.

Claude Waste Rock Pile

Relocation of the entire pile is impractical as the volume exceeds the capacity of all remaining open pits at the site. Accelerating the acid rain drainage (ARD) process through a heap leach-type approach to deplete the contaminants was deemed to be unfeasible due to impermeable layers in the pile which would prohibit effective leaching. Reducing the rate of acid generation with a natural or engineered till cover and a drainage and treatment system is feasible technically, economically, and environmentally. The preferred option proposed by COGEMA is a composite engineered cover on the remaining waste rock pile designed to restrict infiltration and oxygen entry.

The proposed cover will be constructed by compacting the upper layer of waste rock, following recontouring to promote surface drainage, and capping with 1 meter of non-compacted till material. The compacted waste rock serves to limit infiltration while the till material offers a rooting substrate for vegetative material and storage capacity for precipitation. The temporary storage of water will limit oxygen entry into the underlying rock, thus slowing the rate of oxidation, as well as maximizing the ability of the vegetative cover to transpire the moisture, thereby reducing the volume of contaminated leachate which would otherwise seep from the toe of the pile. Under the proposed institutional controls, periodic maintenance of the cover may be required to ensure long-term performance.

Table 8.5
Primary Claude Waste Rock Pile Alternatives Considered

	Preferred Option	**Other Options**		
Claude Waste Rock Pile Options	Decrease rate of acid generation through placement of a dry cover.	Increase rate of acid generation though active leaching	Relocate pile to more suitable above ground location	Minimize the volume of waste rock on surface by backfilling Claude Pit and DJX pit.

Table 8.6
Secondary Claude Waste Rock Pile Alternatives Considered

	Preferred Option	**Other Options**		
Claude Waste Rock Pile	Placement of engineered composite cover system consisting of 1 m of sandy till over the remaining compacted waste rock	Placement of a simple till cover	Placement of engineered composite cover system combined with perimeter drain collection and in-pit treatment	Placement of engineered composite cover system combined with adit under-drain collection system and in-pit treatment

DJN/DJX Pit

The preferred option chosen by COGEMA was based on the best balance of reducing contaminant transport and maintaining reasonable costs. Modeling predictions (COGEMA 2000c, COGEMA 2002b) show that backfilling the pit with waste rock, while eliminating a potential source of contaminated surface water, would increase contaminant transport to Cluff Lake when compared with the preferred option. Following a discussion of appropriate source terms and flow regimes in the initial modeling, the scenario was remodeled using revised input parameters (COGEMA 2002a). The result again indicated that contaminants transported to Cluff Lake would be greater than the levels predicted for the flooding option. Field data will be collected as part of the follow-up program during the post closure monitoring period. The modeling assumptions will be revisited in the future based on this field information. In the event that this information leads to a different conclusion, that backfilling DJX is a significantly better option, it would be possible to dewater and backfill the pit at that time.

Water quality predictions for the preferred flooding option indicate that decommissioning water quality objectives can be achieved. After flooding, some initial short-term water treatment may be required; however, decommissioning objectives are expected to be met in the upper water column in the long term. Other flooding options involving relocation of material into DJX pit or flooding without removing a portion of material in DJN pit, increased the uncertainty of meeting the water quality objectives for the flooded pit.

A regular monitoring program, through the full depth of the water column, is planned as part of the EA Follow-up Program in order to determine whether the limnology has stabilized and water quality objectives specified in section 7.1.2 can be met.

Table 8.7
Primary DJX/DJN Pit Alternatives Considered

	Preferred Option	Other Options			
DJX/DJN Pit	Move material above groundwater equilibrium level from DJN pit to Claude Pit, cap remaining material with 0.3 m compacted till, flood both pits to create a single waterbody	Move material above groundwater equilibrium level from DJN pit to DJX pit, cap with 0.3 m compacted till, flood both pits	Move waste above groundwater equilibrium level from DJN pit, and DJN rock pile, to DJX pit; flood both pits	Allow both pits to flood.	Backfill entire pit from DJN and Claude waste rock piles

DJN Waste Rock Pile

Similar to the OP/DP waste rock pile, the preferred option is to use the material as backfill for the Claude Pit including contaminated soil from underneath the pile. These actions will reduce the source term of the pile to zero and lead to a significant reduction in the predicted peak concentration of uranium and nickel in adjacent surface waters which directly flow into Cluff Lake. In the event that Claude pit is backfilled using Claude waste rock pile material, relocating the DJN Waste rock to the DJX pit or placing an engineered cover over the DJN waste rock pile in the current location, are potential contingency options. The other options involve maintaining a pile on surface which will not eliminate the source term as the preferred option does.

Table 8.8
DJN Waste Rock Pile Alternatives Considered

	Preferred Option	Other Options				
DJN Waste Rock Pile	Relocate pile to Claude Pit as back fill, revegetate site	Relocate pile to DJX pit	Relocate special waste to DJX pit; place engineered cover with drainage	Regrade, vegetation cover	Regrade, till cover	Regrade; composite engineered cover and engineered drainage system

DP and DJ Underground Mines

There were two options considered for closing out the underground mines. One option was flooding to the long-term equilibrium water levels, while the second option assessed was pumping and treatment. The groundwater contaminant transport modeling (COGEMA 2000c) indicates that contaminant loadings from underground mines are inconsequential in relation to other sources, and there is no reason to believe that pumping and treating will significantly improve water quality in the surface waterbodies. In addition, a plan for indefinite pumping and treatment is inconsistent with the decommissioning objective of minimizing long-term care and maintenance requirements. Monitoring, under the EA follow-up program, will provide early warning of higher than anticipated water levels or evidence of contaminated water reporting directly to the surface. The pumping alternative could be implemented at any time as a short-term contingency until a longer term solution can be identified and implemented.

Table 8.9
DP Underground Mine Alternatives Considered

	Preferred Option	**Other Option**
DP Underground Mine	Flood to natural water levels	Hydraulic containment with small capacity pump

Table 8.10
DJ Underground Mine Alternatives Considered

	Preferred Option	**Other Option**
DJ Underground Mine	Flood to natural water levels	Hydraulic containment with small capacity pump

8.1.2 Mill Area

The mill is currently mothballed and will be torn down as soon as practical. Tearing down the mill as soon as possible will remove any hazards associated with the remaining facilities, will allow disposal of the mill remains in the Claude Pit, and allow for earlier revegetation of the mill site and earlier removal of other support facilities.

As exploration activities near the site have been suspended, COGEMA does not plan to retain the mill facility for future use. As such, the option of maintaining the mill in a mothballed state which was considered in the earlier stages of this assessment is no longer viable.

The preferred approach is to recycle and re-use buildings and equipment in accordance with approved procedures as they become redundant, however, the overall condition of the buildings and equipment, and the inherent complexities and costs in decontamination, will strongly limit this approach. Some mill area facilities may be used to support the early stages of decommissioning and will eventually be removed.

Table 8.11
Mill Area Alternatives Considered

	Preferred Option	Other Option
Mill Area	Demolition as soon as practical.	Keep mill mothballed pending results of exploration.
Mill Area Facilities	Recycle and re-use buildings and equipment subject to contamination limitations, after considering expense of decontaminating and overall condition. Assess on a case by case basis.	Dispose of all buildings and equipment into the Claude Pit.

8.1.3 Germaine Camp

For the Germaine Camp, the options are to remove it completely after the active decommissioning period and house the post-closure workforce elsewhere, or to modify the facilities and possibly move administrative activities into the camp; the latter option is preferred. Final decommissioning and salvage of the camp will occur following post-closure monitoring, when the camp is no longer required to accommodate the post-closure workforce.

Table 8.12
Germaine Camp Alternatives Considered

	Preferred Option	Other Option
Germaine Camp	Retain; modify facilities to hold administrative centre during post-closure period, then complete final camp decommissioning	Remove camp and house post-closure workforce at accommodations constructed at City Hall site.

8.1.4 TMA and Industrial Landfill

Tables 8-13 to 8-15 list the alternatives considered for the TMA and industrial landfill.

For the TMA, decommissioning tailings in the current location is feasible due to the initial selection of the site in a topographical low near the upper part of a small watershed. This option is cost-effective and requires no new disturbance to the surrounding area. Reprocessing of the tailings, which was an early consideration, limited efficiency in contaminant removal, and also required separate disposal of more hazardous waste, plus potential occupational exposure during the excavation and processing. Relocation of the tailings bears substantial costs and simply moves the problem to a different location, causing additional disturbance in a new area that must be designed to today’s requirements. Relocation also comes with the inherent risks of spills, increased radiation exposures to workers, and extensive clean-up requirements for the existing TMA.

Evaluation of a variety of cover options (COGEMA 2000b) lead to COGEMA's preferred choice of a till cover (minimum depth of 1 m) over a surface contoured to provide positive drainage. A water cover is not feasible as consistent delivery of cover water could not be assured during dry periods. Also, the increased water head over the tailings surface would significantly increase the infiltration rate through the tailings thereby, increasing contaminants loadings into Snake Lake. A zoned cover, with a low permeability layer, would reduce the infiltration; however, this technique has several drawbacks including increased complexity, quality control challenges, potential construction delays, uncertainties regarding long-term cover durability and performance, as well as considerable cost.

Modeling of a simple till cover over consolidated tailings demonstrated that with a reasonable estimate for attenuation of contaminants along the flowpath, levels of Ra^{226} (the primary contaminant) predicted for the Snake Lake water column meet the SSWQO values for Ra^{226}.

As the industrial landfill is within the groundwater regime of the TMA and any contributions to groundwater contamination from this landfill will be combined with the more substantial contribution from the tailings, the option of burying and revegetating in situ is deemed sufficient and appropriate. Relocation to Claude Pit would lead to increased costs with no apparent benefit.

Table 8.13
Primary TMA Alternatives Considered

	Preferred Option	**Other Options**	
TMA	Decommissioning in situ	Reprocess tailings	Relocate tailings to another site

Table 8.14
Secondary TMA Alternatives Considered

	Preferred Option	**Other Options**		
TMA	Recontour surface and place till cover	No cover	Water cover	Zoned cover

Table 8.15
Industrial Landfill

	Preferred Option	**Other Option**
Industrial Landfill	Cover wastes in place, revegetate	Relocate wastes to Claude Pit

8.1.5 Remediation of Island Lake

As a result of over 20 years of effluent discharge to Island Lake, water and sediment quality have changed from baseline conditions, as was predicted. As noted in section 6.2, subsequent changes have also been observed in benthic and planktonic community structure and in resident fish populations. These changes were expected and documented in previous environmental assessments.

Three remediation alternatives were considered as part of this EA. Removing the contaminated sediment by dredging and placing the sediments in the TMA was viewed as unacceptable for the following reasons:

- serious disruption of the habitat for all organisms resident in Island Lake would occur;
- available disposal space in the TMA is questionable and dependent on the degree of consolidation which would occur post placement; and
- significant cost is associated with this option.

The burial of the contaminated sediments with clean fill was also considered. This could be done through mechanical placement on the winter ice or by hydraulic means. However, habitat disruption remains, as well as the additional surface disturbance related to the development of a borrow area for clean fill.

The preferred option is to allow Island Lake to naturally recover, as was proposed in previous environmental assessments. The reduction and eventual cessation of effluent discharge will result in water quality improvements in the very short term. Although the sediment will continue to transfer some contaminants to the water column, modeling shows this process will be of relatively short duration (< 50 years) for most parameters. The shallow nature of the lake will allow for accelerated natural sediment deposition rates which will bury the contaminated sediment within this timeframe.

Table 8.16
Island Lake

	Preferred Option	**Other Options**	
Island Lake	Do not disturb	Dredge	Cover

8.1.6 Revegetation Alternatives

Revegetation alternatives include unassisted natural revegetation, assisted revegetation with native species, and assisted revegetation with non-native species. During operations, all three options have been used, and that practice will continue during decommissioning depending on design and regulatory requirements.

8.2 Decommissioning Project – Proposed Works and Activities

The sections that follow describe the preferred approach for decommissioning the Cluff Lake Site.

The Comprehensive Study Report reflects the preferred approaches based on information available at the time of analysis. Detailed designs will be optimized taking into account any new information then available, which may be as a result of the compliance monitoring or the follow-up programs. Should any new information indicate that the current preferred option can be further optimized, the design may be altered accordingly or the previously considered options may be re-considered.

8.2.1 D Mine Area

Extensive cleanup, grading and revegetation has been undertaken at the D mine area. A final radiological survey will be conducted on the D pile and the former mining area to identify any residual contamination which does not meet the final decommissioning radiological objectives (see section 7.1.4). Any areas that do not meet the objectives will be cleaned up by removal of the source or covering with clean till and revegetating. This will complete the decommissioning of the D mine area.

8.2.2 Claude Mine Area

Decommissioning the Claude mining area will involve:

- the completion of Claude Pit backfilling and grading of the surrounding area;
- resloping of the Claude waste rock pile and construction of an engineered cover; and
- decommissioning of remaining Claude area buildings and surface infrastructure.

Claude Pit

Decommissioning Claude Pit will involve the following primary work packages:

- pit dewatering;
- pit backfill (including continued disposal of demolition wastes);
- cover placement,;
- area grading; and
- revegetation.

<u>Pit Dewatering</u>

Claude Pit dewatering will involve pumping and treating sufficient water from the pit to allow the completion of the placement of backfill in the pit. It is currently anticipated that 800,000 m^3 to 1,000,000 m^3 of water will require removal, depending on the timing of pit backfill operations. The pit dewatering plan consists of pumping water from Claude Pit to DJX Pit for temporary storage. The water will then be either treated in situ and left in place, or pumped to the TMA for treatment and discharge through the existing STS system.

Claude Pit Backfill

Claude Pit will be backfilled to a stable, final topography that facilitates surface water drainage away from the immediate pit area. Backfilling Claude Pit is anticipated to require between 1.6 to 1.8 Mm^3 of material. The Claude Pit backfill plan involves the relocation of waste rock materials from the DJN backfilled pit and, the DJN and Claude waste rock piles. The current Claude Pit backfill plan anticipates backfill to be completed with:

- all DJX waste rock contained in DJN Pit above the 314 masl elevation (~250,000 m^3);
- the entire DJN waste rock pile (~1.4Mm^3); and
- sufficient Claude waste rock to create the desired final topography (as required).

In addition, consistent with the approved operational practice, demolition wastes during decommissioning of the mill, site buildings and infrastructure will be disposed of in Claude Pit.

Pit backfill will be completed by end dumping the fill materials over the existing backfill face. The final topography will be contoured to provide for possible future settlement, and to facilitate surface water drainage away from the immediate pit area. Depending on the timing of pit backfill operations, backfill may occur concurrently with pit dewatering.

Claude Pit Backfill Cover Placement

Once backfilled, the emplaced waste rock will be covered with glacial till material to facilitate revegetation and minimize exposure of, or intrusion into, underlying contaminated materials. The glacial till material for the cover will be obtained from the existing DJ overburden pile, if sufficient material remains after capping and grading of the Claude waste rock pile. If insufficient material remains in the DJ overburden pile, an additional source of material (i.e. borrow pit) may need to be developed in the Claude area.

Claude Pit Area Grading and Revegetation

To prevent water ponding and provide long-term erosion control, site grading will be required in the area immediately adjacent to the backfilled Claude Pit. This may require the use of till material to backfill low lying areas.

Revegetation of the backfilled Claude Pit will be in accordance with the site-wide revegetation plan developed for the site.

Claude Waste Rock Pile

Decommissioning the Claude waste rock pile will involve the following primary work packages:

- recontouring the remaining pile to a stable and aesthetic topography;
- placement of a till cover on the regraded and compacted waste rock;
- construction of storm water management channels; and
- revegetation.

Claude Waste Rock Pile Grading

Claude waste rock pile grading will involve reducing the existing 2H:1V slopes to approximately 4H:1V and contouring the top area of the pile to direct runoff to an armored collection channel. The resloping is expected to result in a slightly enlarged footprint (~33 ha) for the final pile configuration. Any piezometers required for groundwater monitoring, lost as a result of extending the footprint, have or will be replaced.

Claude Waste Rock Pile Cover Construction and Revegetation

The objective of the Claude waste rock pile cover is to minimize the generation of acid rock drainage and restrict infiltration. The proposed cover design consists of a layer of compacted waste rock overlain with approximately a 1 m layer of uncompacted till. The compacted layer will restrict water infiltration. The uncompacted till layer will provide water storage capacity to reduce oxygen entry, and facilitate evapotranspiration and revegetation.

The 1 m layer of uncompacted till will require approximately 330,000 m^3 of glacial till material. This material will be obtained from the DJ overburden pile. The cover will be designed and constructed so as to effectively manage surface water runoff and control erosion during major rainfall events.

Revegetation of the covered Claude waste rock pile will consist of a grass-legume mixture.

Claude Area Final Cleanup and Revegetation

The only significant building remaining in the Claude mining area is the Claude Shop. The Claude Shop will likely remain intact until near the completion of physical decommissioning construction activities in the Claude area. Once the building is no longer required, the structure will be demolished and disposed either in Claude Pit or buried during regrading of the Claude waste rock pile. Removal of roadways, power lines, and pipelines will be performed following completion of decommissioning construction activities in the Claude area.

As buildings and surface infrastructure are removed, the areas will be scanned and cleaned up, as required, by removal of surface contamination or addition of cover materials to meet decommissioning radiological objectives (see section 7.1.4). The area will then be revegetated in accordance with the site-wide revegetation plan.

8.2.3 OP/DP Mine Area

Decommissioning the OP/DP mining area will involve:

- removal of DP area buildings and surface infrastructure.

As noted in section 6.1, with the cessation of mining in 1999, the OP/DP underground mine was closed out and allowed to flood with natural groundwater inflow.

Unlike DJ underground mine there have been no instances of surface subsidence associated with the OP/DP mining activities. The OP/DP mine is not considered vulnerable to crown pillar failure as is the case for the DJ mine.

The OP/DP raises were completely backfilled while the OP/DP decline was backfilled from approximately 176 m down the ramp to the portal opening. Reinforced concrete caps were placed above all backfilled raises and a concrete plug was poured at the OP/DP portal opening. This is deemed sufficient to mitigate the potential for surface subsidence at these locations. A full report on the prediction of subsidence events at Cluff Lake is included in (COGEMA 2000e, Appendix C).

The DP fresh air raise is equipped with water pumping capabilities. Final water elevations and water quality will determine whether any additional mitigation measures are necessary.

Any remaining surface facilities or structures will be removed and disposed of in Claude Pit.

Subsequently, a radiological survey will be conducted to identify areas of residual contamination. The final decommissioning of the OP/DP mine area will consist of removal or covering of residual contamination and revegetation activities, consistent with the site-wide revegetation plan.

8.2.4 DJ Mine Area

Decommissioning the DJ mining area will involve:

- decommissioning of DJN/DJX Pit and surrounding area;
- decommissioning of the DJN waste rock pile; and
- decommissioning of DJ area buildings and surface infrastructure;

DJN/DJX Pit

Decommissioning the DJN/DJX Pits will involve the relocation of a portion of the existing DJX waste rock contained in the backfilled DJN Pit, treatment of contaminated pit waters, accelerated flooding of the combined DJN/DJX pits, area regrading, storm water management, and revegetation.

Relocation of DJN Pit Backfill

DJX waste rock in backfilled DJN Pit will be lowered to an elevation several meters below the anticipated equilibrium water level in the flooded pit(s) to minimize waste rock oxidation from atmospheric exposure and potential contaminant release. All excavated waste rock will be relocated to the Claude Pit as previously described.

Pit Flooding

Following relocation of the DJX waste rock, pit waters will be treated as required then the combined pits will be flooded, creating a single water body in equilibrium with the surrounding groundwater elevation. To facilitate flooding, Cluff Lake water (~2.5 Mm^3) will be pumped to achieve a surface water elevation below the adjacent Cluff Lake (~317.4 masl). The flooded pit waters will be treated, if required, to ensure decommissioning water quality objectives are met.

The final equilibrium surface water elevation will be established by groundwater inflow.

Area Regrading

The area surrounding the DJ pits will be regraded to a stable, safe and aesthetic configuration. Regrading work will include the DJ yard area, material surrounding the crest of the combined pits and the DJ overburden pile area.

Storm Water Management

An emergency overflow channel may be required to accommodate an overflow condition or an extreme precipitation event. Such a channel will be appropriately designed and constructed to handle a PMP event and located in such a way as to prevent adverse effects to the fish habitat compensation area located south of DJX pit on the shoreline of Cluff Lake.

DJN Waste Rock Pile Relocation

The entire DJN waste rock pile, as well as any underlying contaminated soil, will be used as backfill for the Claude Pit. The remaining area will be recontoured and revegetated consistent with the site-wide revegetation plan.

DJ Underground

As noted in section 6.1.4, there has been one instance of surface subsidence related to mining activities at the DJ underground mine. This is the only area of the DJ mine which sub-outcrops to surface and was therefore, vulnerable to crown pillar failure. It has now been stabilized and eliminated from further ground-fall considerations.

All DJ underground raises and the decline were backfilled to surface with till material. The raises were entirely backfilled from the bottom of the raise to the raise collar elevation. The decline was backfilled from approximately 181 m down the ramp to the portal opening. Reinforced concrete caps were placed above all backfilled raises and a concrete plug was poured at the portal opening. This is deemed sufficient to mitigate the potential for surface subsidence at these locations. A full report on the prediction of subsidence events at Cluff Lake is included in (COGEMA 2000e, Appendix C).

The DJ underground mine continues to flood with groundwater inflow. Follow-up monitoring will help to determine final water quality and water levels in the mine.

No further work is anticipated to remediate the DJ underground mine.

Buildings and Surface Infrastructure

With the exception of a few facilities, all structures in the DJ area were demolished in 2002 and disposed in Claude Pit. Remaining structures include the DJ scanner building and the DJ fueling station. Once these facilities are no longer required, the structures will be demolished and disposed of either in Claude Pit or the TMA Liquids Pond.

Removal of roadways, power lines, and pipelines will be performed following completion of decommissioning activities in the DJ area.

As buildings and surface infrastructures are removed the areas will be scanned and cleaned up by removal of surface contamination or addition of cover materials. The area will then be revegetated in accordance with the site-wide revegetation plan.

8.2.5 Mill Complex and Support Facilities

Final clean-up of the mill area will involve the following phases:

Phase 1 Demolition

In the first phase, all buildings in the mill area which are no longer required to support ongoing site activities, will be demolished and disposed of in Claude Pit. The facilities required to support decommissioning activities will be maintained. These may include the Heavy Duty Shop, warehouse, the office portion of the mill, the mill dry, the powerhouse, the domestic water system, sewage treatment system, any facility/equipment used in water treatment, and the fueling stations.

Phase 2 Demolition

As the support facilities in the milling area become redundant or are transferred to another location (e.g. Germaine Camp), they will be demolished and disposed of in Claude Pit or the TMA Liquids Pond. Both Phase 1 and 2 may be completed at the same time; the timing being dependent on the schedule for regulatory approvals, and the overall evolution of the project.

Following a final grading of the reclaimed mill area, radiological surveys will be conducted to identify areas requiring further remediation. Any areas contaminated with hydrocarbons will be remediated in accordance with provincial and federal guidelines. Following completion of remediation, the area will be revegetated in accordance with the site-wide revegetation plan.

Final Cleanup and Revegetation

Following a final grading of the reclaimed mill area, radiological surveys will be conducted to identify areas requiring further remediation. Following completion of remediation, the area will be revegetated in accordance with the site-wide revegetation plan.

8.2.6 The Tailings Management Area (TMA) Including Effluent Treatment Systems

As noted in section 6.1, a leveling course was placed above the existing tailings surface to surcharge the tailings and expedite consolidation. Within the boundary of the tailings storage area, all runoff and porewater continue to report to the Liquids Pond for collection and treatment.

Decommissioning the TMA area will involve the following primary work packages:

- covering all tailings materials with a minimum 1m glacial till cover and construction of storm water and runoff management systems;
- backfilling the Liquids Pond;
- buttressing the main dam;
- construction of long-term storm water management structures;
- removal of buildings and surface infrastructure; and
- revegetation.

Grading Course Construction

Decommissioning of the TMA Solids Area will involve placement of an additional till cover above the previously constructed leveling course to create the desired final topography within the TMA solids area and to ensure a minimum 1 m till cover over all tailings. The grading course will be constructed using local till material developed from an adjacent borrow area. This is anticipated to require 150,000 m^3 and 200,000 m^3 for the Upper and Lower solids areas, respectively. Following grading course installation, all surface water flow will continue to report to the Liquids Pond and be treated prior to release, until runoff quality acceptable for discharge is established.

Liquids Pond Backfill

While Claude Pit has been identified as the primary disposal facility for contaminated materials, depending on final decommissioning plans and schedules, the Liquids Pond may also be used for contaminated waste disposal. Any waste material or contaminated sediments will be covered with clean till material which will prevent the exposure of underlying material.

As part of final decommissioning, the Liquids Pond will be backfilled to an elevation above the anticipated post-closure phreatic surface, and graded such that ponding of water and/or groundwater seepage do not occur. Discharge of runoff from the backfilled and graded Liquids Pond area may require a small breach in the main dam to allow surface water release.

Main Dam Buttressing

To increase long-term stability, the back-slope of the main dam will be reduced to approximately 4H:1V with glacial till material. Channel discharge points crossing the main dam will be reduced to a lesser slope as appropriate for channel stability.

Storm Water Management

The majority of up gradient flow reporting to the TMA area is currently diverted around the TMA in either the North or South Diversion ditches. Since construction, both ditches have been monitored for performance and stability. Both ditches have been performing as designed and no further work on either ditch is anticipated.

The final cover will be designed and constructed to control and manage surface water runoff, minimize the potential for long-term erosion and prevent the exposure of underlying tailings. This will likely include, but not be limited to, the construction of berms and channels on the cover, and the construction of armored discharge channels to collect and direct any diverted flows.

Buildings and Surface Infrastructure

Decommissioning of buildings and surface infrastructure in the TMA area will primarily involve removal of the PTS and STS structures, roadways, power lines, and pipelines specific to the TMA area.

PTS and STS Buildings

The PTS and STS facilities will be maintained until primary consolidation of the tailings is complete and all significant on-site water treatment needs have been completed. At that time, the PTS will either be re-used or decommissioned and demolished. Demolition debris from the PTS will be disposed of in the Liquids Pond or other licensed facility such as Claude Pit.

During decommissioning, the STS will operate intermittently due to low flows. The existing operational controls, monitoring points, spill control measures, and point of final discharge are anticipated to remain unchanged. Final decommissioning of the STS facility will be completed once final water treatment and water discharge needs for the decommissioned site have been established and it has been demonstrated the facility is no longer required. Depending on timing of the STS facility demolition and regulatory approvals, demolition debris may either be disposed of in the Liquids Pond or in the existing ponds located in the STS area.

Roadways, Power Lines and Pipelines

Removal of roadways, power lines and pipelines will be performed as allowed by site water treatment needs. Procedures for removal of these items are detailed in subsequent sections.

Revegetation

Revegetation of the TMA area will consist of a grass-legume mixture on the TMA cover and revegetation using native trees and shrubs over other reclaimed areas, in accordance with the site-wide revegetation plan.

8.2.7 Ancillary Buildings and Services

Germaine Camp Area

Germaine Camp will continue to be used for accommodation during active decommissioning and post-closure monitoring. It may also serve as the office complex when mill demolition is undertaken.

The existing water treatment plant supplying potable water at Germaine Camp will continue to operate while personnel are required to be continuously on-site. The plant may be replaced by a smaller and more economical system when the number of people required on-site decreases.

As the major decommissioning activities are completed and the number of on-site personnel is reduced, Germaine camp will be progressively decommissioned to eliminate redundant buildings and structures. All salvageable materials, furniture, and equipment will be removed from the area and radiologically scanned to ensure release criteria are met prior to release from the site. The wet well for the potable water system will be infilled with clean soil and the area will be regraded to allow natural revegetation. The remaining camp will be burned in accordance with applicable regulatory approvals and permits, and residual materials buried in place.

A radiological survey will be conducted in the area. Any area not conforming to requirements will either be excavated or covered in order to achieve the decommissioning radiological objectives (see section **7**.1.4). The area will then be regraded and revegetated.

At the end of decommissioning, the sewage treatment plant and freshwater supply plant will no longer be necessary, and will be dismantled. Non-salvageable materials will be buried in place. The lagoon will be backfilled and the tile field will be left in place. The area will then be regraded and revegetated.

Cluff Center

The majority of salvageable equipment and material were previously removed from Cluff Center. All remaining non-salvageable materials will be disposed in Claude Pit and all remaining concrete pads decommissioned. The area will then be regraded and revegetated.

Any drill core that must be stored on-site, as required by regulatory agencies, will remain at Cluff Center. The core storage area will be secured in compliance with regulatory requirements and ownership subsequently transferred to the applicable regulatory agency.

Southgate Entrance

After the major decommissioning activities are completed and the site enters the monitoring phase, it is anticipated that the gate will be relocated to Germaine Camp and access to the site will be via an existing road on the south side of Cluff Lake.

The gatehouse will be decommissioned in the same way used for other buildings at Germaine camp. The security gate will remain and site access controlled until, subject to regulatory approvals, it can be demonstrated that the site is deemed safe for general access.

Batch Plant

All that remains of the batch plant is a concrete foundation and the adjacent borrow areas. The foundation will be removed or buried and the area regraded and revegetated in accordance with the site revegetation plan.

Cluff Lake Pumphouse

The Cluff Lake Pumphouse and associated pipeline to the mill will be needed until the physical decommissioning work is complete. Freshwater may be required for cooling the diesel generators in the powerhouse, for domestic purposes, and for flooding the DJX pit.

When the Cluff Lake Pumphouse is decommissioned, equipment will be removed and salvaged as appropriate. The remaining buildings and pipelines will be removed and disposed of on site.

Airstrip

Once decommissioning activities are complete, a decision on the final outcome of the runway will be determined through discussions with federal and provincial agencies. Final decommissioning will consist of either salvage or disposal of the aboveground aviation fuel storage tank, dismantling and disposal of the two small buildings, and scarification and revegetation of the runway surface.

Site Roads

Upon completion of all decommissioning activities, all on-site roads and travelways will be deactivated. The processes utilized in achieving road deactivation are as follows:

- in consultation with the Fisheries and Oceans Canada, all culverts will be removed and replaced with drive-through cross ditches;
- all road fill slopes that exceed 65% will be reduced to 27% or less and recontoured;
- all road berms that impede natural drainage flows will be removed;
- all ramps will be cross-ditched at no more that 30 m intervals; and
- all travelways will be regraded and revegetated.

Highway Road 955 access to the Cluff Lake site will be required until the end of the decommissioning period. Requirements for food, fuel, parts, and supplies will continue at a slightly reduced frequency than during normal operations.

It is anticipated that the majority of the physical decommissioning work will be completed within two years from the start of decommissioning, at which time the post-decommissioning monitoring period will begin. Personnel requirements on-site will significantly reduce at that time and so will the requirement for supplies.

Once the need for continuing on-site personnel ceases, Highway Road 955 will no longer be required for the Cluff Lake facility. The department of Saskatchewan Highways and Transportation (SHT) may then choose to maintain, abandon or decommission the highway. Depending on the SHT decision, scarifying and revegetating will proceed on the portion of the highway within the surface lease agreement, or transfer responsibility for ongoing maintenance and final decommissioning to SHT.

Fuel Storage Facilities

As fuel tanks are no longer required, they will be drained and prepared for sale or disposed of on-site. Contaminated soils and groundwater (if applicable) at fuel storage areas, maintenance shop areas, and other hazardous material storage facilities will be investigated and remediated as required by provincial and federal guidelines.

Any propane remaining in tanks that is no longer required will be transferred into tanks that will remain in service. The emptied tanks will either be returned to the owner (for rented tanks) or will be sold. Unsalvageable tanks will be crushed and disposed of in Claude Pit or the Liquids Pond. Any concrete bases will be decommissioned.

Power Generation/PowerLines/Substations

As each area on site is permanently taken out of service or, as power generation is converted to local diesel generators, power lines and poles will be taken down. Substations and transformer stations will also be dismantled. All electrical equipment will be salvaged and sold or disposed of in a currently available disposal facility such as Claude Pit. Transformer oils will be sent offsite for reuse or disposal by a licensed disposal facility. The generators will be salvaged and sold.

Contaminated and Treated Effluent Pipelines

Surface pipelines which have transported minewater, tailings slurry or raffinate will be removed and disposed of in Claude Pit or the TMA Liquids Pond. Existing procedures for disconnecting and transporting contaminated pipes will be used to help minimize spills and allow expedient cleanup, should any minor spills occur.

Monitoring Wells

All active piezometers, access casings and boreholes, which are currently part of the environmental monitoring program, will be maintained in operational condition until it is determined that they are no longer required. After monitoring requirements at each location are fulfilled, they will be grouted off with cement or bentonite. Boreholes/piezometers/monitoring wells that penetrate bedrock will be grouted to at least 3m below the top surface of the bedrock.

Spills/Contaminated Areas

All reportable spills that have occurred on the Cluff Lake site are documented in annual reports. Spills have been of limited volume, concentration and impact. Spill response has resulted in the immediate remediation at the time of occurrence and the areas where radiological spills have arisen were scanned following clean up to verify the effectiveness of clean up.

At the end of the physical decommissioning work, a gamma survey will be conducted over the entire site. This will include roadways, and pipeline corridors. The soils and groundwater (if applicable) at all fuel storage facilities, maintenance shop areas, and other hazardous material storage facilities, including the old leach tailings storage area, will be investigated and remediated as needed.

Borrow Areas

There are several borrow areas on the Cluff Lake site. The most significant is the borrow area near the concrete batch plant and the borrow area southwest of the TMA. The borrow area next to the Batch Plant is in the process of being reclaimed while all other non-operating borrow areas have been reclaimed. The borrow area at the TMA is the only active borrow area at this time. The final design calculations for the mining area may indicate a need for an additional borrow area in the mining area. Any new borrow areas will be developed and reclaimed in accordance with applicable provincial regulations.

Solid Waste Landfills

Claude Pit will continue to be the main repository for contaminated wastes. The industrial landfill may continue to be used during the early stages of decommissioning. Industrial and contaminated wastes from the decommissioning project will be disposed of in this landfill or Claude Pit. When this facility is no longer needed, any waste outside the active trench will be collected and placed in the trench, and backfilled with overburden. The area will then be regraded and revegetated.

The Domestic Landfill located between the Mill and Germaine Camp will not be decommissioned until the end of the post-closure monitoring period. Domestic waste will be disposed of in this landfill throughout the decommissioning and post-closure monitoring periods. When usage of the Domestic Landfill is complete, all loose litter in the area will be retrieved and returned to the active trench. The active trench will be backfilled with overburden, and the entire landfill area will be regraded and revegetated.

The two old reclaimed landfills on the Cluff Lake Site (one near Cluff Center and one just south of the mill), are not deemed to pose any significant risk to the environment as they were used for non-hazardous industrial and domestic wastes.

8.2.8 Site-Wide Revegetation Plan

The site-wide revegetation plan involves two different strategies: one for areas of soil covers and a second for the remaining areas of the site.

For the TMA and Claude waste rock pile soil covers, a commercially available mixture of shallow rooting grasses and legumes will be seeded. This type of vegetative cover is expected to establish very quickly and offer a comprehensive ground cover with significant sod formation to limit erosion of the cover material. These types of vegetative covers tend to resist and slow the rate of natural invasion onto the site and will ensure the integrity of the covers for an extended period of time. As the native vegetation progressively invades the area, the soil binding capabilities of the grass/legume understory will persist and be supplemented by the rooting systems of the native varieties. COGEMA will consult with Saskatchewan Environment (SE) in selecting the vegetative mix to be used in these areas.

Soil and soil moisture conditions at Cluff Lake are amenable to natural revegetation and there are several examples on site over the past twenty years where simply allowing nature to take its course has been highly successful. In areas other than those where soil covers have been utilized, the reclamation approach will be to regrade or recontour the site to match local topography and to remove any compaction, which can deter moisture infiltration and root development. Given an appropriate seed bed, early successional species will inhabit these areas over the initial one to three years. This natural process will be aided and accelerated by the planting of local deciduous varieties. This process will maintain the natural genetic base of the indigenous woody revegetation and speed the successional development toward the re-establishment of climax species.

8.3 Regulatory Compliance Programs

The detailed designs and construction plans will be reviewed and approved by regulatory agencies including the CNSC and SE prior to their implementation. As part of obtaining a decommissioning licence, COGEMA will be required to demonstrate that it has the necessary resources and programs to effectively implement the decommissioning project.

The section that follows outlines the key program requirements that will be applied to the decommissioning project. Each program will be the subject of detailed regulatory review by both provincial and federal agencies, as required.

8.3.1 Quality Assurance Program

The requirements of the decommissioning QA (Quality Assurance) program will conform to CNSC requirements. QA system elements which must be addressed in the QA program include: organizational roles and responsibilities, policies, procedures, training and development, communication, document and records management, procurement, process planning and control, verification, non-conformance and corrective and preventative action, change control, audits, self-assessment, and programs in environment protection, radiation protection, safety, engineering design and construction/demolition.

The program should ensure consistency in all activities and provide assurance that the key objectives of the decommissioning project are met.

8.3.2 Radiation Protection Program

The proponent is responsible for the overall protection of workers from radiation and for compliance with the *Radiation Protection Regulations*. In particular, the proponent must ensure that worker exposures to radiation: (1) do not exceed the regulatory dose limits, and (2) are kept As Low As Reasonably Achievable (ALARA) for proponent staff, contractors and members of the public. A radiation protection program, in conformance with applicable regulatory policies, guidelines and regulations, will be established and maintained to:

- establish and apply a Code of Practice for Radiation Protection in all activities;
- effectively train on-site staff and contractors in radiation protection;
- collect, evaluate, and maintain data on radiation levels in the workplace and the environment;
- monitor and establish effective controls for radiological levels in all workplaces;
- measure radiation exposures of monitored individuals;
- report all relevant information;
- control the release of materials from the site with due regards to their potential use and applicable regulatory requirements; and
- generally contribute to the continuous improvement of radiation safety.

Protection of Workers and the Public

During the execution of the decommissioning plan, COGEMA will have to ensure that radiation exposures to both workers and members of the public are less than regulatory limits, and that they are As Low as Reasonably Achievable (ALARA). The decommissioning plan will be designed to ensure that radiation exposures to the public after completion of decommissioning will be less than regulatory limits, and that they will be ALARA.

Members of the Public

The limit on annual effective dose to the most-exposed member of the public under the CNSC's *Radiation Protection Regulations* is 1 mSv. The regulations specify that the proposed limit includes contributions from external sources, inhalation of radon progeny, and ingestion and inhalation of radioactivity according to the sum rule provided [subsection 13(4) of the *Radiation Protection Regulations*]. Environmental pathways analyses established that exposures to members of the public will be well below this limit both during and after the completion of decommissioning activities.

Workers

The limits on effective dose to nuclear energy workers (NEW) under the *Radiation Protection Regulations* are 50 mSv in any year and 100 mSv in any five-year period (an average of 20 mSv per year). The regulations specify that the limit includes committed doses from external sources, inhalation of radon progeny, and ingestion and inhalation of radioactivity according to the sum rule provided [subsection 13(2) of the RPR].

In practice, the annual dose to a worker is expected to be kept well below 20 mSv and as low as reasonably achievable. The maximum individual radiological dose during recent site cleanup and reclamation activities involving earth moving work, the primary work activity during decommissioning, was less than 2 mSv. Mean exposures for decommissioning staff are expected to fall near the regulatory limit for members of the public. After the decommissioning of the TMA, Claude Pile and Claude Pit, all worker exposures are expected to fall below the regulatory limit for members of the public.

As the radiological hazards are eliminated or reduced, and the dosimetry demonstrate that exposures are below the regulatory limit for members of the public, it is anticipated that designated groups will be reclassified as non-Nuclear Energy Worker.

Site Clean-up Criteria

Radiological surveys are described under three broad categories: post-operational, decommissioning, and post-closure. Post-operational surveys will be carried out to complete and refine the knowledge-base for detailed planning purposes. During decommissioning, surveys will be undertaken to support: (a) worker radiation protection programs; (b) environmental monitoring programs; and (c) releases of materials and equipment from the site. Post-closure surveys will be undertaken to identify any further remediation requirements. Surveys will be done in accordance with established procedures.

The proponent has proposed the following criteria for residual radiation levels on site terrain. The annual effective dose to the most exposed person accessing the site after decommissioning will be less than 1 mSv, and wherever possible, gamma levels measured one metre above the surface are not to exceed a maximum of 2.5 µSv/h or an average of 1.0 µSv/h averaged over 100 m^2 x 100 m^2.

Experience gained during site cleanup and reclamation activities, has generally shown that, following reclamation work, maximum gamma levels are below 1 µSv/hr including background, with mean values of 0.5 µSv/hr or less, including background, are achieved. With the exception of some areas which are difficult to remediate (e.g. forested areas) or with elevated natural background levels (e.g. D area Boulder Train), similar or better results are anticipated for the rest of the Cluff Lake site.

Areas with average gamma levels in excess of 1 µSv/h (2.5 µSv/h maximum) are expected to be remediated in one of two ways, by removal of materials of a definable extent to an appropriate planned management facility, or by clean cover placement (i.e. clean glacial till) to attenuate gamma fields and inhibit oxidation.

The appropriateness of these criteria and their application will be the subject of detailed regulatory review during the licensing phase to ensure that ALARA is achieved and that exposures to members to the public remain below 1 mSv.

Final Radiation Survey

The decommissioning objective to maintain radiation doses to potential users of the site below regulatory limits for members of the public and at a small fraction of natural background doses will be confirmed by radiological surveys.

Following decommissioning, a comprehensive gamma survey using ground based gamma survey equipment for disturbed areas and airborne radiometric surveys for undisturbed (forested) areas will be conducted for the entire site to ensure that all surficial radiation sources associated with the Cluff Lake operations are within the levels noted above. Any areas which are not within these levels will be remediated as required to achieve them.

8.3.3 Environmental Protection Program

The proponent will be required to ensure that an effective environmental protection program is in place. Activities which make up the environmental protection program include but are not limited to the following:

- establishment, application and maintenance of an Environmental Code of Practice for all activities;
- development and application of environmental protection procedures;
- training of on-site staff and contractors in environmental protection;
- activities related to ensuring compliance with applicable licenses, permits, and legislation;
- control of situations, including spills, that might have a significant detrimental effect on the environment;
- collection of ground and surface water samples in support of the water quality and hydrogeological monitoring programs;
- collection of air monitoring samples in support of air quality monitoring;
- collection of fish, vegetation, and sediment samples in support of the aquatic biota and sediment monitoring programs;
- computation, evaluation, interpretation, and reporting on all environmental monitoring information;
- identifying unacceptable environmental conditions and initiating appropriate mitigation measures;
- compilation of data on the atmospheric environment including the recording of observations for submission to the atmospheric environment service of Environment Canada;
- development of environmentally sound mine site planning;
- preparation and submission of the Status of Environment report; and
- development and execution of habitat compensation plans.

Currently, an Environmental Management System (EMS) is being implemented by the proponent that is based on the ISO 14001 standard. The proponent is also currently developing an environmental effects monitoring program in compliance with the *Metal Mining Effluent Regulations*.

The current operational monitoring program will continue during the active decommissioning phase and will be modified as facilities are decommissioned and monitoring requirements change. When the decommissioning work is complete, a post-closure monitoring period will begin.

The following sections provide a brief overview of the basis for the monitoring program and the key monitoring requirements.

Objectives of the Monitoring Program

The objectives of the monitoring program are to:

- monitor ongoing operations such as effluent treatment facilities to ensure they conform to regulatory requirements with respect to environmental protection;
- verify the success of decommissioning during and after implementation, and the trigger points for implementing any contingency measures, if needed;
- demonstrate compliance with regulatory requirements; and
- quantify any environmental effects.

Implementation of the Monitoring Program

During the operational period, a monitoring program was in place. This operational monitoring program will continue to be applied during the two to three-year period when decommissioning activities proceed.

Following the completion of the decommissioning activities, the post-closure monitoring program will come into effect. As the various decommissioning work packages are completed, new locations will be added to monitor the effects of the decommissioning. Similarly, certain locations monitored during the operational period will no longer be required as a result of changes made during decommissioning and will be eliminated. The post-closure monitoring program will continue to evaluate the key environmental indicators from the contaminant source through to the receiving environment. The post-closure monitoring program will focus on the key environmental indicators including air, groundwater, surface water, aquatic and terrestrial resources. Climate will be continuously monitored because it has an influence on aspects of the decommissioned site. The details of this proposed program are outlined in COGEMA, 2002e.

In addition to this periodic monitoring, a number of follow-up programs will be implemented to address specific mitigative measures and processes.

During the post-closure monitoring period, routine inspections of all areas and critical facilities will continue to be conducted to ensure that decommissioning efforts continue to be successful and that the site is environmentally secure. An on-site workforce will implement the program for a period of approximately five years.

The data from the post-closure monitoring period will be evaluated prior to the end of the five-year period to confirm decommissioning objectives are achieved and mitigative measures are performing as designed. Once the data indicates the decommissioning objectives are achieved, an observational monitoring program will be initiated.

The majority of the monitoring locations specified in the post-closure program will continue to be monitored but likely at a reduced frequency. The locations and exact frequency of continued monitoring will be determined at that time, subject to regulatory review and approval. It is anticipated that there will be no personnel on site and all facilities and infrastructure will have been removed or decommissioned. The observational monitoring program is proposed to continue for an additional ten years following conclusion of the post-closure monitoring program. The observational monitoring period will conclude when the decommissioning objectives have been achieved to the satisfaction of all stakeholders.

The sub-sections that follow provide further details on each of the key environmental indicators and how they will be monitored.

Climate

Climate has been monitored at Cluff Lake since 1981. Due to its remote location and the need to fly personnel in and out, weather monitoring is imperative.

In 1999, an agreement was reached with Environment Canada to install a new weather station adjacent to the Cluff Lake Airstrip. This station has been purchased and installed by Cluff Lake under the direction of Environment Canada, which assumes the responsibility for upkeep and maintenance.

The station records temperature, relative humidity, precipitation, wind speed and direction. Each parameter is recorded on a solar powered data logger, which can be downloaded through telephone access. This data, recorded on a once per minute frequency, offers real time statistics (important for flight arrivals and departures) as well as long-term record keeping and data averaging for historical documentation.

The station will continue to be operated and maintained under the current arrangement during the decommissioning and post-closure monitoring period. When staff personnel are no longer required at the site, it is anticipated that the telephone connection will be replaced with solar powered radio telemetry to allow periodic downloads from off-site. At this time, Environment Canada is expected to assume full responsibility for operating and maintaining the system.

Air Quality Monitoring

During the operational phase of the Cluff Lake Project, total suspended particulates (TSP) in air were routinely measured by high volume air samplers. The samplers were calibrated on a quarterly basis to retain a constant airflow rate through the filter. Dust particles collected on the filter paper were measured to determine dust concentration in the ambient air. The filters were composited on a semi-annual basis, and the dust was analyzed to determine the concentration of heavy metals and radionuclides.

Similar sampling will be required during the early phase of active decommissioning as dust levels may be elevated due to heavy equipment operations that will involve movement of soil material.

Ambient dust levels are expected to decrease when decommissioning and reclamation activities cease, and vegetation becomes established on reclaimed areas. Monitoring of particulate dust will be discontinued when the dust levels reach and are maintained at levels typical for an undisturbed area.

Radon Monitoring

Radon monitoring will continue to be required to monitor air quality around the major impacted areas. It is anticipated that radon levels will be reduced as radiological sources are eliminated (i.e. mill demolition, waste rock haulage to Claude Pit) and after soil covers have been placed. Monitoring locations will be eliminated when radon levels have been shown to remain near background levels.

Water Quality Monitoring

Water quality monitoring will focus on water in the flooded open pits, flooded underground mines, effluent discharge from the Secondary Treatment System, TMA, seepage from the TMA to Snake Lake, and receiving waters downstream of the TMA and mining areas.

In addition to specific requirements in the follow-up monitoring program, the TMA soil cover performance will be evaluated by collecting surface water runoff samples, seepage samples below the Main Dam, and groundwater and receiving water samples.

The success of the waste rock soil cover and other decommissioning activities in the mining areas will be evaluated through the follow-up monitoring program and by the sampling of surface water runoff, pit waters, underground mine waters at depth and near surface, groundwater observation wells and receiving waters. Receiving water will be monitored in Claude Creek, Claude Lake, Peter River, Earl Creek, Boulder Creek, and Cluff Lake.

Sediment and Benthic Invertebrate Monitoring

Sediment and benthic invertebrates will be sampled concurrently in Snake, Island, and Cluff Lakes to identify possible relationships between sediment quality and benthic invertebrate communities. This monitoring will also document the recovery of the benthic invertebrate community in Island Lake where the benthic community has been adversely impacted during operation.

Fish Sampling

Fish tissue samples will be collected from Snake, Island, Sandy, and Cluff Lakes to ensure contaminant bioaccumulation remains low.

Soil Cover Monitoring

Soil cover monitoring will be conducted on the TMA and the Claude waste rock pile following the placement of the soil covers to monitor and measure soil cover performance. These sites will be instrumented to document the performance of the soil covers. Information collected may include localized weather conditions, runoff, infiltration, settlement/consolidation, and soil temperature, and moisture conditions.

Revegetation

A vegetative cover will be a critical component of the soil covers on the TMA and waste rock. Thus regular sampling and evaluation will be conducted through the post-closure monitoring period. The purpose of the monitoring will be to evaluate the percentage of groundcover and to document the presence and absence of the seeded species and note any colonization by native species.

Groundwater Monitoring

Hydraulic head and groundwater chemistry will be monitored where there are potential sources of groundwater contamination. Hydraulic head values for monitoring stations will be recorded on a monthly basis and groundwater chemistry analyses will be performed on samples collected on a semi-annual basis. Due to the slow movement of contaminants through the groundwater system, the proposed monitoring frequencies will be sufficient to observe any trends which may indicate the potential for future degradation of groundwater quality and downstream surface water quality and will allow mitigative measures to be implemented if required.

In general, monitoring stations for the post-closure period have been selected from existing stations to provide an adequate spatial distribution of monitoring stations down gradient of contaminant sources. Control stations have been retained to characterize background temporal variation of parameters up gradient of contaminant sources. Preference has been given to retaining monitoring stations with substantial historical operational data, thereby allowing a direct comparison with the data collected during the post-closure period.

Tailings Management Area

The TMA has been extensively monitored during the operational phase. Data collected during this phase was used to establish long-term monitoring requirements for the TMA following decommissioning.

Monitoring locations were selected to ensure that areas down gradient of the Upper Solids Pond, Lower Solids Pond, Liquids Pond, and STS are adequately represented in the monitoring program. Attention has been given to areas of preferential groundwater flow between the TMA and Snake Lake.

Mining Area

Existing monitoring stations in the vicinity of the Claude and DJ waste piles will be retained for the post-closure monitoring period. Selected existing monitoring stations located between Claude Pit and Claude Lake will also be included in the monitoring program.

Status of Environment Reports

Status of Environment (SOE) reports are produced every five years. This document reviews the results of operational monitoring programs and special environmental projects, and compares these data with previous SOE reports. These data are also compared with pre-operational baseline conditions, if applicable.

Three SOE reports have been produced thus far for the Cluff Lake mine; 1991 (Swanson), 1995 (TAEM) and 2000 (COGEMA). The next SOE report will be issued in 2005 following detailed sampling and analysis to be conducted in 2004. In addition to meeting current reporting requirements, this next report is expected to fulfill the study requirements for biological monitoring of closed mines as specified in the *Metal Mining Effluent Regulations.*

8.3.4 Occupational Health and Safety Program

The proponent has a well established safety program based on the Internal Responsibility System and the Five Point Safety System. These systems, developed by the mining industry, define the key roles and responsibilities for all personnel and promote the attitude and culture necessary to maintain safe working conditions. The proponent has stated its commitment to its safety program and continuous improvements in safety throughout the decommissioning phase. The proponent will be expected to ensure that accident prevention remains an essential component of all its activities.

The key elements of the safety program include but are not limited to:

- training of and communication with all personnel on the safety program and safe work practices;
- provision, maintenance and proper use of personal protective equipment;
- establishment, application and maintenance of safety procedures including procedures for special work conditions (e.g. hot work, confined space, elevated work, lockout);
- establishment, verification and upkeep of fire protection and prevention equipment;
- establishment, testing and maintenance of an emergency response program including the training of emergency response personnel and the maintenance and upkeep of emergency response equipment;
- injury management;

- accident/incident investigations; and,
- inspection and supervision of workplaces to ensure safety practices and measures are maintained or improved on.

It is anticipated that the safety program requirements will need to be reviewed and modified as decommissioning progresses. The proponent will be expected to maintain a program which is sufficient to reasonably ensure the continued protection of all personnel throughout the decommissioning phase.

8.3.5 Training

A training program involves establishing training needs, devising learning objectives, delivering training, testing, and evaluations. The objective of this training program is to ensure training requirements are identified, learned skills are transferred to the workplace, and behavior modification has taken place.

The proponent has committed to and will be expected to ensure that an adequate training program is in place to support the decommissioning project.

8.3.6 Site Security

Site security measures will continue to be required until such a time as the site is deemed safe for uncontrolled access. The proponent will be expected to maintain the necessary personnel, equipment and procedures to ensure that access to the site is controlled throughout this period.

8.4 Project Scheduling

Figure 8.1 provides a schedule for the active decommissioning phase; assuming a January start date. Since the project requires two summer periods to complete seasonal work, the actual schedule may be influenced by the time of commencement. In addition, refinements in the decommissioning plans may also influence the schedule.

The active phase of decommissioning will be completed over approximately two years followed by an approximately five-year post-closure monitoring period. The final phase of monitoring, the observational monitoring phase will span approximately ten years following the end of the post-closure monitoring period.

Planning for final abandonment will be initiated during the post-closure monitoring period. The monitoring period will be extended until final abandonment approval is received from both the federal and provincial agencies. At that time, the Province will oversee any further requirements for long-term monitoring, maintenance or other institutional controls.

9 ASSESSMENT OF ENVIRONMENTAL EFFECTS

9.1 Introduction

As discussed in section 5.2, the assessment methodology included the identification of the licensing requirements of the project, the CEAA applicability, the scope of the project, and the scope of the assessment. The site description and existing environmental effects resulting from operations were described in section 6. In addition, an assessment of the environmental effects resulting from operations was completed, taking into account the application of criteria, recommended in the Canadian Environmental Assessment Agency guidance documents, for determining “adverse” effects and whether those effects are significant.

The most appreciable present and future environmental effect resulting from operations is associated with effluent discharges to Island Lake. Therefore, section 6 also included a post-operation risk assessment for Island Lake. This provides a baseline by which post-decommissioning recovery could be assessed and evaluated.

Section 7 described the decommissioning objectives which are used to evaluate various decommissioning alternatives and to assess the effects of the preferred decommissioning objectives.

Section 9 identifies and assesses the potential environmental effects of the decommissioning project, as described in section 8, for each environmental component including air quality, surface hydrology, surface and ground water quality, and sediment quality. The potential impacts of these environmental effects on aquatic and terrestrial biota, as well as human health and land use, are also described in this section. Where potential impacts are identified, mitigation measures to minimize or eliminate those impacts are proposed, and any remaining residual effects are documented.

The determination of the significance of any adverse residual effects was based on the CEAA guidance document titled *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects* (2003). The guidance document recommends the following three step process:

Step 1:	Decide whether the environmental effects are adverse;
Step 2:	Decide whether the adverse environmental effects are significant; and
Step 3:	Decide whether significant adverse environmental effects are likely.

No physical work is proposed to remediate Island Lake. Decommissioning activities at Island Lake are limited to reduced effluent discharge during the initial decommissioning phase followed by a complete cessation of effluent releases with no further decommissioning activities. Hence, the determination of “adverse” will be based on these activities only.

The significance of any adverse effects was determined using the criteria recommended in the Canadian Environmental Assessment Agency guidance documents (CEAA 2003), i.e., magnitude (severity), geographic (spatial) extent, and duration or frequency of the effect. The final determination takes into account the likelihood of the occurrence of an effect(s), based on the probability of the occurrence and/or the amount of scientific uncertainty in the assessment.

Additionally, the effects of the environment on the project with respect to long-term global climate change, and seismic events, are discussed, as well as effects of the project on sustainable use of renewable resources (section 9.2.9).

Section 9.4 discusses the cumulative effects which take into account the long-term effects resulting from the combination of pre-decommissioning environmental effects (i.e. exploration and operations) and those resulting from the decommissioning project.

The larger tables and figures referenced throughout this section have been appended to the end of section 9.

9.2 Assessment of Effects of the Project on the Environment

The objectives of the decommissioning activities to be conducted at Cluff Lake are to ensure that:

- the environment is safe for non-human biota and human use;
- long-term adverse effects are minimized;
- all constructed structures are removed or stabilized;
- the reclaimed landscape is self-sustaining; and
- restrictions on future land use are minimized.

This will generally involve the minimization, control or removal of contaminant sources in order to reduce the current and future environmental effects resulting from past operations. This normally results in a reduction of environmental effects relative to the operational phase which may occur immediately or slowly over time.

This concept generally applies at Cluff Lake with the exception of the mining area where the dewatering of the pits and underground mines has resulted in hydrodynamic containment of contaminants during the operational period and the long-term impacts resulting from waste rock piles have not yet been observed. As decommissioning is completed and the natural phreatic surface re-establishes, there may be some movement of contaminants through the groundwater system and into surface waterbodies. The residual effects and their significance are summarized in Table 9.1 and discussed below.

9.2.1 Effects of the Project on Air Quality

Pre-operational and operational air quality was previously discussed in section 6. As noted, the most significant increases in both TSP and radionuclide content were generally associated with the mill and the TMA. Decommissioning will involve the covering or removal of major sources of radiological dust (e.g. demolition of the mill, removal or covering of waste rock piles, and the covering of the tailings management area with till material), and revegetation of disturbed lands. These decommissioning activities will reduce or eliminate future emissions of radioactive dust and the corresponding concentrations of uranium and other radionuclides.

Releases of both radiological and non-radiological dust may occur during the actual period that the physical works will be carried out. For example, mill demolition will potentially increase releases of dust as mill components are brought to the ground. Dust suppression measures are readily available to minimize these releases. The radiation and environmental protection programs during the demolition will be reviewed and approved by the CNSC within the decommissioning licensing process, and will ensure the protection of workers and the environment during these activities.

Non-contaminated road dust will be created as materials are hauled for decommissioning purposes. Examples of these types of tasks include the hauling of till material to cover the TMA and Claude waste rock pile, hauling of DJN waste rock material to backfill Claude Pit, and dozer resloping of the Claude waste rock pile. These tasks will be completed in a series of separate projects which will occur over approximately two years. The dust created will not contain elevated levels of heavy metals or radionuclides. Standard dust suppression measures by road wetting will help to reduce nuisance dust levels.

The covering of the tailings and settling ponds at the TMA will help reduce emissions of radon gas and radon progeny to near background levels. Final detailed design and radiation/environmental protection programs will be reviewed to ensure that adequate provisions are in place to keep these emissions ALARA.

Residual Effects and Significance

The demolition of the mill and the permanent disposal of the contaminated scrap through burial in either the Claude Pit or the Liquids Pond will eliminate any residual atmospheric impacts. Revegetated soil covers on the TMA, Claude waste rock pile, the backfilled Claude Pit, and general site revegetation will also minimize airborne emissions of dust, radon gas, and radon progeny.

No residual effects on air quality are anticipated from the Cluff Lake Decommissioning Project.

9.2.2 Effects of the Project on Surface Hydrology

As noted previously in section 6.2.9, a hydrological monitoring program was established to provide a continuous, long-term streamflow record for both Island Lake and the Cluff Lake watersheds. In addition, instantaneous streamflow measurements are collected at two other locations in the Island Creek drainage and at three other locations in the Cluff Creek drainage. Stage discharge curves have been developed at all monitoring stations.

Island Lake Watershed

The hydrology of the Island Lake watershed has already been adversely impacted as a result of operations. These impacts have been discussed in detail in section 6. The following section outlines the environmental effects resulting from decommissioning the site, namely the continued effluent discharge during the initial decommissioning phase followed by the complete cessation of effluent discharge and the redirection of surface runoff from the TMA to Snake Lake.

As noted in section 8, decommissioning the TMA will involve the placement of a soil cover over the tailings. The soil cover will be revegetated with a dense ground cover of grasses and legumes. The North and South Diversion Ditches are already in place to ensure that future flood events flow around the TMA and do not result in erosional damage to the cover. The surface runoff over the TMA area, which has been captured and treated at the STS during the operational period, will be redirected to Snake Lake once acceptable water quality, has been confirmed. This is similar to pre-mining conditions and will not substantially impact the flow rate through Island Creek.

The major change in flows will be related to the water treatment facilities. During the operational period, all discharges from the mill as well as any mine water pumping were directed to the TMA for treatment. Although the treated volumes were highly variable throughout the operational period depending on mill schedule and mining area pumping requirements, the treated effluent discharged to Snake Creek immediately below Snake Lake increased the natural flow at the outlet of Island Lake by approximately one third as shown in Table 9.2.

Treated effluent flow rates will decrease during the decommissioning period as the requirements for contaminated water treatment decline and eventually come to an end. Estimates of the future volumes are contained in Table 9.3.

Over the past two winters, the TMA water treatment system has not been operated due to low water levels in the Liquids Pond. Subsequently, fish mortality was observed in Island Lake in the spring of 2002 and 2003 in the absence of any effluent discharge. Winter fish kills are a natural occurrence in northern Saskatchewan lakes exhibiting similar morphometry and limnology as Island Lake. In the spring of 2003, several northern lakes reported fish kills due to the early freeze-up of lakes at the end of 2002. The fish kills, observed in Island Lake in 2002 and 2003, are believed to be aggravated by the absence of oxygenated effluent discharge during the winter months.

The return to a natural flow regime will result in lower winter dissolved oxygen levels in Island Lake which may lead to further over-wintering losses in the fish population. It is believed that the fish population will re-establish to pre-mining conditions during the initial post-decommissioning phase as treated effluent flows decrease to zero (i.e., by 2009, See Table 9.3).in the near future.

There is also the potential for a change in Island Lake water levels as the system returns to natural flow rates. However, Island Lake's water level is believed to be primarily groundwater controlled so the return to natural flow rates is not predicted to substantially alter water levels. This is important, as reduced water levels may result in the exposure and oxidization of sediment contaminants accumulated over the operating period, leading to remobilization of contaminants into the water column. The issue of Island Lake water levels and their influence on the potential remobilization of contaminants in exposed sediments is an important component of the follow-up program outlined in section 10.

<u>Residual Effects and Significance</u>

The currently observed impacts on the fish population due to re-adjustments in dissolved oxygen levels as treated effluent flows decrease, are believed to be a natural return to pre-mining conditions. Decommissioning is not expected to result in substantial changes in water levels; therefore, no residual effects are expected.

Cluff Lake Watershed

The decommissioning of the mining area and the re-establishment of the natural groundwater elevations throughout the area is not anticipated to significantly impact the hydrological regime in the Cluff Lake watershed. Mill process water taken from Cluff Lake during operations will no longer be required; however, water will continue to be drawn from Cluff Lake at the same rate to flood the DJX pit over the initial two years. This water removal rate amounts to less than 1% of the average flow through Cluff Lake and is well within the range of natural flow variability. Once flooding of the DJX pit is complete, flows will return to pre-mining conditions.

<u>Residual Effects and Significance</u>

No residual effects are anticipated.

9.2.3 Effects of the Project on Groundwater Quality

The significance of adverse effects of the project on groundwater quality is assessed in relation to water quality objectives. Effects of any groundwater contamination would be considered significant if concentrations exceeded drinking water guidelines and there was an existing or reasonable potential for the groundwater to be used as a source of drinking water. Secondly, effects on groundwater would be considered significant if they entered surface water bodies in concentrations that would result in exceedance of water quality objectives for the protection of biota.

Effects of TMA Decommissioning on Groundwater

At the present time, as noted in section 6.2.8, groundwater monitoring downstream of the main dam shows evidence of a groundwater plume extending to Snake Lake. The most elevated concentrations are associated with abundant (either naturally or present in the tailings and water treatment precipitate) elements such as iron and/or highly mobile contaminants such as sulphate and chloride. Changes in trace metals are generally marginal as a result of low abundance and/or low mobility.

Examples of TMA water chemistry under both oxidizing and reducing conditions exist at the site, providing empirical data that brackets the range of potential long-term concentrations between the Liquids Pond and Snake Lake (COGEMA 2000b, Appendix B). The range of redox states for the system and associated chemical characteristics are summarized below.

Persistent reducing conditions will produce source waters with characteristics similar to the water chemistry measured in Piezometer 98-11B, with:

- Barium and Ra-226 concentrations predictable from the solubility of barite in low sulphate water;
- Uranium immobilized as uraninite; and,
- Low concentrations of iron and sulphate due to quantitative precipitation of FeS (ppt), eventually recrystallizing as pyrite (FeS_2).

Under persistent oxidizing conditions, chemistry typical of Piezometer 98-6A, with:

- Ra-226 and barium concentrations predictable from the solubility of barite in a gypsum saturated solution;
- uranium will be mobile as U(6); and
- sulphate will transport attenuated only by dilution with ambient groundwater.

Under moderately reducing conditions, chemical characteristics typical of Piezometer 98-6B, with:

- elevated iron;
- Ra-226 and barium concentrations predictable from the solubility of barite in a gypsum saturated solution;
- uranium will be immobilized as uraninite; and
- sulphate will be stable, with transport attenuated only by dilution with ambient groundwater.

Development of reducing conditions in the groundwater are observed and anticipated to persist. Redox species are less complex to assess than Ra-226 but more complicated to simulate in transport models. As the system becomes depleted in oxygen, redox species begin to gain electrons, changing from their oxidized valence state to a reduced valence state. Some species may go through several reduction transformations. In the Cluff Lake tailings, the primary redox species of concern is uranium. Other redox species, such as arsenic and molybdenum, are present in only very low concentrations and are considered trace constituents. Uranium transforms from its highly soluble (VI) valence state to the strongly insoluble (IV) valence state at mildly oxidizing redox potentials: around +100 mV, depending on the exact chemistry of the system. Minor oxygen depletion produces complete attenuation of uranium (i.e., immobilization as uranite). When more strongly reducing conditions develop, the iron in the environment is impacted. Reduction produces soluble iron (II) from the strongly insoluble hematitic (FeIII) country rock, causing dissolved iron concentrations to rise dramatically. As oxygen is even further depleted, sulphur undergoes reduction, from S(6) as sulphate to S(2), sulphide. At this point, precipitation of iron and sulphur is quantitative, completely removing both species from solution as amorphous FeS, eventually recrystallizing to pyrite.

In addition to goethite (FeOOH) present along the flow path, amorphous iron oxides and oxyhydroxides are a common mineral constituent of the tailings mass itself.

Table 9.4 summarizes the predictive solute transport modeling in the vicinity of the TMA using the preferred decommissioning alternative, assuming 41 mm of infiltration. Note that the peak groundwater concentrations are the peak concentrations entering Snake Lake. The highest groundwater concentrations in the TMA area will be immediately adjacent to the main dam and are expected to be similar to the exposure concentrations reported in section 6.2.8. Concentrations will decrease moving away from the dam as natural removal mechanisms, dilution and radioactive decay reduce the contaminant concentrations.

Table 9.4
Summary of Contaminant Transport Predictions

Solute	SSWQO for Irrigation	SDWQSO	SSWQO for Aquatic Life	Peak Snake Lake Outlet Concentration	Peak Groundwater Concentration
Radium 226 (Bq/L)	na	0.1	0.11	0.039	0.098
Arsenic (mg/L)	0.1	0.025	0.05	0.002	0.005
Chloride (mg/L)	100	250	na	82	206
Nickel (mg/L)	0.2	na	0.025	0.005	0.012
Uranium (mg/L)	0.01	0.02	na	0.002	0.005

SDWQSO = Saskatchewan Drinking Water Quality Standards and Objectives
SSWQO = Saskatchewan Surface Water Quality Objective

The peak predicted groundwater concentrations reporting to Snake Lake were compared to the SSWQO for irrigation and SDWQSO. As shown in Table 9.4, with the exception of chloride, the peak predicted concentrations fall below these standards and objectives. In addition, the peak predicted Snake Lake water concentrations as a result of groundwater inflows are below the SDWQSO as well as the SSWQOs for irrigation and the protection of aquatic life.

The exposure concentrations reported in section 6.2.8 indicate concentrations of sodium, chloride, iron, molybdenum, and Ra-226 which would present a hazard if it was used for irrigation or potable use.

Residual Effects and Significance

Groundwater quality is expected to be adversely impacted as a result of continued leachate releases from the TMA. The predicted change in groundwater chemistry will not pose any unacceptable risk to biota or human health entering Snake Lake as predicted concentrations are all below the water quality objectives for surface water. However, groundwater in proximity of the main dam is expected to continue to be unsuitable for human consumption or irrigation purposes.

As previously noted in section 6, the installation of wells for potable water use, irrigation or livestock watering is unlikely given the abundance of surface water in the local study area and the relative isolation of the site. The institutional controls necessary to control development on the TMA will need to include provisions to prevent inappropriate use of contaminated groundwaters within the impacted areas. This will further mitigate the risks to human and non-human biota resulting from inadvertent use of contaminated groundwaters for consumption or irrigation.

The groundwater plume at the TMA is limited in spatial extent given the proximity of the main dam to Snake Lake.

Given the limited spatial extent, the low probability of inadvertent use of contaminated groundwaters, and the application of institutional controls to further mitigate this possibility, the effects of the TMA on groundwater are considered adverse but are not deemed significant. In summary, groundwater quality degradation is determined not to be significant as it does not limit existing and potential reasonable uses of both groundwater and surface waters in the region.

Effects of Decommissioning the Mining Areas on Groundwater

As a result of decommissioning, the hydraulic containment of the pits and underground mines will cease. This will lead to adverse changes in groundwater quality which were not present during operations. In addition, the backfilled material in Claude Pit and the adjacent waste rock pile will continue to be important sources of groundwater contamination in the foreseeable future.

Modeling to estimate the long-term water quality resulting from the decommissioned Claude and DJN/DJX areas has been conducted. COGEMA (2000c) predicts the infiltration to the Claude waste rock pile after installation of the cover (Appendix D), calculates the source term from all contributing mines and waste rock piles (Appendix B) based on waste rock characterization testing (Appendix A), and models the concentrations and loadings to the surface receptors (Appendix C).

Following the change to complete backfilling of Claude Pit, the modeling was updated in COGEMA, 2001 (Appendix A) and this submission provided a modeling comparison of the DJX flooding versus backfilling option. As a result of further questions in regards to DJX options, a further report was developed on this issue (COGEMA, 2002a). It includes a systematic review of source terms and flow assumptions and recalculated predicted water quality. All of the decommissioning scenarios predict adverse changes in groundwater quality, however, the magnitude and spatial extent of these changes varies among models.

The preferred decommissioning approach, while reducing the rate of groundwater contamination, will not eliminate it. Further migration of the contaminant plume towards surface water receptors will occur. Based on the modeled steady state particle paths (COGEMA, 2002a), groundwater contamination is expected to predominantly extend to south and east of the Claude waste rock pile to Peter River and from the waste rock pile and Claude pit heading north and east towards Claude Lake and Claude Creek. An additional plume is expected from DJX pit extending to Cluff Lake. Some groundwater contamination will also result from the underground mines, but this effect will be limited in magnitude and will occur at significant depth where low hydraulic conductivity limits groundwater movement.

As shown in section 6.2.8, elevated concentrations of major ions, trace metals and radionuclides exist in the groundwater wells adjacent to the Claude Waste Rock Pile. These concentrations make this water unsuitable for human consumption, irrigation or livestock watering without prior treatment. The modeling did not predict long term groundwater concentrations at various points downstream of the major contaminant sources, however, groundwater concentrations over the flowpath can be expected to range between the modeled peak concentrations in the downstream surface water receptors and the current concentrations in groundwater wells located at the perimeter of the Claude Waste Rock Pile.

As such the existing groundwater plume near Claude Pile, which is limited in spatial extent, may expand to cover an area of approximately 2.5 square kilometers to varying depths predominantly within the overburden and fractured bedrock where the most elevated hydraulic conductivities exist.

Residual Effects and Significance

As noted, groundwater which becomes contaminated to levels similar to those encountered at the perimeter of the Claude waste rock pile will be unsuitable for human consumption, irrigation or livestock watering. The direct effects of groundwater discharge on surface and sediment water quality and its impact on biota and human health are addressed in the remainder of this section.

The population of the region is very low and is expected to remain as such for the foreseeable future. Based on traditional land uses and the abundance of surface water in the area, any water usage can be reasonably assumed to originate from surface water bodies. Therefore, degredation of groundwater quality will not adversely affect existing and potential reasonable use of the groundwater. To mitigate potential adverse effects , institutional control measures to prevent usage of groundwater for drinking and irrigation purposes may be put in place.

On this basis, the effects of the project on the groundwater in the mining areas are adverse but are not deemed significant.

9.2.4 Effects of the Project on Surface Water Quality

Effects on surface water quality would be deemed significant if they resulted in concentrations that could adversely affect the survival or reproduction of aquatic life and wildlife such that recovery of local populations would be unlikely within several generations. Surface water quality degredation would also be considered significant if concentrations posed a human health risk. The human health risk assessment is located in section 9.2.7.1.

Effects of TMA Seepage on Snake Lake Water Quality

The following points summarize the findings of the 3-dimensional solute transport model was used to predict the downstream impacts from the decommissioned TMA.

- The preferred decommissioning alternative would result in an average long-term peak Ra^{226} concentration at the Snake Lake outlet of 0.039 Bq/L, assuming 41 mm of infiltration using 1994 as a median year. The long-term groundwater concentration entering Snake Lake is predicted to be 0.098 Bq/L.
- The preferred decommissioning alternative would result in an average long-term peak Ra^{226} concentration at the Snake Lake outlet of 0.058 Bq/L, assuming 62 mm of infiltration using the full 18 year weather record. The long-term groundwater concentration entering Snake Lake is predicted to be 0.144 Bq/L.
- The sorptive capacity Snake Lake sediments was found to have negligible influence on the Ra^{226} peak concentrations in Snake Lake. Not considering the sediments would result in a slight increase in Snake Lake concentration to 0.039 Bq/L. A substantial increase (factor of 8) in sediments distribution coefficient resulted in a long-term average Snake Lake concentration of 0.037 Bq/L. The long-term groundwater concentration entering Snake Lake is predicted to be 0.098 Bq/L. and 0.093 Bq/L, for each case scenario.
- The Liquids Pond source term was found to have negligible influence on the Ra-226 peak concentrations. Doubling the source term to 0.4 Bq/L resulted in a slight increase in Snake Lake concentration to 0.039 Bq/L. Reducing the Liquids Pond source term to zero would produce an average long-term Snake Lake concentration of 0.037 Bq/L. The long-term groundwater concentration entering Snake Lake is predicted to be 0.098 Bq/L and 0.093 Bq/L, respectively. The insensitivity of the Snake Lake water quality to the Liquids Pond source term indicates the majority of loading will originate from the solid tailings.
- The Snake Lake concentration was found to be highly sensitive to overburden distribution coefficients. Decreasing the distribution coefficients by a factor of two increased the average long-term Snake Lake Ra^{226} concentration to 0.055 Bq/L with the long-term groundwater concentration entering Snake Lake predicted to be 0.137 Bq/L. The distribution coefficient values used in the original analysis (the highly absorptive till material was not accounted for were in the low range of the values expected for the Cluff Lake overburden materials, hence the loading calculations provided results greater than what would be expected to occur. If the highly absorptive till materials were assumed to occupy the lower half of the overburden, the long-term Snake Lake Ra^{226} concentration decreases to 0.018 Bq/L with an average groundwater concentration of 0.045 Bq/L.
- The Snake Lake concentration was found to be much less sensitive to bedrock distribution coefficients. Decreasing the distribution coefficients increased the average long-term Snake Lake Ra^{226} concentration to 0.042 Bq/L. The long-term groundwater concentration entering Snake Lake was predicted to be 0.104 Bq/L. Again, distribution coefficient values used in the original analysis were in the low range of expected values, hence the loading calculations provided results greater than what would be expected to occur.

- The extreme TMA infiltration events were found to influence the Snake Lake concentrations. A 10-year solute transport simulation using 10-year wet steady state infiltration resulted in an average long-term peak Snake Lake Ra-226 concentration of 0.023 Bq/L. The 10-year dry weather infiltration resulted in a long-term peak Snake Lake Ra^{226}concentration of 0.081 Bq/L. The long-term groundwater concentration entering Snake Lake is predicted to be 0.091 Bq/L and 0.095 Bq/L, respectively. These infiltration events are anticipated to be highly extreme events; hence these concentrations would represent unlikely conditions.
- Future Snake Lake sediment accumulation was not accounted for in the predictive modeling program. Additional sediments would provide for additional adsorptive capacity which would lower long-term loading rates. This benefit was not included in the analysis.

Table 9.4, presented in section 9.2.3, summarizes the predictive solute transport modeling in the vicinity of the TMA using the preferred decommissioning alternative, assuming 41 mm of infiltration. Predicted concentrations at the outlet of Snake Lake will be below SSWQO for protection of aquatic life for Ra^{226} sulphate, arsenic, chloride and nickel, and below the decommissioning objective for uranium. The peak predicted concentrations for copper, selenium, molybdenum, and uranium are 7 µg/L, 1 µg/L, 27 µg/L, and 2.5 µg/L respectively, which are all below the SSWQO and decommissioning objectives for each element.

<u>Residual Effects and Significance</u>

The predicted residual effects, as presented in Table 9.4 above, are greater than those that existed at the end of operations. They are therefore deemed adverse. However, they fall below SSWQOs, and the decommissioning objectives for all parameters, consequently, no adverse effects on survival and reproduction of aquatic organisms are anticipated. Hence, the effects are not considered significant.

Effects of Termination of Treated Effluent Release on Island Lake Water Quality

As decommissioning activities are completed, flow rates and concentrations of contaminants in the effluent will taper off resulting in an improvement in water quality in Island Lake. Counteracting this improvement will be a process of contaminant release from the sediments back into the water column. Modeling was conducted to provide an estimate of the rate of water quality (and sediment quality) improvement and the time to re-establishment of background conditions.

Following calibration of the INTAKE model using monitoring data from 1982 through 1999, the future water quality in the Island Creek system was predicted for 10,000 years (COGEMA, 2000d, Appendix B). The predicted water quality in Island Lake is shown in Figure 9.1. The modelling assumes the following schedule:

- a decommissioning period extending from 2002 to 2006;
- a post-closure monitoring period, wherein the Secondary Treatment System (STS) continues to treat site run-off and tailings consolidation water until 2008; and
- a post-decommissioning period.

As the source loadings decrease and eventually cease, the modelling demonstrates a gradual decrease in surface water contaminant concentrations. The rate of contaminant reduction in the Island Lake water column is related to water contaminant residence, time (flushing rate) and the rate of sediment contaminant reflux based on the water-to-sediment partitioning coefficients, (K_d values). Contaminants that partition to sediments when the concentration in the water column is high will start to flux into the water column as the aqueous concentration decreases. Therefore, contaminants with a high K_d will take longer to return to background levels due to the dynamic exchange between the water column and the sediment layer. For example, conservative parameters such as chloride, sulphate, and TDS rapidly recover to background levels. Conversely, recovery of surface water quality for metals is more gradual as they have a higher water-sediment partitioning coefficient (K_d).

Most surface water contaminant concentrations are predicted to rapidly decrease after cessation of treated effluent discharge. Within 100 years, all contaminants are anticipated to be at background levels. The only parameter predicted to exceed the SSWQO is ammonia. This is predicted to occur over the initial 10 to 20 years. The ecological risk assessment (section 9.2.6) found these concentrations are not likely to pose any risk to aquatic biota. Ammonia concentrations will be carefully monitored as part of the decommissioning monitoring program.

An additional factor not modeled was the influence of treated effluent releases on winter oxygen concentrations in the area localized around the point of release. Island Lake is relatively shallow and quite biologically active, key characteristics of lakes that periodically experience winter fish kills due to low dissolved oxygen levels. Over the operational period, it is likely that treated effluent served as a source of oxygenated water, especially through the ice covered period. This may have minimized the incidence of winter fish kills in the lake. This conclusion is supported by the winter-kill events that occurred in the late winter of 2002 and 2003, when no effluent was released during the ice-covered period. Winter-kills may become more frequent post-decommissioning with the cessation of effluent releases. This may result in a lower fish carrying capacity for the lake, consistent with pre-mining conditions, and a corresponding decrease in the fish over-wintering population.

Residual Effects and Significance

As discussed in section 6, operational releases to Island Lake have resulted in adverse water quality. As a result, initial post decommissioning (i.e., after cessation of effluent release) water quality in Island Lake will be elevated for a number of contaminants relative to pre-operational and reference conditions. However, at no time after decommissioning are contaminant water concentrations expected to exceed those reached during peak operational releases or those predicted to occur at the time of cessation of releases.

The time to recovery for Island Lake and environs is based on the cumulative effects of conditions resulting from the operational releases, and natural recovery mechanisms (e.g., the rate of reflux from the sediments and the rate of flushing from Island Lake). The cumulative assessment indicates that post decommissioning water quality is initially adverse (due to operational releases), however, with the removal of the major source term (effluent), improvements in water quality are predicted with pre-mining levels attained within 50 to 100 years. Under the worst case conditions observed during operational releases, a functioning aquatic system has been maintained with the primary effect being a shift in aquatic community composition. Thus at no time during the post-decommissioning phase would the magnitude of any effects be considered severe. The geographic extent of the adverse water quality has been and should continue to be restricted to Island Lake with little transport beyond the fen.

Therefore, because of the limited spatial extant of the observed and predicted adverse effects, and the expectation that improvements in water quality will allow biological recovery in Island Lake, the cumulative effects of operations and decommissioning would not be classified as a significant adverse effect.

The potential changes in fish carrying capacity are expected to reflect conditions similar to those which existed prior to operations. The follow-up program (section 10) and the environmental monitoring program (section 8.3.3) will specifically monitor the fish population, the reflux of sediment contaminants into the water column, and the continued performance of the fen to ensure that the downstream water quality remains below the decommissioning water quality objectives. Mitigative action may be required should contaminant release from Island Lake and fen sediments fail to behave as predicted resulting in the potential for impairment of downstream water quality.

Effects of Decommissioning the Mining Areas on Water Quality in the Cluff Lake Watershed

Upon completion of decommissioning, groundwater seepage from the open pits and underground mining areas, in combination with the associated waste rock piles, will drain to small streams or rivers which discharge to the north end of Cluff Lake. The Claude Pit and waste rock pile will drain to Claude Lake/Creek and the Peter River. The DJX pit will seep directly to Cluff Lake while D-pit and the D waste rock pile will contribute loadings to Boulder Creek. The general location of the mining areas in relation to the north end of Cluff Lake is shown on Figure 2.3.

The predicted concentrations for all key parameters including nickel, uranium, selenium, molybdenum, and cobalt are all below the SSWQOs and the decommissioning objectives (COGEMA, 2001, Appendix A). Predicted uranium and nickel concentrations in Claude Lake, Peter River, and Cluff Lake are shown in Figures 9.2, 9.3, and 9.4. For all surface waterbodies, model predictions indicate that uranium concentrations will remain within the hardness-related objective levels as outlined in section 7.1.2.

The hardness level in Claude Lake is expected to remain high (above 200 mg/L $CaCO_3$ equivalent) as a result of continued seepage from the backfilled Claude Pit (COGEMA, 2002b, Section 3.1). The peak concentrations in Figure 9.2, of 72 µg/L uranium and 42 µg/L nickel are well below the hardness corrected objective of 400 µg/L for uranium and 100 µg/L for nickel. It is of note that the predicted values in Claude Lake and Peter River are higher for the DJX flooding option. This is because the present volume of the Claude waste rock pile will remain in its current location for the flooding option, whereas for the DJX backfill option, much of the rock would have been moved to the pit which would no longer contribute contaminants to Claude Lake and Peter River.

Residual Effects and Significance

The control of mine water during the mining operational phase has minimized the impacts on surface water quality in the Cluff Lake watershed. Following decommissioning, natural groundwater levels will re-establish and contaminant migration to surface waterbodies will occur. The concentration of these contaminants in surface waters is predicted to rise slightly in relation to current background levels; hence, this is classified as an adverse effect.

The increase in water quality parameters for Claude Lake, the Peter River, and Cluff Lake are predicted to remain below the decommissioning water quality objectives. Thus, they are not predicted to be significant with little likelihood of measurable biological effects. For uranium, this conclusion is dependent on the suitability of the uranium toxicity and hardness relationships. Refinement of the uranium toxicity hardness function is presently the primary objective of the regional water quality and sediment quality working group. COGEMA's participation in this group as well as the completion of uranium toxicity tests on Cluff Lake waters are components of the follow-up program described in section 10.

Effects of Decommissioning D-pit on Pit Water Quality

As noted in section 6, the flooded water column in D-pit exhibits a stable chemocline. The adjacent waste rock pile is generally stable with no evidence of significant erosion which might lead to exposure of underlying waste rock and the potential increase in the release of contaminants to the pit. Furthermore, D-pit is separated from any other surface water body.

Residual Effects and Significance

The effect of D-pit water quality on the environment, as a result of current conditions, was discussed in section 6.

Since the flooded water column exhibits a stable chemocline which is expected to continue in the foreseeable future, there are no adverse effects resulting from the final decommissioning of D-pit as there is no predicted change from current operational conditions. Given that the current and future water quality, above the chemocline, meets the decommissioning water objectives specified in section 7, the cumulative effects of operational and decommissioning activities are considered adverse but not significant.

Effects of Decommissioning DJX Pit on Pit Water Quality

The DJX and DJN pits are adjacent to each other, resulting in a single waterbody once flooding is complete (see Figure 6.3). Therefore, the initial flooding of DJX Pit will result in the release of contaminants from the exposed pit walls and the oxidized waste rock material remaining in DJN Pit. These contaminated waters will mix with contaminated waters already present in the pit resulting in potentially elevated concentrations of key contaminants such as nickel and uranium. If decommissioning water quality objectives are not met after initial flooding, the water will be treated until the water quality objectives have been met.

A chemocline similar to that observed at D-pit is expected to establish in the long term resulting in cleaner waters at surface and increasing contaminant concentrations at depth. Long-term water quality is predicted to be similar to that in D-pit and at a minimum, below the water quality objectives for flooded pits, as specified in section 7. The pit will remain isolated from other surface water bodies except in extreme precipitation events when there is potential for overflow into Cluff Lake. In such an event, the cleaner waters from the upper water column would be released to Cluff Lake resulting in negligible impacts.

The attainment of the decommissioning objectives for DJX pit relies on the effective establishment of a chemocline in the upper 50% of the water column. Confirmation of this phenomenon and the development of contingencies, should they be deemed necessary, are part of the follow-up monitoring program discussed in section 10.

Residual Effects and Significance

The effects of the DJX pit water quality on downstream water quality have already been assessed and discussed in section 9.2.3 and 9.2.4.

In its current state, the pit waters are not readily accessible to wildlife. Once the pit is flooded and treated as required, it is anticipated that the final water quality in the upper water column will be better then the current water quality in DJX pit. However, it is recognized that the water quality is not the same as that in natural surface waters and that in a flooded state, the pit will become accessible to wildlife. On this basis, the effects from decommissioning DJX pit are considered adverse.

On the basis that the water quality objectives will be met and that similar conditions that currently exist in D-pit will also establish in the DJX pit, residual effects are not considered significant as SSWQO are predicted to be achieved above the deep water chemocline. The only contaminant not meeting SSWQO is likely iron; however, levels should be consistent with natural groundwater quality in the area and small local watercourses which are predominantly groundwater fed. The assessment of risks to biota based on the experience at D-pit, indicates that the water quality will not pose a substantial risk, a conclusion supported by the documentation of a naturally established aquatic community consisting of plankton, benthic invertebrates, and aquatic macrophytes in D-pit. The risk to wildlife utilizing the pit for drinking water was also found to be negligible (section 9.2.6.3).

9.2.5 Effects of the Project on Sediment Quality

Effects on sediment quality would be deemed significant if contaminant concentrations adversely affected survival and reproduction of aquatic life such that recovery of local populations would be unlikely within several generations.

Background

Based on the water quality predictions, a subsequent step in the INTAKE model was to calculate the corresponding sediment concentrations at each time step. The detailed initial modeling is described in COGEMA, 2000d, Appendix B where the Island, Snake and Cluff Lake water and sediment quality was predicted over the next 2000 years. Subsequent to the change in decommissioning strategy for the mining area (decision to backfill Claude Pit), the Cluff Lake water and sediment quality was re-modeled (COGEMA, 2001, Appendix B). In 2002, additional modeling of Cluff Lake water quality was undertaken to assess the DJX pit backfill and flooding options (COGEMA, 2002a). These most recent water quality predictions were not substantially different from the previous estimate, as shown in Table 9.5, so further sediment quality modeling was not undertaken. As there was no change to the Snake and Island Lake modeling scenarios, the sediment values predicted in the original document remain valid.

Table 9.5
Comparison of Water Quality Predictions in Cluff Lake Documentation

	Units	COGEMA, 2001	COGEMA, 2002a
		Peak 50th Percentile Concentration	Peak 50th Percentile Concentration
Uranium	µg/L	20	15
Nickel	µg/L	4.2	7

Potential Effects and Proposed Mitigation

As previously discussed in section 6.2.11, sediment quality was assessed against the available sediment quality guidelines and the recent scientific literature (Table 7.2). Radionuclides are not discussed within this section as sediment quality is best assessed by calculating overall radiation dose from the combined exposure to multiple radionuclides rather than through the use of individual contaminant sediment quality guidelines. This assessment is provided in section 9.2.6.

The predicted sediment quality for the primary lakes of interest is shown in Figures 9.5 (Snake Lake), Figure 9.6 (Island Lake) and Figure 9.7 (Cluff Lake). These figures include curves of the median (50th percentile), 5th and 95th percentile, calculated from 100 probabilistic trials, over the first 2000 years of the 10,000 year simulation. The median value represents the best estimate of the expected quality while the 5th and 95th percentiles bound the expected range. Values are closely related to the predicted changes in lake water quality.

From these figures, it is evident that contaminant concentrations in Snake Lake and Cluff Lake sediments increase post-decommissioning to an asymptote and either stabilize or steadily decline. Hence, the selected decommissioning options adversely affect sediment quality. In the following paragraphs, the significance of this adverse effect is assessed by comparing the peak contaminant concentrations to the available guidelines.

For Island Lake, peak sediment contaminants are associated with the operational period with contaminants declining post-decommissioning. Hence, the preferred decommissioning option (natural recovery) does not adversely influence sediment quality. The cumulative effect, and in particular, the recovery time, are based on the severity of the operational loadings and the natural recovery mechanisms (e.g., reflux to water column and long-term sequestering within sediments). For the sake of continuity, the cumulative effects on Island Lake are assessed in the following paragraphs. Cumulative effects are again revisited in section 9.4 to summarize the cumulative effects of operational and decommissioning activities and to present any additional effects that may be associated with activities outside of the Cluff Lake facility.

Snake Lake

In section 6.2.11, it was demonstrated that operational activities only marginally influenced sediment quality in Snake Lake. This involved minor increases in sediment bound uranium and radium-226, neither of which were determined to be elevated enough to significantly affect biota. With the decommissioning of the TMA, additional releases to Snake Lake are predicted to occur. Figure 9.5 indicates that seepage from the decommissioned TMA will result in a slow increase in a number of sediment contaminants followed by stabilization or a gradual decline as seepage rates decrease. The implications of this are assessed by comparisons to the guidelines in Table 7.2.

The median and the 95th percentile predictions for both uranium and zinc are within or below the lower boundary ranges provided by the guidelines. In addition, the median predicted concentrations for arsenic, copper, lead, molybdenum, nickel, uranium, and zinc are near or below the lower guideline boundaries and/or within regional background concentrations. The only contaminants with predicted 95th percentile values not substantially below the lower guideline boundaries are arsenic, nickel, and molybdenum. However, the predicted values for these contaminants are substantially below the upper boundaries calculated by Thompson et al (2003) from a database restricted to uranium mining regions in Canada using the same analytical procedures used to generate the Ontario MOE guidelines. In addition, the peak arsenic prediction is below the upper range documented for local background (23 µg/g) in the Cluff Lake area. Hence, sediment quality in Snake Lake is not expected to be significantly impaired with the decommissioning of the Cluff Lake mine.

Island Lake

Operational releases to Island Lake have resulted in sediment contaminant accumulation to levels that are considered adverse and have altered the benthic macroinvertebrate community (see section 6.2). With the cessation of effluent release to Island Lake, contaminant concentrations in the surficial sediments are predicted to decrease as shown in Figure 9.6. Molybdenum, nickel, uranium, and selenium levels were identified as the primary contaminants of potential concern (see section 6.2). Hence, it is the rate of recovery for these contaminants that is of specific interest. This is discussed in the following paragraphs, with the exception of selenium, which is addressed in the ecological risk assessment because dietary uptake of selenium is the most significant route of exposure.

Substantial decreases are predicted for all of these contaminants within the first 50 years. Molybdenum median concentrations are predicted to decrease by approximately 50% to less than 100 µg/g substantially below the SEL guideline range (540 – 1239 µg/g). The 95th percentile is expected to decrease to approximately 500 µg/g also below the lower range SEL. Nickel median concentrations are predicted to decrease to below all of the proposed low effects boundaries (approximately 10 µg/g) with the 95th percentile decreasing (approx. 30-35 µg/g), well below three of the four proposed upper guidelines (Table 7.2). Recovery to background conditions for both these contaminants occurs between the 50 to 100-year time period.

Like molybdenum, the median sediment uranium concentration is also predicted to decrease by approximately 50% by 50 years post-decommissioning, to approximately 200 µg/g. In the same time interval, the 95th percentile estimate decreases from an excess of 800 µg/g to approximately 500 µg/g. Hence, within the first 50 years post-decommissioning uranium concentrations, while potentially detrimental, will have substantially improved and will remain substantially below the severe effect level calculated by Thompson et al. (2003). Recovery to below the low effects boundary (104 µg/g) is achieved within approximately 100 years to 150 years for the 50th and 95th percentile estimates, respectively.

It is expected that the presently impacted benthic communities will gradually recover as sediment quality improves through the first 50 years post-decommissioning. The community that develops will be more complex than the present community (greater taxonomic richness and diversity). The benthic community will likely continue to consist of more metal tolerant species similar to those established in naturally metal enriched waterbodies such as Zimmer Lake at the Key Lake mine area (Conor Pacific 2000, Golder 2002), until background conditions are established for all contaminants approximately 100 years post-decommissioning.

Cluff Lake

Table 9.6 lists the measured background sediment concentrations for Cluff Lake in 1998 while Figure 9.7 provides the model predictions for future Cluff Lake sediment quality. Data for only the initial 2000 years of the 3000 year simulation are shown, as peak predicted levels for all contaminants occurred within this period and trends were generally decreasing towards the end of the simulation period. It should be noted that predicted contaminant levels are total concentrations and include background values.

Table 9.6
Peak Predicted Sediment Concentrations – Cluff Lake

Contaminant	Units	Measured Background		
		5th	50th	95th
Arsenic	µg/g dry	20.0	30.5	56.0
Copper	µg/g dry	11.8	19.0	35.5
Lead	µg/g dry	21.3	23.0	23.0
Molybdenum	µg/g dry	5.3	13.0	15.0
Nickel	µg/g dry	20.5	25.5	31.0
Uranium	µg/g dry	18.1	19.2	23.1
Zinc	µg/g dry	120.0	125.0	167.5
Cobalt	µg/g dry	11.0	14.0	18.5
Selenium	µg/g dry	-	-	-
Lead-210	Bq/g dry	1.1	1.7	2.7
Polonium-210	Bq/g dry	0.9	1.5	2.4
Radium-226	Bq/g dry	0.35	0.55	0.99
Thorium-230	Bq/g dry	0.18	0.24	0.40

The model predictions suggest there will be a relatively small increase in the cobalt, copper, lead, molybdenum, selenium, and zinc concentrations. The contaminants exhibiting the greatest increase in concentrations, in order of increasing rate of change are arsenic, nickel, and uranium.

The 1998 field sediment sampling program demonstrated that natural arsenic concentrations can exceed the lower and even the upper guideline boundaries proposed by the CCME and the Ontario MOE (e.g., the reference lake, Lac Phillip mean=23.4 µg/g). The elevated arsenic concentrations in Cluff Lake are also assumed to be natural as dewatering activities during operations restricted contaminant migration to the pits and underground mines. This conclusion is supported by exploration sediment chemistry that documented a sediment arsenic anomaly located downstream from the Cluff Lake ore body encompassing an area that included the northern portion of Cluff Lake (Dunn 1980). The highest measured arsenic concentration was 56 µg/g: collected from the northeastern tip of Cluff Lake. The predicted peak 50th and 95th percentile arsenic concentrations are substantially below the SEL range (346 – 5874 µg/g) proposed by Thompson et al. (2003). This suggests that any effects arising from elevated arsenic concentrations will not be severe in magnitude and likely restricted to those portions of Cluff Lake containing naturally elevated concentrations.

Nickel concentrations, like those of arsenic are naturally elevated in the Cluff Lake drainage. Dunn (1980) identified this area as a nickel sediment anomaly where concentrations were greater than three times the regional median value (>36 µg/g). This conclusion is supported by the 1998 sampling; where a mean value of 37.7 µg/g was measured. Hence, this area naturally exceeds the proposed low effects guidelines. The benthic community that will be exposed to increased nickel concentrations as a result of the proposed decommissioning is one that has been established in an elevated nickel environment. This pre-exposure, and the fact that the predicted 50th and 95th percentile concentrations are substantially lower than the upper guideline boundaries proposed for uranium mining regions, means severe alteration of the benthic community would not be expected.

Uranium sediment concentrations are predicted to show the greatest increase with the proposed decommissioning activity. Despite this the predicted 50th percentile concentrations is below the proposed low effect guideline. Only the 95th percentile has the potential of exceeding the low effect guideline. However, this predicted concentration of 222 µg/g is well below the SEL range of 3410 - 5874 µg/g proposed for uranium mining regions. Hence, any effects on the benthic community would not be expected to be severe, especially in light of the potential for pre-adaptation of the resident community to high uranium concentrations as the Cluff Lake drainage is identified as a high uranium bearing region (Dunn 1980).

Residual Effects and Significance

Snake Lake

Environmental effects on Snake Lake resulting from operations have been minor. As a result of decommissioning, a minor increase in a few contaminants is expected, with all but the 95th percentile predictions for nickel and molybdenum being below or near regional baseline values or low threshold guidelines. As a result of the predicted increase in contaminants, effects arising from the decommissioning activities are classified as adverse. However, this adverse effect would not be considered significant as concentrations are expected to be well below upper threshold guidelines (SEL or PEL), and therefore biological effects, if any, would be limited in magnitude, would have no measurable influence beyond Snake Lake and would lesson with time as seepage water quality improves.

There is no need to further assess the cumulative effects of operational releases and the proposed decommissioning option as operational releases were too minor to be considered adverse and would not substantially influence modelling predictions.

Island Lake

Operational effects on sediment quality in Island Lake are classified as adverse based on sediment quality guidelines and the results of biological monitoring. As described in section 6, the effect is restricted in magnitude to a shift in the benthic community composition while maintaining total abundance, a factor important to the lake’s benthic foraging white sucker population. The modeling and field data support the conclusion that the effect is primarily restricted in geographic extent to Island Lake (181 hectare).

The proposed decommissioning option, referred to as natural recovery, involves the cessation of effluent releases to the drainage and allowing natural processes to gradually lock contaminants into deeper sediment horizons decreasing their potential for future transport and their bioavailability. As a result, there are no additional adverse effects associated with the decommissioning option. The time to recovery for Island Lake and downstream waterbodies is based on the cumulative effects of conditions resulting from the operational releases, and the natural recovery mechanisms (e.g., the rate of reflux from the sediments and the rate of flushing from Island Lake).

The cumulative assessment indicates that post decommissioning sediment quality, while initially adverse (due to operational releases), will improve with the removal of the major source term (effluent). Substantial improvements in sediment quality are predicted within the first 50 years, with even the upper range predictions (95th percentile) for sediment uranium and molybdenum reaching the high end of regional background conditions by 100 to 150 years. Since at the end of the operation, a functioning aquatic system remains, with the primary effect being a shift in benthic community composition, the magnitude of any residual effects associated with the slower improvement in sediment uranium and molybdenum concentrations would not be significant.

In summary, the cumulative effect is considered to be adverse but not significant. Sediment contaminant levels are within local upper background concentrations and/or less than the upper guidance threshold developed from the northern Saskatchewan database. Sediment quality will substantially improve over the next 50 to 100 years. Thus, on the application of criteria, recommended in the Canadian Environmental Assessment Agency guidance documents, such as magnitude, geographic extant, duration and reversibility, the cumulative effect of operational activities in combination with the proposed decommissioning activity on sediment quality is not considered to be a significant adverse effect.

Alternatives to passive recovery, such as dredging activities, are not considered to be appropriate. Dredging would have severe adverse effects on benthic organisms, macrophytes, and fishes and has the potential for initiating downstream transport of contaminants. Natural recovery is considered the preferred option from an overall ecological perspective. The appropriateness of this plan based on predictive modeling relating to the flux of sediment contaminants to the Island Lake water column and their subsequent sequestering in the bordering Island lake fen. Verification of this process will be addressed through the Island Lake fen stability follow-up program outlined in section 10.4.

Cluff Lake

The proposed decommissioning option for Cluff Lake has the potential for adverse residual effects (primarily for 95th percentile predictions). These are likely to be minor in magnitude, localized to only a portion of Cluff Lake and will have no effect on regional populations within the drainage. Hence, they are not considered to be significant adverse effects. These conclusions are based on the modeling of the contaminant flow-path associated with the flooded pits and decommissioned rock-piles. Follow-up programs addressing the key processes and parameters in the modeling are provided in section 10.3.

There is no need to further assess the cumulative effects of operational releases and the proposed decommissioning option as operational activities are not believed to have impacted Cluff Lake sediment quality.

9.2.6 Effects of the Project on Non-Human Biota

The previous sections compared water and sediment quality predictions in waterbodies impacted by the decommissioning project with generic guidelines and regional or site-specific objectives to determine the nature of any residual effects. The environmental effects of past operations and in particular effects on Island Lake were discussed in section 6.

This section focuses on the risks to non-human biota from exposure to contaminated environmental media (e.g., water, sediment, vegetation). Risk was estimated by comparing exposure through time to selected critical toxicity benchmarks. An effect on biota will be deemed significant when a risk quotient greater than 1 is predicted to occur over a proportion of habitat or home range such that a decline in a regional population may occur. An adverse effect on biota would also be determined to be significant if recovery of a local population would not occur within several generations after removal of the source of contamination.

Background

A comprehensive ecological risk assessment was conducted to evaluate the risk to valued ecosystem components, both aquatic and terrestrial, at key impacted sites. Impacts on aquatic receptors from various trophic levels (phytoplankton, zooplankton, benthic invertebrates, pelagic and benthic fish) were assessed using water and sediment quality predictions for both non-radioactive and radioactive contaminants far into the future. A pathways modeling approach was used to assess risk to terrestrial receptors on a watershed basis, but again, largely dependent on a small number of environmental source terms. For interpretation, the assessment included estimates of risk from natural, regional background. The approach to the ecological risk assessment is described in COGEMA, 2000d, Sub-Appendix B3.

Initial, conservative (Tier 1) modeling is described in COGEMA, 2000d, Appendix B. It used generic parameters and conservative critical toxicity values (NOELs, No-Observed-Effects Levels). As a result of the decision to backfill Claude Pit, the Tier I analysis was repeated (COGEMA, 2001, Appendix B). Results from the Tier I analysis indicated potential for long-term, adverse effects on a variety of VECs from non-radiological contaminants in certain areas. This suggested the need for a more realistic evaluation of risk, especially at realistic times of potential abandonment (10, 50, 100 years).

A realistic Tier 2 evaluation was therefore conducted incorporating limited site-specific data, and selected, less conservative parameters, focusing on pathways where results were highly sensitive to the values chosen (COGEMA, 2002b, section 3.7). Risk to non-human biota was also further interpreted in terms of critical toxicity benchmarks indicative of low-level effects (LOELs, Lowest-Observed-Effects Levels), rather than no effects.

Only the results for the realistic Tier 2 assessment are presented here, along with a brief discussion of the sensitivity of risk estimates to key model parameters and assumptions. Background information is also provided on the relevance and suitability of some critical toxicity benchmarks for interpretation of effects on non-human biota.

9.2.6.1 Effects on Aquatic Organisms

Non-radioactive contaminants:

Neither Cluff Lake nor Sandy Lake accumulated contaminants over the operational period to an extent requiring a risk assessment. For these waterbodies, the risk assessment was completed on the 50th and 95th percentile peak predicted water contaminant concentrations. These concentrations occur post-decommissioning therefore the assessment is of the risks associated with the preferred decommissioning options. Island Lake and the associated fen and riparian habitats are the only areas to have accumulated contaminants over the operational period to levels of potential concern to aquatic and terrestrial biota. Hence, the ecological risk assessment (ERA) was completed to assess the present (pre-decommissioning) risk to aquatic and terrestrial biota (VECs) associated with the Island Lake area. This establishes the benchmark conditions against which time to recovery or any additional impacts associated with decommissioning activities are measured. The results of this assessment were presented in section 6 but will be revisited in the following paragraphs when discussing time to recovery.

In addition to the assessment of recent conditions (year 2000), potential impacts to aquatic receptors were also assessed for 2009 and 2050 (post decommissioning). In each case, the INTAKE model was run probabilistically and summary statistics consisting of the 50th and 95th percentile were estimated from 100 trials. The initial assessment (COGEMA, 2000d, Appendix B) concluded that Snake and Sandy Lakes are considered to be negligibly impacted (all screening indices < 1); hence, Snake Lake was excluded from the Tier 2 assessment. Sandy Lake, however, was included as it is the point at which the effluents from the Island Lake and Cluff Lake watersheds combine.

The aquatic receptors in this assessment consist of simplified representatives of several trophic levels in a typical lake ecosystem and are discussed in greater detail in section 6.2.14. They include primary producers (algae and aquatic macrophytes), primary consumers (zooplankton), detritivores (benthic invertebrates), and secondary consumers (northern pike and white sucker). Risks to benthic biota from water-borne contaminants are addressed herein, with risks from sediment contaminants addressed in section 9.2.5. Aquatic mammals and birds are included in the terrestrial biota assessment.

The results of the calculations for Island Lake, Cluff Lake, and Sandy Lake are presented in Tables 9.7 to 9.9, respectively. Results are presented in the form of screening indices consisting of the ratio of the predicted peak exposure concentration (i.e., water) to the benchmark value. Screening indices above 1 indicate a potential for an adverse effect on the individual or population. No values exceeded 1 for the following contaminants: ammonia, arsenic, cobalt, lead, selenium, and zinc. Hence, these water-borne contaminants are considered to pose no risk to aquatic organisms in any of the assessed waterbodies.

The screening indices for the 95th percentile concentration of copper indicate the potential for impacts to primary producers and fishes in all three lakes. However, it is evident from the background indices that copper levels in these lakes are naturally above the selected toxicity benchmarks for these VECs. Similar observations have been made while conducting baseline work in the Cigar Lake and McArthur River mine areas where natural water copper concentrations ranged up to 0.005 and 0.008 mg/L, respectively (CLMC 1995). These concentrations substantially exceed the modeled peak 50th percentile with the

McArthur value exceeding the 95th percentile (0.0074 mg/L) exposure assessment. Given the presence of healthy aquatic systems in these reference lakes with naturally elevated copper concentrations, the predicted copper exposures are unlikely to pose a threat to the native aquatic biota.

Island Lake pre-decommissioning molybdenum concentrations (50th and 95th percentile) may pose a risk to zooplankton and northern pike (Table 9.7). However, by the year 2050, impacts are not expected for any of the aquatic VECs. In Cluff Lake and Sandy Lake, concentrations of molybdenum are below toxicity benchmarks for all aquatic VECs.

Screening indices for nickel are all below 1 with the exception of primary producers in Cluff Lake and Island Lake. The 95th percentile prediction continues to marginally exceed 1 for both the 2009 (1.5) and 2050 (1.07) scenarios. The phytoplankton risk quotients in Island and Cluff lakes are primarily a result of the use of a conservative toxicity benchmark (0.005 mg/L). The similarity between the risk quotients for background and exposure lakes, and the fact that modeled exposure concentrations are less than the CCME water quality guideline of 0.025 mg/L (CCME guidelines are considered to be protective of aquatic life in general), suggests nickel concentrations pose little risk.

Screening index values based on predicted uranium concentrations in Island Lake are above 1 for primary producers and zooplankton (Table 9.7). These elevated indices are predominantly a function of the selected toxicity benchmark. The calculation of the toxicity benchmark was strongly influenced by the preponderance of plankton studies completed under conditions of very low water hardness (2 to 4 mg/L as $CaCO_3$) which is known to increase uranium toxicity. Current hardness levels in the Island Lake watershed are artificially elevated as a result of incoming effluent, however, natural hardness values in the system range between 35 and 45 mg/L as $CaCO_3$ (based on 2001 and 2002 values in the North Diversion Ditch). Thus, the benchmark values for primary producers and zooplankton are considered to be conservative [approximately 8 times higher than would be expected after applying a qualifying factor for increased hardness (See COGEMA 2001)] resulting in a similarly conservative estimate for the screening index. When the uranium toxicity benchmark is corrected for hardness (COGEMA 2001) the screening index values fall below before the Year 2050. Periodic monitoring of biological systems during this period will assess the accuracy of these predictions and the rate of ecological recovery.

As shown in Table 9.8, uranium may be a potential contaminant of concern for Cluff Lake. However, as previously discussed the toxicity benchmark does not account for hardness which will also increase with the selected decommissioning option. Should the previously mentioned hardness relationship be accurate or conservative, then the risk quotients for uranium in Cluff Lake will be less than one. The follow-up program involves the completion of uranium toxicity tests on Cluff Lake waters as well as studies to improve our understanding of the relationship between uranium toxicity and hardness (see section 10.6).

The risk modeling indicates that water-borne selenium poses no risk to aquatic biota (Table 9.7 to 9.9). However, as discussed in section 6, water based selenium toxicity benchmarks are poor means of assessing risks from selenium (Sappington 2002). Studies in Island Lake indicate that selenium has accumulated in fish tissues during the operational period to levels that may pose a risk. This issue is presently being investigated as part of the follow-up program. For further information, see the discussions in section 10.8.

Residual Effects and Significance

Island Lake

The current biological status of Island Lake represents an altered, but functioning, aquatic community. Present effects are moderate in magnitude and are spatially (geographically) limited as they are expected to remain restricted to Island Lake (181 ha, 27×10^5 m^3). The Tier 2 risk assessment identifies the most likely causal contaminants as molybdenum and uranium. However, as previously noted, fish tissue analyses for Island Lake suggest that Se may also pose a risk to fish. Salinity and possible synergisms with other contaminants may also be contributing factors. As previously discussed, these effects are a result of effluent discharged during the operational period. There are no additional adverse effects associated with decommissioning.

The cumulative assessment indicated that ecological risks for most aquatic biota are ameliorated within approximately 10 years post-decommissioning for molybdenum, with uranium recovery occurring somewhat more slowly after approximately 50 years. Risks to sediment dwelling organisms decline more slowly, requiring approximately 50 years for molybdenum, and approximately 100 years for uranium (see section 9.2.5). The risks to biota and the associated recovery time for selenium will be the subject of further evaluation as part of the follow-up program.

Thus, the cumulative effect of operational and decommissioning activities is classified as adverse. The adverse effects are moderate in magnitude, spatially (geographically) limited to Island Lake and reversible, with substantial recovery in the first 50-100 years. Therefore, adverse effects on biota are not considered significant because they are restricted to local populations and recovery will occur over several generations. Based on the application of CEAA criteria, the cumulative effects, while adverse, are not considered significant.

Cluff Lake

There have been minimal operational effects on Cluff Lake (slight increase in sulphate levels); hence, the risk assessment was restricted to the predicted peak post-decommissioning conditions. The ERA indicated that uranium may affect primary producers and zooplankton in Cluff Lake. Effects would not be severe as the ERA resulted in low risk quotients (1.8 to 2.2) despite the use of a relatively conservative toxicity benchmark. Although the potential residual effects to Cluff Lake aquatic organisms are adverse, they are likely to be low in magnitude, given the presence of phytoplankton and zooplankton in Island Lake at uranium concentrations approximately ten times greater (note hardness amelioration). Any effects would be geographically limited to Cluff Lake. Therefore, the effects on aquatic biota in Cluff Lake are considered adverse but not significant.

Sandy Lake

Sandy Lake was included in the ERA as it represents a far-field location with potential exposure to contaminants from both the Island and Cluff lake drainages and would be representative of regional populations. The ERA indicated that Sandy Lake should not be affected by decommissioning activities in either of the drainages. Hence, activities are not expected to adversely affect resident aquatic biota.

Radionuclides

At the present time, there are no standard methods for the calculation of radiation dose to biota. The methodology used in the technical supporting documents (COGEMA 2000d: Appendix B, pp. B-33 to B-36) incorporated an effects benchmark of 10 mGy/d and a relative biological effectiveness correction for alpha particles of 5. This assessment concluded that radiation dose posed no measurable risk to aquatic biota associated with the Cluff Lake decommissioning (i.e., all indices <1). An alternative methodology for calculating radiation dose to biota has recently been developed. It involves lower effect benchmarks for specific aquatic taxonomic groups (0.54 mGy/d to 5.4 mGy/d) and uses an alpha particle RBE of 40 (Bird et al. 2002). Even with the application of this more stringent assessment method, the screening indices for Island Lake (the highest exposure waterbody) did not exceed 1 .Hence; the presence of radionuclides in the water column or sediments in the Cluff Lake and Island Lake watersheds while adverse is not expected to have a significant effect on aquatic biota.

9.2.6.2 Effects on Terrestrial Organisms – Island Lake and Cluff Lake Watersheds

This section presents results for the Tier 2 assessment of impacts from non-radioactive substances and radionuclides on terrestrial VECs in the Island Lake and Cluff Lake watersheds. This analysis quantified the risk to wildlife drinking water, foraging for food, and ingesting soil/sediment, calculated from predicted contaminant concentrations in water, prey items, vegetation, sediment or soil. For wide-ranging or migratory species, diets were adjusted for expected use of the impacted areas (e.g. waterfowl were assumed to be exposed for six months of the year, COGEMA 2000d, Sub-Appendix B3). As only limited site-specific data were available for most parameters (especially for specifying probability distributions), wildlife risk estimates were highly dependent on modeled water and soil/sediment concentrations, and their associated diet transfer factors. Given the simplicity of this approach, mean risk estimates (50th percentile) should be interpreted with caution. Certain key parameters need to be verified in the follow-up program to ensure confidence in the levels of realism implied by the Tier 2 probabilistic results.

The ERA for the Cluff Lake was restricted to predicted peak decommissioning conditions as there have been minimal operational effects. The Island Lake assessment involved modeling of the risks associated with operational releases (2000) as well as conditions at three post decommissioning time intervals (2009, 2050, 2100). Regional background conditions were also modeled for comparison with predicted conditions at the Cluff Lake site.

Non-Radionuclides

At Island Lake, screening indices were all below one for current and future conditions for arsenic, cobalt, copper, lead, nickel, and zinc (Table 9.10). Short-term potential risk to a few species (mallard, scaup, muskrat, and otter) was evident for selenium, with screening indices remaining slightly above one until

2009, but only for the 95th percentile. Overall, risk declined rapidly with time for this group of elements. Typically, screening indices approached background values by 2100.

Extremely high screening indices were found initially in the Tier I analysis for molybdenum and uranium at Island Lake (COGEMA, 2001), with even 50th percentile risk estimates remaining highly elevated for several species far into the future. In the Tier 2 analysis (Table 9.10), screening indices for both elements dropped by orders of magnitude, and hence, only a few risk estimates for molybdenum (mallard, scaup, muskrat, otter) remained above one; only until 2009, and only for the 95th percentile. The differences between Tier 1 and Tier 2 results for these two important elements, and their interpretation, are discussed separately below.

At Cluff Lake (Table 9.11), maximum screening indices at all times were typically much less than one, with only a few maximum values at the 95th percentile approaching one. Overall, there was little indication of potential risk to wildlife over a wide range of species and contaminants.

Molybdenum at Island Lake

The Tier 1 analysis indicated potential for residual effects on various species far into the future, with screening indices remaining above one at the 50th percentile in 2100 for muskrat (40.2), otter (8.3), moose (2.1), and bear (1.2). However, high background values (e.g. up to 8.6) in this initial screening suggested that some generic parameters or assumptions were either hyper-conservative, or inappropriate for this region. Screening indices were further refined in the Tier 2 analysis by calculating diet-related transfer factors (water-aquatic vegetation, water-fish, etc.) from limited site-specific data. Consideration was also given to the consumption of soils/sediments on a wet weight rather than a dry weight basis, and assumptions concerning the bioavailability of contaminants were derived from available literature. Depending on the species-diet combination, changes in transfer factors largely accounted for major reductions in risk estimates in the Tier 2 analysis. Estimates fell below one for most species by 2009 (Table 9.10), relative to an expected background risk no higher than 0.03 (50th percentile, otter).

Changes in wildlife screening indices through time were directly dependent on the linkage of the wildlife pathways to the predicted water (Figure 9.1) and sediment (Figure 9.6) concentrations from the watershed model. For molybdenum, these two source terms remained elevated for many years, accounting for the prolonged decline in wildlife risk through time. Patterns among species were largely a function of diet specifications and fixed ecological characteristics (e.g. predicted use of the Island Lake area). Verification of predicted concentrations in representative diet items, as consumed by wildlife (e.g. muskrats eating roots of *Typha latifolia* with adhering sediments, predators consuming whole fish containing sediment in the gastrointestinal tract), is therefore necessary as part of the follow-up program. Comparison of measured with predicted values will ensure confidence in various approaches to estimation of both the magnitude and duration of risk to wildlife, as the watershed gradually returns to a background state.

The 50th percentile risk quotients for mallard and scaup are less than one. However, because the toxicity benchmark is a Lowest Observed Effects Level (LOEL) representing complete embryonic mortality during incubation, the 95th percentile prediction is taken into account. The 95th percentile risk estimate indicates there is some potential risk for reproductive impairment of these birds up to year 2009 with risk declining to less than one by 2050. The realism of this modeling will be assessed by measuring molybdenum concentrates in food items for these VECs during the follow-up program.

Tier 2 risk quotients are not presented for caribou and moose (see table 9-10). Caribou are not addressed any further as their dietary pathway (primarily lichens) is not linked to the aquatic molybdenum releases. In the case of moose, recent information suggests that the benchmark based on reproductive effects in rodents may not be appropriate to assess the effects of molybdenum. In ruminants such as moose, exposure to Mo may lead to molybdenosis, a nutritional disease of domestic ruminants recognized throughout the world (Thounten, 2002). This disease is well documented in domestic ruminants consuming forage containing elevated molybdenum concentrations. There is recent scientific literature on the sensitivity of moose to molybdenosis (e.g., Frank et al., 2002) in environments containing naturally low levels of bioavailable copper. Copper bioavailability in the diet is important as the concentration of molybdenum leading to molybdenosis is influenced by the copper status of the animal. Excess molybdenum concentrations can result in reduced uptake of copper and hence copper deficiency.

Limited data from northern Saskatchewan suggests that copper levels in vegetation are below copper dietary requirements for cattle. The effect of molybdenum is also exacerbated by increased sulfur levels in the diet (O'Connor et al., 2001).

There is evidence of moose utilizing the habitat surrounding Island Lake (e.g., observations of animals and scat) with no reported incidence of dead or ill moose. The post-decommissioning environment at the Cluff Lake site may increase the suitability of the habitat for moose (i.e., less human activity, and increased availability of early successional brouse) with a resultant increase in residence time and potential increase exposure to molybdenum from Island Lake forage (macrophytes and riparian vegetation). Therefore, the likelihood of risk of molybdenosis will require follow-up monitoring to determine the copper status of forage in the region and molybdenum and sulfur concentration in Island Lake forage. Should the chemical analysis confirm the potential risk of molybdenosis at Island Lake, moose utilization of the site will have to be monitored and if moose are found to use the site extensively, the health of the animals will need to be investigated. These requirements will be incorporated into the follow-up program.

The potentially adverse effect of molybdenum on scaup, mallard and on moose is not considered significant because it is spatially limited to Island Lake and the risk will decrease over time after decommissioning and cessation of effluent discharge. Preventing the possibility of mobilization of contaminants from Island Lake Fen sediments downstream to Sandy Lake and the Douglas River, following withdrawal of mill effluent input to the watershed, is crucial.

Monitoring of the Fen and the predicted decline in concentrations of contaminants with time is therefore essential in the follow-up program to ensure overall protection of wildlife on a watershed basis. For example, in the final stages of mill closure (March 2003), the filtering effect of the Island Lake Fen reduced molybdenum concentrations by 99% in water downstream at Island Creek (reduced to 0.014 mg/L from a concentration of 1.0 mg/L at the Island Lake outlet).

Uranium at Island Lake

Evaluation of screening indices for uranium at Island Lake is also influenced by similar issues of interpretation and uncertainty that were raised in connection with molybdenum. The Tier 1 analysis indicated potential residual effects on some species far into the future, with screening indices remaining above one at the 50th percentile in 2100 for muskrat (5.0), otter (1.7), moose (1.5), and scaup (1.5). For comparison, simulated background values were slightly below 1.0 (e.g. up to 0.8), reflecting the high background expected for a uranium mining region, and some conservatism in parameter choices. As for molybdenum, modifications in the Tier 2 assessment in transfer factors, soil/sediment ingestion rates, bioavailability, and the nature of the toxicity benchmarks resulted in substantial reductions in risk estimates (Table 9.10), such that no risk estimate remained above one at the 50th percentile, in the context of a background risk no higher than 0.06. To verify the level of realism in wildlife exposure predictions for uranium, this element also needs to be monitored in critical diet items and environmental media within the Island Lake watershed in the follow-up program.

Interpretation of risk requires consideration of the uncertainties and extrapolations being made from the underlying toxicity benchmarks for uranium. In the absence of a suitable benchmark for waterfowl, a proposed benchmark from the literature was used as a default (Haseltine & Sileo, 1983). This experimental study found no effects on black ducks ingesting metallic uranium up to a dose of 160 mg/kg/d. However, this study used metallic uranium as the dietary source, making it impossible to determine the amount of uranium that was physiologically available. Available data on uranium concentrations in waterfowl inhabiting the Cluff Lake Tailings Management Area (TMA) indicate that uranium released to the environment at this site is bioavailable. Despite the deficiencies in the toxicity benchmark, the Cluff Lake TMA waterfowl data support the risk assessment conclusion that uranium exposure represents a low risk to waterfowl. Uranium concentrations in the kidneys of the waterfowl harvested in 2001 were well below the estimated no effect value (ENEV) of 0.5 mg/kg wet weight for kidney function (kidney function is the primary target for uranium toxicity).

Better-quality comparative toxicity data were available from laboratory experiments with mammals ensuring a higher level of confidence in the benchmark chosen (Gilman et al., 1998a,b). The selected toxicity benchmark represents short-term effects on reproduction, growth and survival and consequently to the low risk quotients for mammals indicate that short-term effects are not likely. However, the potential for chronic effects resulting from long-term (possibly multi-generational) exposure have not been completely accounted for. Thus confirmation monitoring through appropriate sampling of potentially significant exposure pathways has been included in the follow-up program.

Residual Effects and Significance

At Island Lake, operational activities have resulted in conditions that are potentially adverse to wildlife. The contaminants of potential concern are: molybdenum, uranium, and to a much lesser extent, selenium. These effects are reversible, as they are the result of historical releases, with a very gradual recovery to background conditions. The magnitude of risk varies by species and contaminant and is strongly influenced by assumptions about diet and ecological characteristics. For several species, magnitude is high at present and in the immediate future. The time to complete recovery is also long, due to the natural recovery decommissioning strategy. Screening indices indicative of low-level effects may remain above one for molybdenum and uranium for a few species beyond expected periods of monitoring and observation (e.g. to 2050-2100). Any implications of adverse, residual effects at the time of abandonment will need to be revisited with more realistic models, once reliable site-specific data are obtained in the follow-up program.

The geographical extent of adverse effects is predicted to be confined to the immediate vicinity of Island Lake (181 ha), and is hence small. In an ecological context, adverse effects on some individuals of wildlife species living at or near Island Lake are unlikely to translate into any significant impact on regional numbers of wildlife. The most highly impacted species are common throughout the boreal forest, and no endangered or threatened species are affected. End-state utilization for traditional purposes of a few species (muskrat, otter, moose, waterfowl) may be affected within the immediate area of Island Lake in the medium-term. Downstream impacts on a large spatial scale (i.e., Sandy Lake and the Douglas River) are highly unlikely, given watershed models that predict a gradual release of contaminants retained within the Island Lake Fen. Effects of the prolonged return to background levels of molybdenum, uranium, and selenium are therefore not considered to be significant ecologically, or in terms of traditional use of wildlife in the area. This conclusion is dependent on the stability of the Island Lake Fen, and therefore needs to be verified in the follow-up program (section 10.4).

At Cluff Lake, all realistic Tier 2 screening indices for wildlife were below one for non-radioactive contaminants. Residual effects are therefore highly unlikely and are of no significance.

Radionuclides

Wildlife screening indices for radionuclides were calculated using the same pathways modeling approach as for non-radioactive contaminants. Risk estimates were therefore also highly dependent on key watershed source terms and estimates of transfer factors leading to ingestion of radionuclides through the diet. A summary of the 50th and 95th percentile results for screening indices using background conditions, maximum predicted concentrations, and the concentrations at year 2009 is presented in Table 9.12. Both the absorbed dose and the equivalent dose based on a relative biological effectiveness (RBE) of 5 for alpha radiation, are presented. The data represent the highest expected exposure of wildlife in the project area at Island Lake.

With one exception for an extreme case (the 95th percentile of the maximum concentration, for the mallard), all screening indices were well below one. Use of a conservative RBE value of 40 in calculations would increase equivalent doses about 7-fold (depending on the alpha contribution of the radionuclides involved). This would not change the overall pattern for low mean risk from any maximum concentration and very low mean risk for the predicted state of the watershed in 2009. The special case of the mallard has a low probability of occurrence, and is the result of the importance of sediment ingestion and bioaccumulation resulting from certain high transfer factors, including the intrinsically high transfer factors for diet-to-flesh for birds versus mammals. This low probability result should be interpreted in terms of major uncertainties in specifying transfer factors specific to birds, which necessitates the use of a particularly wide range of default parameter distributions. Limited historical survey data indicate only minimal use of the Island Lake area by waterfowl, with most breeding and staging occurring in the Claude Lake area.

Residual Effects and Significance

For radionuclides, there is a low probability of a residual, adverse effect for mallards at Island Lake based on relatively generic modeling for birds. The magnitude of the effect is small for most scenarios. It is of short duration, with elevated screening indices only for low probability, maximum scenarios in the initial years after mine/mill closure. Effects are plausible only in a small area at Island Lake and are reversible, gradually improving with time. Waterfowl populations in the project area are not well-studied, but are generally similar to those found throughout the northern Saskatchewan mining region. The mallard is both migratory and common throughout the region. Hence, this effect is not considered to be significant in an ecological context.

9.2.6.3 Effects on Terrestrial Organisms – Flooded Pits

The previous section presented the potential risks to non-human biota utilizing resources associated with the local study area. These assessments assumed drinking water was obtained from natural waterbodies. A further assessment is required to determine whether substantial additional risk would arise if non-human biota were to utilize the flooded pits for drinking.

This section describes the assessment of potential incremental effects to ecological receptors drinking water at the D and DJX Pits.

Water Quality

Table 9.13 summarizes water concentrations used for the assessment of incremental effects on ecological and human health through the drinking water pathway.

The D-pit has been flooded and monitored for water quality since 1985. Generally, water quality has stabilized, and is expected to remain stable far into the future. Uranium levels in D-pit are, however, not stable, with fluctuations resulting from adjacent waste rock pile runoff/seepage associated with heavy rainfall.

The DJX Pit will be flooded in the future. New modeling was therefore completed to estimate the concentrations of uranium and nickel in the DJX Pit. Other contaminant concentrations were developed based on predictions for pit water quality completed by SENES (1992). Modeling results indicated that water quality was comparable for the D and DJX Pits for all contaminants other than uranium. Hence, only the D-pit was assessed (higher uranium concentration).

Island Lake and Snake Lake 50th percentile water concentrations (maximum in year 2000) were obtained from the Tier 2 modeling exercise (COGEMA, 2002b). Water concentrations were obtained using the same assumptions and parameters as presented in Appendix B of COGEMA (2001). Values differ slightly from other presentations due to random sampling differences in the model run; however, these changes are insignificant.

Table 9.13
Water Quality for Drinking Water Assessment

Contaminant	Units	D-pit Water Concentration	DJX Pit Water Concentration	Island Lake Water Concentration [a]	Snake Lake Water Concentration [a]	Drinking Water Quality Guideline [c]
Arsenic	mg/L	0.026	0.026	0.001	0.0006	0.025
Cobalt	mg/L	nd	nd	0.0006	0.0009	-
Copper	mg/L	0.007	0.007	0.003	0.002	1.0 [d]
Lead	mg/L	0.012	0.012	0.005	0.001	0.010
Molybdenum	mg/L	0.008	0.008	0.801	0.026	-
Nickel	mg/L	0.028	0.028	0.006	0.005	-
Selenium	mg/L	nd	nd	0.004	0.0004	0.01
Uranium	µg/L	340	110	179	2	20
Zinc	mg/L	0.069	0.069	0.006	0.003	5.0 [d]
Thorium-230	Bq/L	0.017	0.017	0.019	0.012	0.4
Radium-226	Bq/L	0.071	0.071	0.021	0.029	0.6
Lead-210	Bq/L	0.107	0.107	0.040	0.014	0.1
Polonium-210	Bq/L	0.107 [b]	0.107 [b]	0.007	0.003	-

Note: a – maximum (year 2000) 50th percentile predicted concentration
b – assumed equal to lead-210 concentration
c – from CCME (1999)
d – guideline for an aesthetic objective

nd – no data available
- - guideline not available

Ecological Assessment at Flooded Pits

The assessment of ecological receptors at the flooded pits considered the following receptors: black bear, caribou, bald eagle, hare, ptarmigan, moose, and wolf. Waterfowl were not considered, since it is unlikely that they would use the flooded pit for any length of time given the abundance of good quality wetlands within the site study area. Terrestrial receptors were expected to use the area around the pits for food and habitat, and it was assumed they would drink water from the pit. Receptor characteristics, including water ingestion rates and the fraction of water from the site, used in this analysis and the preceding Tier 2 risk assessment, are provided in COGEMA (2002b).

This section presents results for the assessment of incremental effects from the D-pit (and DJX Pit) as a source of drinking water for terrestrial receptors. The screening indices presented herein represent the incremental risk from drinking pit water and hence is additive to the screening indices presented in the previous section.

Non-Radioactive Contaminants

Table 9.14 presents screening indices associated with the ingestion of water from the D-pit by wildlife. Indices for copper, lead, nickel and zinc are all extremely low. Arsenic and uranium concentrations in the D-pit result in similarly low screening indices. The largest value in Table 9.14 is a screening index of 0.039 associated with uranium and the moose. If this value is added to the screening index of 0.188 for the moose in the Island Lake watershed (Table 9.10, year 2000, 95th percentile), the total screening index remains well below one (0.039 + 0.188 = 0.227). Similar calculations for other species/contaminants also result in risk quotients below one.

The water quality in D-pit is poorer than at Snake Lake for all contaminants, and hence wildlife using Snake Lake as a source of drinking water would also be exposed to very low risk. Previous Tier 2 wildlife risk estimates included consumption of water from Island Lake; results were presented in section 9.2.6.

Table 9.14
Incremental Screening Index Values for Non-Radionuclides to Terrestrial Receptors
D-pit Drinking Water Pathway

	Bear	Caribou	Eagle	Hare	Moose	Ptarmigan	Wolf
Arsenic	0.012	0.016	< 0.001	0.006	0.014	< 0.001	0.003
Cobalt	Nd	nd	nd	nd	nd	nd	Nd
Copper	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Lead	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Molybdenum	0.002	0.002	< 0.001	0.001	0.002	< 0.001	< 0.001
Nickel	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Selenium	Nd	nd	nd	nd	nd	nd	Nd
Uranium	0.030	0.025	0.001	0.009	0.039	0.001	0.020
Zinc	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Note: nd – no data available for these parameters

Radioactive Contaminants

Table 9.15 presents wildlife screening indices associated with ingestion of radionuclides in drinking water from the D-pit. The values are all extremely low, regardless of species, or choice of the RBE for alpha radiation. As for non-radioactive contaminants, since the water quality in Snake Lake is better than that of the D-pit, screening indices are also negligible for Snake Lake.

Table 9.15
Incremental Screening Index Values for Radionuclides To Terrestrial Receptors
D-pit Drinking Water Pathway

	Bear	Caribou	Eagle	Hare	Moose	Ptarmigan	Wolf
RBE of 5	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001
RBE of 10	< 0.0001	< 0.0001	0.0001	< 0.0001	0.0001	0.0002	< 0.0001
RBE of 20	< 0.0001	< 0.0001	0.0002	< 0.0001	0.0001	0.0003	< 0.0001

Residual Effects and Significance

Low to negligible incremental screening indices for wildlife obtaining water from the flooded pits (D or DJX), or Snake Lake indicate no residual effects on terrestrial receptors using these areas as sources of drinking water.

9.2.7 Effects of the Project on Human Health

This section presents results of the assessment of the impacts of exposure to non-radioactive contaminants and radionuclides on human health. The first subsection presents the effects of traditional use of the project area (trapping), under the assumption that local trappers would obtain drinking water from Cluff or Sandy Lakes. The second subsection identifies the incremental risk if the same receptors were to drink water from flooded pits, Island and Snake Lakes.

9.2.7.1 Effects from Living in the Project Area

Non-Radioactive Contaminants

A Tier 2 risk assessment was carried out over a 10,000 year time period for two hypothetical trappers assumed to reside year-round at Sandy Lake or Cluff Lake (COGEMA, 2002b). The trappers are assumed to obtain drinking water and fish from these lakes and consume local berries from the project area. They hunt local game from the most contaminated watershed (moose, ptarmigan, hare and duck from the Island Creek watershed), or in the case of woodland caribou, from the entire project area. Conservative assumptions were used in the pathways models (COGEMA, 2000d, Appendix B). Of the non-radioactive contaminants, only arsenic is carcinogenic. Exposure by both direct and indirect pathways generally resulted in very low hazard quotients, similar to background (Table 9.16). Only zinc, at the 95th percentile maximum concentration had a hazard quotient marginally greater than one, but in the context of a similar background value. Arsenic intakes and risk levels for incidence of cancer were well within the range of those for background exposure to arsenic across Canada (typical intake levels 1.2 x 10^{-4} to 7 x 10^{-4} mg/(kg d) and risks of 7 x 10^{-4} to 1.1 x 10^{-3}) (EC 1993).

Radionuclides

Incremental dose estimates (50th and 95th percentiles) for three post-decommissioning time intervals (2009, 2050 and 2100) are shown in Table 9.17. In addition to the pathways modeled for non-radioactive contaminants, dose estimates included the contributions from inhalation of radon and dust. The largest predicted incremental dose was 170 µSv/yr (95th percentile for the Cluff Lake trapper). This incremental maximum dose can be compared to a nominal natural background dose in Canada of approximately 2,000 µSv/yr, and the regulatory public dose limit of 1,000 µSv/yr.

__Residual Effects and Significance__

For year-round residents, potential risks from exposure to natural foods and drinking water from the most likely traditional use of the area (trapping) are either similar to, or only slightly elevated, relative to risks from natural background exposure. Hence, no adverse effects are predicted on human health for realistic scenarios of expected use of the decommissioned area.

9.2.7.2 Human Health Assessment For the Flooded Pits, Island Lake and Snake Lake

Potential effects on human receptors were assessed for casual, i.e. short-term, use of drinking water at sites that might provide opportunistic sources of water for human consumption, particularly when the project area returns to a natural state, e.g. at flooded pits, Island Lake, and Snake Lake. Adults were assumed to collect sufficient water to sustain them for 20 days at a rate of 2 L per day. The Sandy Lake Trapper was hypothesized to consume water from Island Lake or Snake Lake. The Cluff Lake trapper consumed water from the D-pit (encompassing exposure from the DJX Pit). Predicted water quality is presented in Table 9.13.

This section discusses the results for the assessment of short-term effects for the hypothetical Sandy Lake and Cluff Lake trappers. These are considered the most representative of human receptors.

Non-Radioactive Contaminants

Table 9.18 shows hazard quotients for short-term exposure relative to acute toxicity benchmarks, or available guidelines (e.g. the Tolerable Upper Intake Level, Dietary Reference Intake for molybdenum from the Institute of Medicine (IOM), COGEMA 2002b). With two exceptions, hazard quotients were very low for all contaminants and receptors. For the Cluff Lake trapper, a hazard quotient of 0.149 was found for arsenic. Arsenic is rapidly eliminated from the human body (< 1 day, ATSDR, 2000). Casual exposure to arsenic in flooded pit waters should therefore not result in health concerns, given the reasonable assumption that individuals would normally obtain their regular water supply from Cluff Lake for which the hazard quotient is less than one.

For the Sandy Lake trapper, a hazard quotient of 0.789 was obtained for the predicted 50th percentile molybdenum concentration at Island Lake of 0.8 mg/L for the year 2000, relative to a consensus North American dietary guideline. For comparison, in the most comparable experimental study to date, no effects were found in four male volunteers ingesting molybdenum at levels up to 1.5 mg/d for 24 days, (Turnlund et al 1995). Measured concentrations of molybdenum at Island Lake were 1.0 mg/L in March, 2003 as operations were being shut down. Island Lake molybdenum concentrations should drop substantially in the short term, but will only return to background levels after a very long period (Figure 9.1). Hence, some residual risk is possible if Island Lake water is used for human consumption in initial years. The magnitude of this risk is difficult to quantify accurately, as no short-term benchmark exists for molybdenum, however, it is unlikely that water from Island Lake (1.5 m depth) would be used as a regular water source by the hypothetical Sandy Lake Trapper, limiting the possibility of significant health effects.

Table 9.18
Short-Term Hazard Quotient Values for Non-Radioactive Contaminants to Human Receptors – Drinking Water Pathway

	Cluff Lake Trapper D-pit	Sandy Lake Trapper Island Lake	Sandy Lake Trapper Snake Lake
Arsenic	0.149	0.006	0.003
Cobalt	Nd	< 0.001	< 0.001
Copper	0.001	0.001	< 0.001
Lead	0.017	0.008	0.001
Molybdenum	0.008	0.789	0.026
Nickel	0.057	0.013	0.011
Selenium	Nd	0.018	0.002
Uranium	0.007	0.004	< 0.001
Zinc	0.003	< 0.001	< 0.001

Note: nd – no data available for these parameters

Radionuclides

Table 9.19 shows the incremental dose to human receptors associated with drinking water from D-pit, Island Lake, and Snake Lake over a 20-day period. The predicted incremental doses are all below the CNSC's regulatory dose limit of 1000 µSv/yr.

Table 9.19
Incremental Radiation Dose from Radionuclides to Human Receptors
Drinking Water Pathway

	D-pit	Island Lake	Snake Lake
Incremental Dose (µSv/y)	478	194	19

Residual Effects and Significance

There are minimal effects on humans for non-radioactive and radioactive contaminants for realistic scenarios of traditional use of the overall project area by hypothetical long-term, resident trappers. Only short-term use of certain water bodies for drinking water during prolonged recovery to background conditions has some potential for effects, e.g. molybdenum at Island Lake. The magnitude of these effects, however, is lower than available benchmarks, (i.e. risk quotients less than 1) and therefore poses a low risk to humans. Potential effects on human health are therefore classified as adverse but not significant.

9.2.8 Effects of the Project on Land Use

Land Reclamation and Land Use

Out of 4,131 hectares in the surface lease, 418 hectares have been developed or disturbed, not including the D-pit which has been reclaimed. The disturbed lands will be reclaimed naturally, aided with plantings of local deciduous species. At two specific areas (TMA of 55 ha and Claude waste rock pile of 36 ha), soil covers will be employed to restrict infiltration. These areas will be seeded with grass/legume varieties to promote initial transpiration and soil cover stabilization. Natural invasion of local vegetation will be delayed in these areas. However, the reclamation plan will allow safe use of the area for hunting, trapping and fishing, which is consistent with previous and current land use in the area. The timeframe for this recovery is anticipated to take 10 to 15 years.

The final decommissioning of the TMA, Claude Pit, Claude Pile, and D Pile will leave areas which will permit casual access.

Residual Effects and Significance

Institutional controls will be required to prevent any permanent residency, or use of groundwater for potable use, on major reclaimed areas including the TMA, Claude Pit, D Pile, and Claude Pile. However, the remoteness of the site precludes any such development in the foreseeable future and much of the remaining site could be used without such restrictions. The TMA, Claude Pit, D Pile, and Claude Pile areas represent only a small portion of the site study area and significantly less of the local study area.

On completion of decommissioning, traditional land use by aboriginal people consisting of seasonal use for trapping and subsistence hunting and fishing will not be restricted.

As reclamation will mitigate the disturbance resulting from the operational period, some restrictions on future land use are required over a small portion of the site study area, the residual effects are deemed adverse but not significant.

Ambient Radiological Levels

Areas that will require remediation include the Claude Pit area, TMA, DJN/DJX area, DP area, and the mill area. Some areas of the mill will have high gamma levels during mill demolition. Consequently, an effective radiation protection program will be required to keep worker exposures ALARA. Upon final decommissioning, radioactive residual materials will be disposed of in the Claude Pit or the Liquids Pond thereby significantly reducing ground gamma levels in the affected areas.

Gamma scanning in the mine areas will indicate areas needing excavation or covering before revegetation. In the post-closure period, levels should be comparable to background levels, and casual use of areas with slightly elevated radiation doses (such as the TMA and waste rock areas) will be inconsequential in terms of expected dose.

Radon flux will be reduced by a factor of 2 for each 0.5 m of soil cover, so levels at the TMA and Claude waste rock pile will be greatly reduced. Predicted incremental concentrations of radon will fall to near background levels within a few hundred meters of the TMA.

Total Suspended Particulates (TSP) values can be converted into an airborne long-lived radioactive dust (LLRD) concentration, to estimate levels during decommissioning. Expected LLRD concentrations have been calculated at 0.02 – 0.11 Bq/m^3. More elevated levels may be encountered during mill demolition, however, radiological monitoring coupled with effective use of dust suppression methods and use of personal protective equipment as required, should help keep exposures to decommissioning personnel as low as reasonably achievable and well below regulatory limits. After completion of physical works, TSP and LLRD values are expected to fall to near background values, thus eliminating any further exposures.

Residual Effects and Significance

The mitigative measures, demolition and disposal of contaminated buildings/equipment, removal or burial of contaminated soil, will be conducted to meet the objectives described in section 7.7 at all locations of the site. Therefore, any residual radiological doses will not be adverse or significant because they will be below the public dose limit and only a small fraction of natural background radiation.

9.2.9 Effects on Sustainable Use of Renewable Resources

As noted in section 9.2.10, reclamation plans for the disturbed landscape at the Cluff Lake site include revegetation in most areas with grass/legume seeding over covers. The plan for natural revegetation will provide suitable habitat for wildlife species which are indigenous to the area. The grass/legume seeding of the cover areas (TMA and Claude waste rock pile) may provide additional grazing potential and increase the carrying capacity of small mammals, small mammal predators and ungulates, in relation to the capacity which existed prior to land disturbance.

No significant long-term effects are predicted in surface waterbodies that would deter the development of a strong aquatic ecology in these areas.

The Cluff Lake site will continue to provide terrestrial and aquatic habitat and support the previous land use activities of occasional hunting, trapping, and fishing. There are no permanent residents in the area, although there are some seasonal traditional users. Residual effects of temporary habitat loss are not *adverse* as the decommissioning will re-create habitat lost during the operational phase.

9.2.10 Socio-Economic Effects of the Project

The decommissioning project will provide short-term employment. COGEMA has committed to preferentially offer employment to current employees and residents of the communities within the regional study area. Similarly, COGEMA has committed to provide northerners with the first opportunity for acquiring any salvageable asset.

The purchase of materials and equipment will inject some funds into the regional economy over the short term.

The completion of decommissioning and eventually the return to uncontrolled access will facilitate the return of the land to traditional uses including trapping, fishing, and hunting. However, the need for limited long-term institutional controls presents a small burden on future generations.

Residual Effects and Significance

The financial and employment benefits are limited to the duration of the project. The eventual return to traditional land use is considered a positive effect.

The proposed decommissioning approach has been developed so as to minimize long-term institutional controls and minimize burden on future generations. The final designs will be reviewed and modified as required to ensure that long-term maintenance requirements are minimized.

As such, the residual socio-economic effects are considered adverse due to the need for institutional controls but they are not considered significant.

9.3 Effects of the Environment on the Project

Unusual geologic or climatic events may have an impact on the mitigation measures which will be implemented. This section identifies those potential events and comments on:

- the probability of their occurrence,
- the consequences of their occurrence,
- additional measures which have been adopted to minimize the consequence.

9.3.1 Seismic Events

Atomic Energy of Canada Limited (AECL) has carried out extensive research related to the tectonic stability of the Canadian Shield. AECL concluded that the Canadian Shield is one of the most tectonically stable areas in the world (COGEMA 1997). Seismic activity will likely not be an issue for a decommissioned Cluff Lake mine due to the low probability of significant activity in the region.

The Main Dam of the TMA is the only engineered structure which will remain following decommissioning for which there would be any associated potential risk. Due to the consequence of failure and to ensure that this risk is minimal, the downstream slope of the Main Dam will be buttressed with till material to ensure the Main Dam is stable in the long-term.

9.3.2 Short-term Climatic Effects

Extended Drought

To define whether a drought exists and what its severity is, Standard Precipitation Index (SPI) values were calculated and applied to Cluff Lake seasonal (winter, spring, summer and fall) precipitation data.

The 100-year, low precipitation values for winter, spring, summer and fall are 2.8 mm, 41.7 mm, 57.2 mm and 30.2 mm, respectively. According to the SPI, the 100-year precipitation value for the winter, spring and summer corresponds to an extreme drought, whereas the 100-year precipitation value for the fall corresponds to near normal conditions. The variance for fall precipitation values from 1981 to 1998 is sufficiently low resulting in near normal (SPI) conditions throughout this period.

When applying return periods to design models, the 100-year, low precipitation value may not correspond to the beginning of an extreme drought. Precipitation values alone cannot describe drought, therefore, the existence and severity of a drought can only be determined by establishing boundary conditions, as in the SPI. Based on the assessment of the data, the return period for an extreme drought in the Cluff Lake area is approximately 25 years for the winter, spring and summer periods.

Cover modeling for both the TMA and the Claude waste rock pile have included sensitivity analysis for dry periods and show low sensitivity to these events (COGEMA 2000b and 2000c). The primary purpose of these covers is to restrict water entry; therefore, a drought period has no consequence other than reducing the amount of dilution water available in the downstream system and stressing the vegetative cover which is the major erosion control feature under wet conditions. For the Claude waste rock pile, reduced water content within the cover will temporarily increase the amount of oxygen entering the pile and could result in a short-term increase in the rate of acid rock drainage production. Neither of these potential problems are expected to significantly increase the predicted concentration of contaminants in groundwater and in downstream surface water receptors or have any long-term effect on the integrity of the decommissioned areas.

Major Precipitation

Precipitation has been monitored since 1981 at the Cluff Lake site. The largest 24-hour rainfall extreme record at the Cluff Lake climatological station was 62.2 mm recorded on July 7, 1981. This 24-hour duration rainfall has a probability of occurrence of 0.05 to 0.02 in any given year resulting in a return period of 20 to 50 years, respectively. Probable Maximum Precipitation (PMP) is used in the design of structures, the failure of which would result in environmental or physical damage or the loss of human life (Hopkinson 1994). PMP is used to test and revise preliminary return-period designs to substantiate that the final design will function properly under the most extreme conditions. The annual point PMP estimate for Cluff Lake, over a 24-hour duration, is 497 mm (Hopkinson 1994).

Drainage diversion ditches have been constructed around the TMA which are sized to accommodate a PMP event. This has effectively limited the catchment area of the TMA to as small an area as is possible. The final reclaimed surface of the TMA will be designed with a low overall gradient with runoff channeled toward Snake Lake. A strong vegetative cover with a well developed root mass will minimize erosion on the TMA surface. The outlet channel will be designed and constructed to accommodate a severe runoff situation. A major rainfall event (i.e. PMP) may cause some local erosional damage but is not anticipated to compromise the cover.

The situation is similar for the Claude waste rock pile where the top surface will be graded to direct and control runoff. The side slopes of the pile will be resloped, however, this will still result in a significantly higher gradient than the TMA. In addition to ground cover vegetation, engineered structures, such as willow silt fences, will be established in the side slope drain channels to slow high velocity flows and minimize erosion.

The final design and construction plans for decommissioning will be reviewed and approved by both the federal and provincial agencies to confirm that adequate provisions are in place to control erosion and silting where and as-needed.

9.3.3 Global Warming

The effects of global warming on the Cluff Lake decommissioning project were addressed using three General Circulation Models (GCM). General Circulation Models (GCMs) are used to simulate radiative effects of various concentrations of greenhouse gasses on the global climate. GCMs differ somewhat in terms of the mathematical and physical formulations used in their development. Consequently, they do yield somewhat different results in terms of the climate change scenarios produced. Hence, the use of three models adds robustness to this assessment.

Under the doubling of CO_2 scenario, recent GCM estimates predict that the global annual average surface temperature will increase between 1.0 and 4.5 °C. On regional or subcontinent scale, it is not possible to know with certainty the finer details of how the climate will change (EC, 1997). Results from GCMs, currently provide the best estimates of climate change under the simulated doubling of CO_2 scenario.

GCMs have not been used to predict climate changes for smaller areas such as northwestern Saskatchewan (Cluff Lake area. However, predictions for the prairies have been made using GCMs, under the CO_2 doubling scenario. The prairies are subdivided into the prairie and the northwestern forest region. In terms of predicting what climatic changes may occur for the Cluff Lake area, results for the northwestern forest region provide the best available estimates and are assumed appropriate for use in the Cluff Lake area.

Precipitation and Temperature

Table 9.20 summarizes the projected changes in seasonal temperature and precipitation produced by three different GCMs for the northwestern forest region. The lower and higher values in each category represent spatial variability in projected changes over the region. The temperature values are the amount that the predicted temperature differs from the present normal temperature. The precipitation values are the percentage change that the predicted value differs from the present normals. Although the temperature values are quite variable, it is noted that in all cases they are positive (i.e., an increase relative to current norms). Precipitation is more difficult to model, and as a result, these predictions are more variable than those for temperature.

Table 9.20

Predicted Seasonal Temperature (°C) and Precipitation (%) Changes for Northwest Forest Region by Three General Circulation Models for a doubled CO^2 Atmosphere

Northwestern Forest					
		Temperature Range (°C)		**Precipitation Range (% change)**	
Season	Model	Lower	Higher	Lower	Higher
Winter (DJF)	CCC	4.5	7.0	0	30
	GFDL	2.5	4.0	5	20
	GISS	2.5	3.0	0	15
Spring (MAM)	CCC	3.0	5.0	-5	25
	GFDL	2.5	3.5	5	15
	GISS	1.5	2.0	5	20
Summer (JJA)	CCC	3.5	5.5	-15	10
	GFDL	2.0	2.5	-10	15
	GISS	0.5	1.0	10	40
Fall (SON)	CCC	2.5	3.5	5	30
	GFDL	3.5	4.5	-5	10
	GISS	1.5	2.5	0	20

Note:

- CCC is the Canadian Centre for Climate Modeling and Analysis
- GFDL is the Princeton University's Geophysical Fluid Dynamics Laboratory
- GISS is NASA's Goddard Institute of Space Studies

Source: Environment Canada 1997.

Evaporation and Evapotranspiration

There does not appear to be any specific references that quantify predicted changes to evaporation and evapotranspiration for the northwest forest area. In general, the specific effects of climate change on evaporation are not well known.

However, evaporation and evapotranspiration generally increases with temperature. In a 20 year investigation at the Experimental Lakes Area (ELA) in northwestern Ontario, the relationship between temperature and evaporation was quantified in small boreal lakes. Over the 20 year experimental experiment period, air temperature increased by 1.6 °C and annual lake evaporation increased by 35 mm per 1.0°C increase in annual air temperature (EC, 1998).

Given that a doubling of CO_2 results in higher air temperatures for most of Canada, evaporation and evapotranspiration are expected to increase, though higher precipitation is also expected for many areas of Canada. Studies suggest that higher evapotranspiration will offset higher precipitation in climate change scenarios in the Great Lakes and Mackenzie River Basin (EC, 1998).

For Cluff Lake, the GCMs predict higher average annual temperatures, with more noticeable increases in the fall and winter periods. Increased winter precipitation may lead to more intense runoff events, however, by designing the facilities to handle the more serious PMP event (see section 9.3.2), these potential increases can be easily accommodated.

9.3.4 Forest Fire

Fire occurrence characteristics are closely related to weather and climate. Climatic conditions, such as intense and extended droughts, generally are associated with severe fire seasons. Forest fire frequency in the northern boreal region of western Canada have average fire cycles of approximately 39 years for jack pine or aspen dominated forests, 78 years for black spruce dominated forests and 96 years for white spruce dominated forests (Larsen 1997).

Reduced interception because of the burned canopy will cause more precipitation to reach the ground, potentially increasing water availability to the soils and runoff. Soil storage opportunity is reduced because of reduced transpiration losses of soil moisture. This results in wetter soils in burned areas, higher water tables in areas of shallow groundwater and increased zones of saturated soil near stream channels. Fire may consume forest floor materials, which also reduces the soil water storage capacity and exposes mineral soil to erosive forces.

The above concerns have consequences primarily to the TMA and Claude waste rock pile where the efficiency and long-term sustainability of the cover material is, to a large extent, based on the success of the revegetation. In the initial years after decommissioning, the vegetative cover will be dominated by a grass-legume crop. This vegetative type is not adversely impacted by forest fire as their root zones remain intact and the combustion of the litter layer speeds the recycling of nutrients. Re-establishment after fire is immediate and usually more intense than existed prior to the fire. In such an event, post-closure monitoring will verify that re-establishment is happening in a timely manner. Revegetation may be undertaken, if necessary, to expedite the re-establishment of the vegetative cover.

In the longer term, ecological succession will result in progression toward natural vegetation and ultimately to establishment of the climax species, jack pine. It is anticipated that the grass-legume varieties will maintain an understory presence even after the establishment of intermingled woody vegetation. This continued presence along with earlier succession species, such as willow and alder, will ensure a quick recovery in the event of a forest fire. It is also notable that jack pine itself is a fire successional species which will regenerate quickly from such events. The recurrent nature of forest fires in Northern Saskatchewan are not expected to have a detrimental effect on the Cluff Lake decommissioning.

9.4 Cumulative Environmental Effects

There are no other current or proposed mining, forestry or other industrial developments at or near the Cluff Lake site. Potential cumulative effects are restricted to operational effects in association with the effects of the decommissioning activities.

Discharge of effluents during operations have been to a drainage system which has been unaffected by any other development (Douglas River) and environmental impacts have been limited to areas in the direct vicinity of the Cluff Lake site. As such, cumulative impacts are those associated with the operational impacts prior to commencement of decommissioning, any further impacts resulting from decommissioning activities and the time to recovery extending to the foreseeable future. Section 6 discussed the existing impacts as a result of operations. Section 9 identified impacts associated with decommissioning and assessed the cumulative effects of decommissioning activities in association with operational effects (e.g., Island Lake). Table 9.21 summarizes the cumulative environmental effects.

Long-term effects are predicted for surface and ground water quality, sediment quality, aquatic organisms and terrestrial organisms. The most substantial effect is expected to be associated with past operations, namely the impact of effluent discharges on Island Lake.

As noted in section 9.3, there exist a number of climatic events, including droughts, major precipitation events and forest fires, which could affect the project. Design features and construction controls, which will be the subject of detailed regulatory review and approval, will be used to ensure that these potential effects are adequately mitigated. Follow-up monitoring will verify the performance of the various designs and trigger suitable contingencies should they prove necessary.

While adverse cumulative environmental effects are anticipated from past operations in association with the proposed decommissioning activities, none of these effects are deemed significant.

10 FOLLOW-UP PROGRAM

10.1 Introduction

As noted in section 9, the environmental effects of the project while adverse are not considered significant. This conclusion, however, relies on the success of the various decommissioning designs, the successful recovery of Island Lake and the confirmation that ecological effects are as predicted.

Section 8.3.3 described the environmental protection program as it applies to existing operations and its evolution throughout the decommissioning period. The environmental monitoring program will continue to be used to evaluate current environmental conditions and any changes over time.

This section outlines the follow-up program which will supplement the current environmental monitoring program and will be established to verify that the mitigative measures proposed for the decommissioning project are adequate and effective in achieving the decommissioning objectives.

It deals with the primary decommissioning activities, specifically the decommissioning of the TMA and the decommissioning of the Claude and DJ waste rock piles and pits. Furthermore, the program addresses other issues which arose during the public and regulatory review phase of the Comprehensive Study process.

The EA Follow-up Program will be a key component of the decommissioning licencing documentation submitted in support of any future licensing application pursuant to the *Nuclear Safety and Control Act* (NSCA). Follow-up programs have been an important component of the environmental assessment process, and remain so under the recently revised *Canadian Environmental Assessment Act* (CEAA). Section 14 of the CEAA remains unchanged, and continues to state that “The environmental assessment process includes, where applicable, the design and implementation of a follow-up program”, Subsection 14 (c). The revised Act continues to define follow-up program as “a program for (a) verifying the accuracy of the environmental assessment of a project, and (b) deferring the effectiveness of any measures taken to mitigate the adverse environmental effects of the project.”

10.2 Objectives

The CEAA defines follow-up as:

> *"a program for verifying the accuracy of the environmental assessment of a project, and determining the effectiveness of any measures taken to mitigate the adverse environmental effects of the project...”*

Based on CEAA 2002, there are four key reasons which dictate the need for a follow-up program, including:

- to facilitate better overall project management by considering follow-up program framework at the earliest stages of project planning;
- to provide information on environmental effects and mitigation resulting from project implementation that can be used to improve and/or support future EA's including cumulative effects assessments;
- to aid in the detection of unanticipated environmental effects; and
- to support or verify predictions made concerning the determination of "no significant environmental effects".

For Cluff Lake decommissioning, there is a specific need for a follow-up program to:

- address public concerns raised during the consultation process such as the current status of the temporary tailings vault storage area;
- verify the accuracy or conservatism of the predictions, primarily for long-term water and sediment quality in the Island and Cluff Lake watersheds, the risks to biota;
- assess the effectiveness of mitigative measures, primarily the soil covers proposed for the TMA and Claude waste rock pile; and
- continue pertinent research to more fully understand natural processes, specifically the Claude Lake sediment removal and toxicity testing in Cluff Lake.

10.3 Post-Decommissioning Contaminant Source Terms and Migration

Two primary potentially adverse effects have been predicted within this assessment.

- seepage from the TMA which will result in adverse affects to groundwater quality, and surface water quality in Snake Lake and downstream; waterbodies;
- seepage, from waste rock piles, underground mines, and backfilled pits, which will adversely effect downstream groundwater quality and surface water quality in the Claude Creek and Peter River systems draining to Cluff Lake

These may further result in adverse effects on sediment quality and potential risks to human and non-human biota.

The success of the preferred decommissioning approaches for the major areas rely on effective covers that will reduce infiltration, and passive removal mechanisms which will remain effective and reliable in the longer term. In addition, the source term, such as tailings porewater and waste rock backfill porewater concentrations, must be verified and confirmed. The following sections briefly summarize the follow-up program proposed to evaluate the various items noted above and identify any contingencies to be considered in the event that expectations are not met.

10.3.1 TMA

As discussed in section 9.2.4, modeling was utilized to predict the long-term water quality in Snake Lake, immediately below the TMA. Confirmation of two key factors is required to verify the modeling predictions: the rate of infiltration through the cover; and the tailings porewater source term.

Cover Infiltration

A field monitoring program will be implemented to measure cover performance. To monitor infiltration, four lysimeters will be installed, two in the upper solids area and two in the lower solids area, as shown on Table 10.1. It is anticipated that there may be significant variability between lysimeters owing to differences in revegetation success, tailings and soil cover characteristics. However, the information gathered will provide some bounds for future modeling.

Table 10.1
TMA Soil Cover Monitoring

Company Station Number	Sampling Location	Parameters	Frequency
CS 1100L	South area of TMA - Coarse Tailings Area	Climate, infiltration, settlement, soil temperature	M
CN 1000L (new)	North area of TMA - Coarse Tailings Area	Infiltration, settlement, soil temperature	M
FN 1200L (new)	North area of TMA - Fine Tailings Area		
FS 1300L (new)	South area of TMA - Fine Tailings Area		

Porewater Source Term

In the past, the collection of tailings porewater data for determining source terms, has been hampered by the inability to access the tailings area and collect a sample without disturbing the surrounding tailings. With the placement of the cover, piezometers can be installed and regularly monitored to provide accurate porewater quality measurements. The proposed monitoring program is shown in Table 10.2. The parameters included in Class B analyses include HCO3/CO3, Ca, CI, Mg, K, Na, S04, TSS, TDS, Ra-226, U, As, Cu, Co, Fe, Se, Mn, Ni, Zn, Pb, pH, Mo, Conductivity, Total Hardness, Sum of Ions and Turbidity. Sampling will be completed on a quarterly frequency and will include measurement of water level (WL).

Table 10.2
TMA Porewater Monitoring

Company Station Number	Sampling Location	Parameters	Frequency
CN 1000G	North area of TMA – Coarse Tailings Area	Class B WL	Q Q
CS 1100G	South area of TMA – Coarse Tailings Area		
FN 1200G	North area of TMA – Fine Tailings Area		
FS 1300G	South area of TMA – Fine Tailings Area		

The TMA performance will be monitored to determine actual rates of infiltration through the cover and the tailings porewater quality. If infiltration or porewater contaminant concentrations are greater than predicted, contaminant transport modeling revisions will be undertaken. If results of monitoring suggest that contaminant values in Snake Lake will exceed SSWQO, the TMA cover will be re-evaluated in terms of investigating ways to further reduce infiltration.

If the ground cover vegetation proves incapable of controlling erosion, rip rap or other methods for controlling erosion will be investigated and implemented as required.

10.3.2 Mining Area

The modeling conducted for the mining area was very complex as discussed in section 9.2.4.3. There are a number of key issues and assumptions which could impact the modeling results including:

- the source terms for waste rock in submerged and above ground conditions
- the rate of infiltration through the cover on the Claude waste rock pile
- the utility and potential effectiveness of the peat trench
- the porewater quality of the Claude Pit backfill
- the effectiveness of contaminant removal by the Claude Lake sediments.

Additionally, it is important to determine whether or not the quality in the upper water column of the flooded DJX pit will meet and remain within decommissioning objective values.

Groundwater monitoring downgradient of the mining area (for hydraulic head and water quality) will be conducted as part of the ongoing post-decommissioning monitoring program and will be used as further verification that the decommissioning approach is working as designed (COGEMA 2000d, Appendix A, Section 6.4).

Source Term Verification

The source terms used for the mining area were based on all available waste rock leaching tests (i.e. modified BC SWEP tests, humidity cell tests, partially saturated column tests and saturated tank leaching tests). For the Claude waste rock pile, source terms were also derived from the observed concentrations in the groundwater monitoring wells immediately downgradient from the Claude pile.

Additional waste rock testing and interpretation of groundwater and surface water concentrations downgradient from the Claude and DJN piles will be carried out to support the impact predictions of various waste rock decommissioning options on ground and surface waters and to support the predicted environmental advantage of COGEMA's preferred option to backfill Claude pit. The alternative option of using the DJX pit to dispose of additional problematic waste rock below ground surface remains available and will be further evaluated. Additional proposed testing will include:

- leaching tests for the DJN special waste, DJN waste rock and Claude waste rock under similar submerged conditions,
- the installation of additional groundwater monitoring wells downgradient of the DJN and Claude waste rock pile in order to validate contaminant transport predictions, and
- the analysis of additional surface water samples along the Claude Creek and Peter River.

The results of the above evaluations will be utilized within a follow up contaminant transport modeling program to more accurately predict the long term effects associated with the remaining alternatives such as backfilling the DJX pit. The modeling will include a sensitivity analysis to assess the effect of varying the hydraulic conductivity of the fracture zones between DJX pit and Cluff Lake, the hydraulic conductivity of the underground workings and the degree of connections between the DJX pit, the underground workings and the facture zones. In the event that the DJX pit should be partially or completely backfilled, the sensitivity analysis will also include the effect of varying the hydraulic conductivity of the placed waste rock.

Also, since target criteria for uranium and nickel concentration in surface water are based on water hardness concentrations, the follow up modeling will also predict the temporal evolution of hardness concentrations in Claude Lake and a flooded DJX pit during the period that both contaminants and hardness (i.e. calcium and magnesium) are transported to these receptors from their sources.

Should the results of the follow-up testing and modeling program indicate that other assessed options or contingencies are desirable, additional work will be undertaken to implement these options and contingencies."

Infiltration through the Claude Waste Rock Pile Cover

Similar to the TMA, the rate of infiltration through the cover will be monitored through the installation of lysimeters. This equipment was installed in the fall of 2001. One of the lysimeters is located on the top surface of the pile while the second is located on a 4:1 side slope. Drainage from the lysimeters is collected, the volume measured and samples sent for chemical and radiological analysis. Results to date demonstrate that the equipment is functional in frost free months but does not yet adequately predict infiltration rate as the surficial area was only recently revegetated in the spring of 2003. Continued monitoring of these lysimeters will be used to evaluate the assumptions made in the modeling.

In the event that monitoring results are significantly different from the modeling assumptions, the modeling will be repeated using the field measurements to assess the effects on downstream groundwater and surface water quality. Should this modeling indicate that surface water or sediment quality will no longer achieve the decommissioning objectives, methods of reducing the permeability of the cover will be evaluated and implemented.

Peat Trench

A peat-filled trench located adjacent to the Claude waste rock pile was considered as a supplementary removal mechanism for contaminated groundwater moving away from the pile. In particular, literature reviews and site testing demonstrated the ability of such a medium to remove uranium from solution (COGEMA 2000c, Appendix C, Section 8.1).

The follow-up program will begin by excavating a few small test pits to bedrock perpendicular to the groundwater flow direction and monitoring to determine if there is groundwater movement through the overburden. In the event there is groundwater present above the bedrock, a trench consisting of a mixture of locally available peat material and scrap steel will be designed and constructed.

In the event that the peat trench is constructed, shallow piezometers will be installed upgradient and downgradient of the trench. Groundwater samples will be collected on a quarterly basis to evaluate the removal success, primarily of uranium and nickel.

It should be noted that the assessment did not account for any contaminant removal by a peat trench. The trench has been considered only as a supplemental method of removal to reduce the overall loading to Claude Pit.

Porewater Quality in the Backfilled Claude Pit

A piezometer will be installed in the Claude Pit backfill or on the edge of the pit to assist quarterly groundwater sampling. The measured contaminant concentrations will be compared with the estimates utilized in the modeling.

In the event that monitoring results are significantly different from the modeling assumptions, the modeling will be repeated using the monitoring values to assess the effects on downstream water quality. Should this modeling indicate that surface water or sediment quality will no longer achieve the decommissioning objectives, methods of reducing the concentration of the porewater will be evaluated.

Contaminant Removal by Claude Lake Sediments

Groundwater discharge from the Claude waste rock pile and the backfilled Claude pit to Claude Lake must first migrate through a 1.5 to 2 m thick organic sediment layer at the bottom of Claude Lake. A portion of the contaminants will be absorbed or precipitated out of solution within this organic sediment layer. This is predicted to significantly lower the amount of contaminants available in Claude Lake water. A laboratory test has been designed and conducted over the past 1.5 years at Cluff Lake to determine the effectiveness of removal, particularly of uranium and nickel which will be the prime contaminants of concern in the groundwater plume.

The research project was developed to evaluate the efficiency and capacity of the sediment removal system in order to verify and quantify the predictions of contaminant capture. Two organic sediment columns were collected at each of five locations in Claude Lake in late April of 2001 by auguring through the ice and inserting 10 cm diameter clear plexiglas tubes. The tubes were extracted and sealed to prevent oxygen entry and moved to the on site laboratory where the experiment was set up. Three columns were erected and supported in an upright position, equipped with ported caps on both ends of the plexiglas tubes to allow water entry and exit. A stainless steel screen and glass beads were added at the bottom of the column to allow even delivery of inflow water. Contaminated water from one of the Claude pile perimeter wells (HYD0312G) was collected as feed water to be fed into the bottom of the column.

Initial porewater, feedwater, and sediment analysis included a full suite of physical, heavy metal, and radionuclide parameters. Feed water was contained within an elevated carboy and fed by gravity through the sediment core. Rate of flow was adjusted by changing the elevation of the carbouy in relation to the column.

Water overflowing the top of the column was directed to a graduated beaker and collected regularly for analysis. The head spaces in the feed water and the collected water vessels were flooded with nitrogen to maintain anoxic conditions throughout the test.

A detailed discussion of the preliminary results is presented in COGEMA, 2002b. Uranium removal rates have consistently remained above 99% even at column flow rates approximately 35 times greater than flows predicted by the modeling. Additionally, the average uranium concentration in the feedwater has been approximately 28 times greater than the Claude Pit source term assumed in the model. The model conservatively assumed 90% uranium removal and predicted values in Claude Lake of approximately 72 ug/L. Given a predicted hardness in Claude Lake water of >200 mg/L $CaCO_3$ equivalent and applying the decommissioning objective for uranium of 0.002[Hardness], the uranium objective in Claude Lake for this scenario would be 400 ug/L.

Early test results indicated that nickel removal in the columns stabilized at approximately 60%. Given a predicted hardness in Claude Lake water of >200 mg/L $CaCO_3$ equivalent, the SSWQO value for nickel is 100 ug/L. The modeling, which assumes a 60 % removal rate from Claude Lake sediments, predicts a peak nickel concentration in Claude Lake water of 36 µg/L.

The follow-up program involves the continuation of the sediment column experiments until breakthrough of one or more of the major contaminants is observed. This will be evident by a sudden increase in the contaminants in the column outflow. At that time the columns will be sent to a laboratory for sectioning to determine:

- the uranium and nickel distribution within the sediment column;
- the form of uranium and nickel captured by the column;
- the mechanism of removal (initial assumptions are absorption for uranium and sulphate reduction for nickel and other metals); and
- estimation of the remaining capacity (for the parameter(s) which did not breakthrough).

This information, if significantly different from the original assumptions, will be re-evaluated within the modeling to determine whether incorporation of the actual removal rates will allow achievement of the decommissioning objectives. In the event that further uncertainties remain, continued testing may be appropriate.

In the event that the modeling indicates that these objectives are not achievable using field derived information, the proposed contingency will be the construction of a wide, shallow channel from Claude Pit directly to Claude Creek with a wetland in the ditch bottom for passive removal of contaminants. The invert of the ditch will be slightly below the Claude Lake elevation to preclude any further groundwater movement to Claude Lake.

10.4 Island Lake Fen Follow-up Program

The Island Lake fen, located immediately downstream of Island Lake, has accumulated a substantial contaminant load over the operational period. The fen has and continues to limit the transport of contaminants further down the Island Lake drainage. There is a potential for the fen sediments to serve as a delayed source of metal contaminants through a process similar to that which produces acid mine drainage (COGEMA, 2001, Response to Comment #20).

A follow-up program will be completed to address this issue. During the initial phase of the program the hydrological regime for Island Lake and the associated fen (hereafter referred to as the study area) will be characterized. This will be accomplished through the monitoring of groundwater and lake elevations as well as surface water discharges into and out of the study area commencing spring 2003 with the monitoring stations and wells presently in place (Table 10.3). The suitability of the present groundwater monitoring network for this purpose will be reviewed by the Responsible Authorities (RA) and Federal Authorities (FA) for program approval prior to any future application for a decommissioning license. The routine compliance monitoring program will retain a water quality monitoring site downstream of the fen to identify any future releases.

The water monitoring component will be augmented by remote sensing of the wetland vegetation community to assess current status and provide a baseline for future comparison. Soil/sediment and vegetation grid sampling and anlayses (using uranium as a tracer) have commenced to establish contaminant deposition patterns and determine the remaining capacity for passive removal within the fen. This will also serve to characterize contaminant distribution and acid generation potential in areas identified as potentially susceptible to atmospheric exposure.

Table 10.3: Island Lake Fen Monitoring

Groundwater Elevation

Company Station Number	Sampling Location	Parameters	Frequency
HYD01-19AG	Near Island Lake Outlet	Class B WL	SA Q
HYD01-19BG			
HYD01-20AG	Near Agnes Lake Inlet		
HYD01-20BG			

Lake Elevation

Company Station Number	Sampling Location	Parameters	Frequency
ISLSG-2	Agnes Lake	Water Elevation (masl)	M
ISLSG-3	Island Lake		
ISLSG-4	Snake Lake		

Streamflow Rates

Company Station Number	Sampling Location	Parameters	Frequency
ISLHYD-1	Island Creek at Dolomites	Streamflow Rate	Continuous
ISLHYD-2	Bridle Creek at Sandy Lake Road Crossing	Streamflow Rate	M
ISLHYD-3	Snake Creek below effluent discharge point		

Sediment/Vegetation Characterization

Company Station Number	Sampling Location	Type	Parameters	Frequency (1)
New Locations	Island Lake Fen – Substrate	Grid Sampling	Uranium	2002
		9 Composites	Class H	2002
New Locations	Island Lake Fen – Vegetation – Composite of at least five plants from each of the 9 substrate areas	Cattail - Roots	Class H	2003
		Cattail - Foliage	Class H	2003

(1) A one-time sampling program conducted in the year shown. Results will be reviewed to determine whether additional sampling is required.

Contingency options for maintaining groundwater levels in the Island Lake fen will be examined in the event that the follow-up program indicates contaminant mobilization from wetland soils subject to atmospheric exposure is a concern. The present short term contingency plan will be to pump water from Cluff Lake to the Island Creek system to re-establish operational surface water levels (COGEMA, 2002b, Section 3.5).

10.5 Landfill Sites Groundwater Monitoring

The current description and decommissioning strategy for the main landfill sites were discussed in COGEMA, 2000a, Section 2.4.3. Subsequent concerns were expressed by reviewers with respect to assessment and monitoring of other small landfill sites in the area (COGEMA, 2001, Response to Comment #58 and 88).

The follow-up program contains a series of groundwater monitoring locations near each of these landfill sites as shown on Table 10.4.

Table 10.4
Groundwater Monitoring Near Landfill Sites

Company Station Number	Sampling Location	Parameters	Frequency
HYD01-101G	Cluff Centre Landfill Area	Class B Class I WL	A A Q
HYD01-102G			
HYD01-103G			
HYD01-104G			
HYD01-105G	Mill Road Landfill		
HYD01-106G			
HYD01-107G			
HYD01-108G			
HYD01-109G			
HYD01-110G			
HYD9710G	Domestic Landfill area		
HYD9711G			
HYD01-111G			
HYD01-112G			
HYD01-113G			
HYD01-114G	Industrial Landfill near TMA		
HYD01-115G			
HYD01-116G			
HYD01-117G			
HYD01-118G	Former Drum Storage Area		
HYD01-119G			
HYD01-120G			
TZZ9723G			

In the event that monitoring indicates seepages from these landfill sites has the potential to affect groundwater quality and water quality in downstream surface water receptors, further monitoring and analysis will be conducted to evaluate any contaminant plumes and potential environmental effects. Based on the results of these evaluations, should these environmental effects be deemed significant then remedial actions will be identified and implemented. This may include installation of an appropriate cover to reduce infiltration or removal of the material to a safe and contained landfill location.

10.6 Toxicity Testing for Uranium

There are presently no Saskatchewan or Canadian surface water quality guidelines for uranium. It is generally recognized that uranium toxicity is ameliorated with increased hardness. Hence, the uranium water quality objectives for Cluff Lake decommissioning varies as a function of hardness as documented in COGEMA 2002b (Section 3.6). The uranium objective will be further refined as part of the follow-up program.

The follow-up program will include toxicity tests on one fish, one zooplankton, and one algal species indigenous to Cluff Lake, using mean and peak predicted uranium exposure concentrations. In addition to this work, the uranium objective will be further refined by the information obtained from the Regional Water and Sediment Quality Working Group. This group which includes representatives from the federal and provincial regulatory agencies, and industry representatives, is conducting literature surveys and specific research regarding the effects of various metal and radionuclide contaminants on the health of indigenous aquatic communities in Northern Saskatchewan environments. The working group’s current focus is the issue of uranium toxicity considering various water characteristics, most notably hardness, in Northern Saskatchewan waterbodies.

10.7 Water Quality in the Flooded DJX Pit

Historical observation of the water quality in D Pit (COGEMA, 2000c, Appendix E) and other flooded open pits in western Canada (COGEMA, 2000c, Appendix C, Section 8.2) has suggested that a stable chemocline will form in the water column of the flooded DJN/DJX Pit. Poorer quality water will be permanently maintained near the pit bottom while the water in the upper water column is expected to achieve SSWQO and other decommissioning objectives.

A monitoring program has been proposed to regularly check water quality after flooding (at seven different depth intervals) to confirm this phenomenon. In the event that water quality does not meet the previously mentioned objectives in the upper water column, additional *in situ* treatment will be conducted to favorably adjust the surface water quality. Alternatively, the pit may be partially or completely backfilled.

10.8 Leach Vault Temporary Storage Area

Comments from a member of the public expressed concern about adequate clean up of the leach vault temporary storage area used in 1980-1983 to retain tailings prior to a second phase of milling.

The leach vault temporary storage area is located south of the Mill. It was used as a laydown area for storing concrete silos containing tailings from the milling of ore from the D orebody. During the storage period, some of the vaults leaked and allowed tailings to be spilled within the area. Final milling of the tailings for gold recovery and further uranium extraction, and the disposal of the vaults in the TMA was completed in 1986.

While the area was cleaned up at the time, concerns were raised regarding the adequacy of this cleanup.

A detailed gamma survey will be conducted of the area to verify that all contaminated material was cleaned up and that the decommissioning objectives specified in section 7 are satisfied. A soil and vegetation sampling program will also be undertaken in the leach vault storage area to supplement the gamma survey and verify that existing reclamation poses no danger to wildlife.

Any area which does not meet the decommissioning objectives will be cleaned up and reclaimed in accordance with the site cleanup criteria and approach specified in section 8.3.2.

10.9 Issues Relating to Aquatic and Terrestrial Biota

10.9.1 Implications of Selenium to Fish Reproduction

Elevated selenium levels (above tissue residue guidelines) have been measured in fishes associated with Island Lake. A follow-up program has been implemented to assess the implications of these levels to fish reproduction in Island Lake. The study program involves the collection of gametes from Island Lake fish for fertilization and laboratory rearing for comparison to populations associated with natural background selenium conditions. The resultant embryos and larvae are then assessed for the incidence of terratogenic deformities which are known to result from chronic selenium exposure.

10.9.2 Risks to Wildlife Resulting from Chronic Exposure to Uranium and Molybdenum Associated with the Island Lake Drainage

The risk modeling indicated there was the potential for adverse effects to wildlife exposed to the present concentrations of uranium and molybdenum associated with Island Lake. These adverse effects were not considered significant based on Tier II modeling results. The modeling results were substantially influenced by such factors as receptor exposure (e.g., occupancy, dietary composition), concentrations of contaminants within the diet and associated transfer factors. The follow-up program is required to increase the confidence in the values used in the modeling for these parameters.

The program will involve the determination of site-specific contaminant (U, Mo, and Se in specific pathways) concentrations in the key dietary exposure pathways. Examples of the dietary components of interest are:

- littoral sediments associated with aquatic macrophytes (moose and muskrat forage);
- muskrat forage (e.g., Typha sp.);

- aquatic invertebrates ingested by waterfowl; and
- whole fish (including gut content) for otter.

The risks associated with molybdenosis to ungulates will be specifically addressed by determining the copper status of forage in the region and the molybdenum and sulphur concentrations in Island Lake forage. Should this work indicate that forage associated with Island Lake poses a molybdenosis risk then moose utilization of the site will be monitored with the health of individuals being assessed should moose be found to extensively forgae in the area.

The specifics of these programs will be developed within the proposed follow-up program document and presented for regulatory review and approval as part of the decommissioning licencing process.

10.9.3 Baseline Wildlife Investigation Survey

A wildlife decommissioning baseline is required as a benchmark for assessing the success of reclamation activities. At the present time information on wildlife abundance for the area consists of a relatively dated one-time snapshot (COGEMA, 2001, Comment #188a). The company has committed to conducting a comprehensive wildlife investigation at the Cluff Lake site upon cessation of operations. A key element of this program will be determining the presence or absence of muskrat and moose, the biota identified as at most risk. The presence of these biota in habitat associated with Island lake would alleviate much of the uncertainty with respect to the risks of exposure to the elevated levels of contaminants. The results of the wildlife assessment would also assist in determining the feasibility of directly assessing the health of any resident high risk biota under the current exposure conditions.

10.9.4 Baseline Aquatic Monitoring of the Island and Cluff Lake Drainages

An aquatic decommissioning baseline is required after cessation of operations, against which the recovery of Island Lake system and the potential future effects on Cluff Lake could be measured (COGEMA, 2001, Comment #188b and 189). COGEMA have committed to conducting a comprehensive aquatic survey, including abiotic as well as biotic components, in conjunction with the required Environmental Effects Monitoring Program and the Status of the Environment Report for which data collection is required in 2004.

10.10 Long-Term Monitoring

Section 8.3.3 identifies the environmental monitoring program and its evolution over the project duration.

Included in the program is an observational monitoring program that will be implemented at the end of the post-closure monitoring period. This long term monitoring program will be conducted on a minimum annual frequency with access by float plane or helicopter. The objective of the program will be to confirm that mitigation measures are effective in the long term and abandonment may be considered in the foreseeable future.

The monitoring locations and exact frequency of sampling will be determined at the end of the post closure monitoring period. Monitoring will be conducted for about ten years following the post closure period and will only conclude when decommissioning objectives have been achieved and sustained, to the satisfaction of all stakeholders.

11 PUBLIC AND STAKEHOLDER CONSULTATION

The CEAA requires that every comprehensive study consider comments from the public, and that public access to the report be facilitated [Subsection 22(1) and paragraph 16(1)c)]. The RA is responsible for ensuring that public concerns are identified and addressed at appropriate stages of the process.

The public consultation objectives are not only to inform the public at all stages of the EA, but also to provide a variety of opportunities for the public to offer ideas and information, to react to proposals, and to influence recommendations and decisions (CEAA, 1999). To fulfill these goals, information may be provided through public meetings or announcements in the media. Receiving information and comments from the public must be facilitated, and issues discussed in an appropriate setting, such as workshops. It may be necessary to build consensus among stakeholders or among those individuals most affected by the project.

For the Cluff Lake decommissioning project, both the CNSC and COGEMA have conducted public consultation programs.

11.1 CNSC Public Consultation Programs

In developing the scoping guidelines for the Comprehensive Study, CNSC staff consulted with a variety of federal agencies and the province. In addition, the EA process included a period for public comment on the draft Scope of Project and Assessment Report. These comments were incorporated into the final report.

In addition, CNSC staff has participated in public workshops and meetings with interested stakeholders throughout the EA process.

Furthermore, CNSC staff has consulted with the Agency on comments received from the formal review.

11.2 COGEMA’s Public and Stakeholder Consultation Program

A Public Involvement Plan was developed and geared towards recognizing all interested members of the public and providing them with “a variety of opportunities: to be informed at all stages of the study, to offer ideas and information, to react to proposals in order to influence recommendations and decisions and to be informed of all decisions” (Government of Canada, 1999, p.23). Some of the key goals of the public consultation program included building consensus among key groups or individuals affected by the project, and informing the participants of results and decisions. Means have been provided for receiving input from all interested parties, and have included comments from the public within the Comprehensive Study.

The consultation program has gone through three stages to date. Stage one included a workshop on-site that was used to develop the *Public Involvement Plan*, and to create a list of issues. In Stage two, a brochure presented preliminary decommissioning plans to stakeholders, and their feedback was received.

In addition, open houses and community meetings were held. The results were organized into four categories and provided to company planners.

Stage three included in-depth discussions and communication with stakeholders about the issues raised in Stage two. COGEMA personnel also met with and provided an update to several northern contractors. Members of the West Side Environmental Quality Committee (EQC) were taken to visit decommissioned uranium sites in Ontario.

Updates on the decommissioning plan and comprehensive study are included in routine company publications distributed to all stakeholders.

Key issues raised by stakeholders fit into four categories – employment and business effects, concerns about the physical environment, community and health impacts, and public involvement.

In particular, members of West Side communities expressed interest in employment and business opportunities with regard to the potential to benefit from decommissioning activities. Environmental concerns include public safety as well as more specific issues related to air and water quality, residual contamination, reliability of models, monitoring, the company's experience in the field of decommissioning, and long-term responsibility. Community and health impact concerns were focused on the future of mine-related infrastructure, safety regarding future use of the site, land and resource use and rights. Issues regarding public involvement include the importance of communities having a voice in approving site abandonment, and northerner involvement in monitoring.

To address employment and business opportunity concerns, the company intends to involve local residents and northern companies in decommissioning activities and future exploration activities as much as possible, provide outplacing services to laid-off employees, and to consider specific requests for use of salvageable materials, as described in earlier sections of this report.

A scholarship program is provided to assist northerners, and would be pleased to help those with suitable qualifications get professional experience at their operations.

The majority of the public concerns about the physical environment are discussed in this study. The company has used its experience, and the experience of other companies in the region, in decommissioning mines as a source of confidence in an environmentally sound decommissioning process.

To address community and health concerns, it was determined that although claims for injury are to be made to the Worker's Compensation Board within six months of the injury, if the notification is delayed, the employee will still be considered for compensation provided that the Board considers the claim just and allowable. It was also stated that the decommissioned site would pose no dangers to northerners in the long term, and that the government will make final decisions on future land use and rights.

In addition, COGEMA will consult with the Fort Chipewyan community, if required.

Government agencies have been represented at workshops and meetings, and have also had specific consultations for technical issues.

As the decommissioning plan is implemented, communication will be regular with the EQC, and publications with respect to site status and decommissioning progress will be sent to communities regularly. Also, a dialogue in the north will be maintained through the active decommissioning and post closure monitoring periods and staff will visit impact communities. The web-site and toll free numbers will remain available.

12 CONCLUSIONS

CNSC staff concludes that the proposed Cluff Lake Decommissioning Project is not likely to cause significant adverse environmental effects, taking into account the proposed mitigation measures. Should the decommissioning project proceed to licensing, the CNSC staff will ensure the implementation of an EA Follow-up Program in accordance with the commitments on mitigation measures and the proposed Follow-up Program design detailed in this CSR.

The expert Federal Authorities for this project have signified their agreement that the CSR is considered complete for the purpose of the submission for public review under CEAA. The CNSC, as a Responsible Authority for the project under CEAA, is satisfied that the CSR meets the requirements of the CEAA, and that it may be forwarded to the Minister of Environment and the Canadian Environmental Assessment Agency for review and decision pursuant to sections 22 and 23 of the CEAA.

13 REFERENCES

Amok Ltd., 1992. (Amok, 1992). **“Environmental Impact Statement Dominique-Janine Extension”** consisting of an Executive Summary, Main Document and four Supporting Documents, February, 1992.

Agency for Toxic Substances and Disease Registry 2000. (ATSDR, 2000) **“Toxicological Profile for Arsenic”** (Update). U.S. Department of Health and Human Services, Public Health Service. September.

Bayda, E.D. 1978. (Bayda, 1978) **“Final Report - Cluff Lake Board of Inquiry”**. Regina, Saskatchewan

Beyer, W.N., Connor, E.E. & Gerould, S. 1994. **Estimates of soil ingestion by wildlife.** Journal of Wildlife Management 58, 375-382.

Canadian Environmental Assessment Agency, 1999. (CEAA, 1999). **“Responsible Authority’s Guide.”** Canadian Environmental Assessment Act - Training Compendium.

Canadian Environmental Assessment Agency. 2002. (CEAA, 2002). **“Follow Up Programs under the Canadian Environmental Assessment Act”.** Operational Policy Statement, OPS/EPO-6-2002, October, 2002.

Cluff Mining. 1982. (Cluff, 1982) **“Cluff Lake Development Phase II Environmental Impact Assessment”**. SRC Publication, November, 1982.

COGEMA Resources Inc., 1994. (COGEMA, 1994) **“Aquatic Biological Assessment of the Island Lake Drainage”**.

COGEMA Resources Inc., 1994. (COGEMA, 1994b) **“Cluff Mining Partnership Dominique-Janine Extension Project Update”.** March, 1994.

COGEMA Resources Inc. 1997. (COGEMA, 1997) **“Cluff Lake Project Operational Optimization Plan for the Cluff Lake Tailings Management Area”**.

COGEMA Resources Inc., 1998. (COGEMA, 1998a) **“Cluff Lake Project. Snake Lake Investigations – Final Report”**. June 1998.

COGEMA Resources Inc., 1998. (COGEMA, 1998b). **“Cluff Lake Project. Application for Approval to Discharge Tailings into the Lower Solids Pond of the TMA”.** December, 1998.

COGEMA Resources Inc., 2000. (COGEMA, 2000a). **“Cluff Lake Project Comprehensive Study For Decommissioning, Comprehensive Study Report”** Version 1, December 2000.

COGEMA Resources Inc., 2000. (COGEMA, 2000b). **"Cluff Lake Project Comprehensive Study For Decommissioning, Supporting Document #1 – Tailings Management Area"** Version1, December 2000.

COGEMA Resources Inc., 2000. (COGEMA, 2000c). **"Cluff Lake Project Comprehensive Study For Decommissioning, Supporting Document #2 – Mines and Waste Rock"** Version 1, December 2000.

COGEMA Resources Inc., 2000. (COGEMA, 2000d). **"Cluff Lake Project Comprehensive Study For Decommissioning, Appendices – Volume 1 of 2 (A & B)"** Version 1, December 2000.

COGEMA Resources Inc., 2000. (COGEMA, 2000e). **"Cluff Lake Project Comprehensive Study For Decommissioning, Appendices – Volume 2 of 2 (C, D, E & F)"** Version 1, December 2000.

COGEMA Resources Inc., 2000 (COGEMA 2000f). **"Cluff Lake Project , 2000 Status of the Environment Report,"** May 2000.

COGEMA Resources Inc., 2001. (COGEMA, 2001). **"Cluff Lake Project Comprehensive Study For Decommissioning, Responses to Regulatory Comments"** November, 2001.

COGEMA Resources Inc., 2001. (COGEMA, 2002a). **"Cluff Lake Decommissioning Project Review of the Source Terms, Flow and Transport Models, Comparison of the Backfilled DJX and Flooded DJX Pit Decommissioning Options ".** August, 2002.

COGEMA Resources Inc., 2002. (COGEMA, 2002b). **"Cluff Lake Project Comprehensive Study for Decommissioning, Responses to Supplementary Regulatory Comments".** December 2002.

Conor Pacific 2000. McArthur River Pre-milling Baseline for the Key Lake Project Area, 1998-1999. A report prepared for Cameco Corporation. Prepared by Conor Pacific Environmental Technologies Inc., Saskatoon, SK.

Dunn, C.E. 1980. Lake sediment and water geochemistry of the Carswell Structure, Northwestern Saskatchewan. Saskatchewan Mineral Resources. Report 224.

Environment Canada 1977. **"Metal Mining Liquid Effluent Regulations and Guidelines"** EPS 1-WP-77-1.

Environment Canada. 1993. (EC, 1993) **"Canadian Environmental Protection Act: Priority Substances List Assessment Report – Arsenic"**.

Environment Canada. 1997. (EC, 1997) **"The Canada Country Study: Climate Impacts and Adaptations"**. Volume Three: Responding to global climate change – In the prairies.

Environment Canada. 1998. (EC, 1998) **"The Canada Country Study: Climate Impacts and Adaptations"**. Volume Seven: National Sectoral Volume, Chapter 1.

Frank, A., Wibom, R. & Danielsson, R. 2002. **Myocardial cyotchrome *c* oxidase activity in Swedish moose (*Alces alces* L.) affected by molybdenosis.** Science of the Total Environment 290, 121-129.

Franklin, N.M., J.L. Stauber, S.J. Markich and R.P. Lim. 2000. (Franklin et al., 2000) **"pH-dependent Toxicity of Copper and Uranium to a Tropical Freshwater Algae (Chlorella sp.)"**. Aquatic Toxicology 48: 275-289. {cited in EC/HC 2001}.

Golder 2002. Key Lake Operation 2001 Aquatic Monitoring Program, Key Lake Mine Site, Saskatchewan. A report prepared for Cameco Corporation. Prepared by Golder Associates, Saskatoon, SK.

Government of Canada. 1999 **"Scope of the Project and Assessment for the Preparation of a CEAA Comprehensive Study Cluff Lake Decommissioning Project, Saskatchewan"**. October, 1999.

Gilman, A.P., Villeneuve, D.C., Secours, V.E., Yagminas, A.P., Tracy, B.L., Quinn, J.M., Valli, V.E., Wiles, R.J., & Moss, M.A. 1998a. **Uranyl nitrate: 28-day and 91-day toxicity studies in the Sprague-Dawley rat.** Toxicological Sciences 41, 117-128.

Gilman, A.P., Villeneuve, D.C., Secours, V.E., Yagminas, A.P., Tracy, B.L., Quinn, J.M., Valli, V.E., & Moss, M.A. 1998b. **Uranyl nitrate: 91-day toxicity studies in the New Zealand White rabbit.** Toxicological Sciences 41, 129-137.

Haseltine, S.D. &. Sileo, D. 1983. **Response of American Black ducks to dietary uranium: a proposed substitute for lead shot.** Journal of Wildlife Management 47, 1124-1129.

Hopkinson, R.F. 1994. (Hopkinson, 1994) **"Point probable maximum precipitation in northern Saskatchewan"**. Environment Canada, Atmospheric Environment Service. Report No. CSS-R94-01. March, 1994.

International Commission on Radiological Protection (ICRP) 1996. **"Age-dependent Doses to Members of the Public from Intake of Radionuclides: Parts Compilation of Ingestion and Inhalation Dose Coefficients"**. ICRP Publication 72. Vol. 26, No. 1, Elsevier Science Ltd., Oxford.

Joint Federal-Provincial Panel on Uranium Mining Developments in Northern Saskatchewan, 1993. (JFPP, 1993) **"Dominique-Janine Extension, McClean Lake Project, and Midwest Joint Venture"**. Report, October, 1993.

Kurias, J., P. Thompson and S. Munger 2000. (Kurias et al., 2000) "**Using Benthic Invertebrates and Sediment Chemistry Monitoring Data for Estimating LELs and SELs for Contaminants of Concern at Uranium Mine Sites in Northern Saskatchewan"**. Atomic Energy Control Board of Canada. In press.

Larsen, C.P.S. 1997. (Larsen, 1997) **"Spatial and temporal variations in boreal forest fire frequency in northern Alberta"**. Journal of Biogeography. 24: 663-673.

Lee. D., J.F. Archibald, J. Dantouze, R. Neal and A. Yassi. 1992. **"Guidelines for the preparation of Environmental Impact Statements and government information requests for the Cigar Lake and McArthur River Projects**". Joint Federal/Provincial Panel on Uranium Miming Developments in Northern Saskatchewan.

Leland, H.V. and J.S. Kuwabara. 1985. (Leland and Kuwabara, 1985) **"Trace Metals"**. Pp. 374-415. In Rand, G.M. and S.R. Petrocelli (eds.) Aquatic Toxicology. Hemisphere Publishing Corporation, New York.

Lepore, P.D. & Miller, R.F. 1965. **Embryonic viability as influenced by excess molybdenum in chicken breeder diets.** Proceedings of the Society of Experimental Biology and Medicine 118, 155-157.

Levin, S.A., M.A. Harwell, J.R. Kelly and K.D. Kimball (eds.) 1989. (Levin et al., 1989) **"Ecotoxicology: Problems and Approaches"**. Springer-Verlag, New York. 547.

Liber, K. and S.L. White Sobey 2000. (Liber and White Sobey, 2000) **"Toxicity of Uranium, Molybdenum, Nickel and Arsenic to <u>Hyalella azteca</u> and <u>Chironomus tentans</u> in Water Only and Spiked-Sediment Toxicity Tests"**. In press.

Long, E.R., MacDonald, D.D., Smith, S.L. & Calder, E.D. 1995. (Long et al., 1995) **"Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments"**. Environmental Management 19, 81–97.

Mines Pollution Control Branch (MCPB). 1989. **"Environmental monitoring guidelines for operational monitoring at uranium and gold mining and milling operations in Saskatchewan"**. Saskatchewan Environment and Public Safety.

O’Connor, G.A., Brobst, R.B., Chaney, R.L., Kincaid, R.L., McDowell, L.R., Pierzynski, G.M., Rubin, A. & Van Riper, G.G. 2001. **A modified risk assessment to establish molybdenum standards for land application of biosolids.** Journal of Environmental Quality 30, 1490-1507.

Paternain, J. L., Domingo, J.L., Ortega, A. & Llobet, J.M. 1989. **The effects of uranium on reproduction, gestation, and postnatal survival in mice.** Ecotoxicology and Environmental Safety 17, 291-296.

Robertson, A. MacG. 2000. (Robertson, 2000). **“International Experience in Tailings Pond Remediation”**. Paper presented at the international conference “WISMUT 2000 – Mine Rehabiitation”, Schlema, Germany, July 11 to 14, 2000.

Sample, B.E., Opresko, D.M. & Suter, G.W. 1996. **Toxicology benchmarks for wildlife – 1996 Revision.** Report No. ES/ER/TM-86/R3, Risk Assessment Program, Health Sciences Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Schroeder, H.A. & Mitchener, M. 1971. **Toxic effects of trace elements on the reproduction of mice and rats.** Archives of Environmental Health. 23, 102-106.

Swanson, S. [ed.]. 1991. Cluff Lake status of the environment report. A review of predicted and observed environmental impacts at the Amok Ltd. Cluff Lake Mine and Mill Site. SRC Pub.E-2200-2-E-91.

Terrestrial & Aquatic Environmental Managers Ltd. (TAEM) and SENES Consultants Limited (SENES) 1995. (TAEM and SENES, 1995) **“Cluff Lake Operation: Status of the Environment Report”**. Prepared for COGEMA Resources Inc.

Thompson, P.A., J.A. Kurias, and S. Mihok. (Thompson et. al., 2002) **“Using Benthic Invetebrates and Sediment Chemistry Monitoring Data For Estimating Lowest Effect/Severe Effect Levels at Uranium Mines In Canada”.** Canadian Nuclear Safety Commission - Working Benchmarks. 2002 in preparation.

Thornton, I. 2002. **Geochemistry and the mineral nutrition of agricultural livestock and wildlife.** Applied Geochemistry 17, 1017-1028.

Turnlund, J.R.// Keyes, W.R. & Peiffer, G.L. 1995. **Molybdenum absorption, excretion, and retention studied with stable isotopes in young men at five intakes of dietary molybdenum.** American Journal of Clinical Nutrition 62, 790-796.

Vyskočil, A. & Viau, C. 1999. **Assessment of molybdenum toxicity in humans.** Journal of Applied Toxicology. 19, 185-192.

Appendix A

Disposition of Comments Received on the Cluff Lake Comprehensive Study Technical Documents

Disposition of Comments Received on the Cluff Lake Comprehensive Study Technical Documents

The preparation and review of technical documents supporting the decommissioning approach for the Cluff Lake Project have been ongoing since April 1999. Over that time there have been two major iterations of review by stakeholders for which written comments have been received.

In January 2001, a five volume set of technical documents were submitted for formal review. In September 2001, detailed comments were received. In January 2002, COGEMA Resources Inc. submitted a separate volume (Responses to Regulatory Comments) addressing each of these comments and providing additional technical study to support the response. A summary of these comments is attached as Table 1; refer to the document above for the detailed questions and responses. The shaded rows identify the major comments for which additional technical assessment was required.

In April of 2002, COGEMA Resources Inc. received a second round of formal comments. Table 2 separates the comments by subject area and provides the responses to those comments. The shaded rows within the table refer to comments that have required a more detailed response and have been separately addressed with written letters to (and subsequent responses from) the originating agencies. These detailed responses can be found in an additional volume (Responses to Supplementary Regulatory Comments) submitted December 2002. The column entitled “More Detail Provided in COGEMA 2002b” provides the specific Section in which these letters and responses are contained. The column entitled “Relates to Previous Comment #” refers to a previous question on the same subject raised in the September 2001 comments.

Table 1 - Summary of Initial Regulatory Comments

Page #	Comment #	Agency	Comment
Section 2 - Assessment Methodology			
2	C1	CEAA	Summarize methodology in the CSR
3	C1	CEAA	General lack of clarity in Section 5; use of terms with several meanings (i.e. screening)
3	C1	CEAA	No discussion of malfunctions or accidents
3	C1	CEAA	Cumulative effects needs greater detail
3	C1	CEAA	Define spatial boundaries
4	C2	CEAA	Need to correlate our ratings with significance
4	C2	CEAA	Significance should focus on decommissioning
5	C6	CEAA	Need a section on Purpose of the Project
6	C7	CEAA	Further discussion of the environmental effects of technically and economically feasible alternatives
6	C8	CEAA	Identify who is responsible for monitoring and who is responsible to review monitoring and take remedial actions
7	C9	CEAA	Need to include the effects of the project on the capacity of renewable resources and the range that would be affected
7	C13	CEAA	Discuss environmental effects of a special purpose pit for mill waste
8	C16	HC	Needs an Executive Summary and Glossary
Section 3 - Abandonment Criteria and Compliance Points			
	Section 3.1 - Water Quality in Natural Watersheds		
8	C17	DFO	SSWQO met at mid depth in centre of Snake Lake
8	C17	DFO	SSWQO, or appropriate target values, attained for all contaminants in Claude Creek
8	C18	SERM	Indicate if there are areas in Snake that won't meet SSWQO and if so evaluate the impacts
9	C19	CNSC	Need a minimum of 2 water quality stations, Snake and Island and likely below the fen
9	C20	CNSC	Atmospheric exposure of fen sediments
10	C21	SERM	Evaluate the potential for degradation of water quality within Sandy Lake
10	C22	EC	Recommends an assessment of impacts on small mammals and waterfowl using the decommissioned area
10	C23	EC	Establish site specific objectives throughout the site, not just at Cluff Lake north and Snake Lake
	Section 3.2 - Surface Water Objectives for Uranium, Molybdenum and Cobalt		
11	C24	SERM	Clarify that the site specific values proposed for these elements will be met in Snake Lake
12	C25	SERM	Clarify that the site specific values proposed for cobalt will be met in north end of Cluff Lake
12	C26	CNSC	Cluff Lake calculations based on fully mixed assumption
12	C27	SERM	Elaborate on how recovery time lines for Island Lake were determined
12	C29	EC	Do not support site specific criteria proposed esp. for uranium
13	C30	CNSC	Do not support site specific criteria proposed for uranium in Cluff Lake as it is 100X higher than current; propose 23 ug/L
14	C31	CNSC	Do not support site specific criteria proposed for molybdenum; propose 73 ug/L for Cluff and accept 500 ug/L for Island
14	C32	CNSC	Do not support site specific criteria proposed for cobalt; propose 0.9 ug/L for Cluff
	Section 3.3 - Sediment Quality in Natural Waterbodies		
15	C33	DFO	General comments such as achieving PEL values; remobilization of contaminants from sediments
15	C34	CNSC	Request data on selenium content in Island Lake sediments
15	C35	EC	Need to justify why nickel sediment concentrations in excess of national guidelines do not have ecological implications; suggest field and lab toxicity testing
	Section 3.4 - Water Quality in Flooded Pits		
16 17 18	C36 C37 C38 C39 C40	DFO SERM CNSC EC	Disagree with MMLER as criteria for flooded pits; must meet SSWQO or assess the impacts; include impact on humans in the assessment; modeling indicates flooded pits are a significant source term; assess complete backfilling of Claude Pit with waste rock
	Section 3.5 - Radiological Criteria		
18	C41	HC	Require a clear statement on gamma and radon exposure criteria to correct ambiguity; lower criteria if possible
19	C42	CNSC	More restrictive gamma criteria are achievable; under the current proposal, institutional controls required
20	C43	CNSC	No clearance criteria for surface contamination
Section 4 - General Comments			
	Section 4.1 - TMA and Waste Rock		
21	C44	NRCAN	Should include provisions for the collection and treatment of surface and groundwater seepages
21	C45	HC	Provide tailings and waste rock analyses for sulphides
21	C46	CNSC	ARD potential of DJN pile
22	C47	EC	No geochemical information on the D waste rock pile
22	C48	NRCAN	Need longer term humidity and column leach results
22	C48	NRCAN	Oxidation of iron could produce acidity and impair passive removal in the trench
22	C48	NRCAN	Need shallow and deep groundwater piezos for source term
22	C48	NRCAN	Questions on the modeling of uranium decay products
22 23 24	C48 C49 C50	NRCAN CNSC SERM	Fully investigate the option of moving Claude pile to the Claude and DJ pits; no cost/benefit analysis; (SERM comment relates to Claude pit only)
24	C51	EC	Comprehensive monitoring program around TMA to confirm modeling predictions
25	C52	NRCAN	ARD in vadose zone of the tailings
25	C52	NRCAN	Contingencies in the event of sulphate depletion
25	C52	NRCAN	Need shallow and deep groundwater piezos for source term
25	C52	NRCAN	Major sand conduit between TMA and Snake Lake
25	C52	NRCAN	Will increased values in piezos and Snake continue post decommissioning
25	C52	NRCAN	Decrease of Kd with sulphate depletion will increase Ra
25	C52	NRCAN	Desorption of the sediments in Snake and Island Lakes
26	C53	DFO	Contingencies in the event of sulphate depletion
26	C54	DFO	Provide total loadings to Cluff Lake

Table 1 - Summary of Initial Regulatory Comments

Page #	Comment #	Agency	Comment
26	C55	DFO	Resolve saturation point for wetlands as contaminant "sinks"

Table 1 - Summary of Initial Regulatory Comments

Page #	Comment #	Agency	Comment
	Section 4.2 - Other General Comments		
27	C56	EC	Faster rate of release from the sediments in Island Lake may occur; evaluate "technically-achievable" contingencies
27	C57	EC	Soil survey required to determine metal accumulation
27	C58	EC	Request assessment of the three smaller landfill sites
28	C59	EC	Criteria to define an acceptable vegetation cover condition
28	C60	EC	Inadequate contingencies for groundwater contamination
29	C60	EC	Inadequate contingencies for failure of natural processes in Claude Pit
29	C60	EC	Inadequate contingencies for cover failure from tree toppling, burrowing animals and frost heaving
29	C61	DFO	Detailed plans for covers if infiltration is excessive
29	C62	EC	Must relate climate change to impacts on site decommissioning
30	C62	EC	Greater security if more impervious cover to TMA
30	C62	EC	Potential likelihood for Claude Pit and DJX Pit overflow during flood; impact on Cluff Lake?
30	C62	EC	Thicker till cover for DJN pile
30	C63	EC	Biological significance of wildlife observations absent
32	C63	EC	Potential exposure of birds to radionuclides during operations and closure
32	C63	EC	Undertake pathways analysis for metal and radionuclide predictions in aquatic and terrestrial wildlife; monitor small mammals
32	C64 C65 C66 C67	CNSC	Screening assessment for chemical toxicity to wildlife required
35 36	C68 C69 C70	EC DFO SERM	Other regulations to be considered
Section 5 - Detailed Comments on the CSR and Supporting Documents			
	Section 5.1 - Comprehensive Study Report - Main Document		
37	C71	CNSC	Decommissioning of the mill
37	C73	SERM	Contents of Claude Pit
37	C75	DFO	Groundwater chemistry for Claude pile for 2000
37	C76	CNSC	Passive mechanisms will develop; statement needs support
38	C77	DFO	Define end of post closure period
38	C78	SERM	Timeframe for Claude pile resloping; impact of exposing PAG rock and possible mitigation
38	C79	DFO	Liming the resloped surfaced of Claude pile
38	C80	DFO	Source of water for DJN (probably means DJX) flooding and sketch of overflow to Cluff Lake
38	C81	DFO	Vent raise caps?
38	C82	CNSC	Support the statement that chemical reactions and anoxic conditions will control contaminants
39	C83	DFO	Selenium in Snake Lake problematic to fish?
39	C84	DFO	Rates of porewater expulsion based on modeling?
39	C85	DFO	Selenium in Snake Creek above CWQG
39	C86	DFO	Deposition of sewage sludge
39	C87	SERM	Sampling and decommissioning of tile fields
39	C88	SERM	Details of investigation of other landfills
39	C89	SERM	Map of all landfills and waste management areas
40	C90	CNSC	All waste disposal areas identified?
40	C91	CNSC	Standard practice to remediate spills in 1983?
40	C93	NRCAN	Final gamma scan details
40	C94	SERM	Update spills to add rest of 1999 and 2000
40	C95	NRCAN	Gamma scan on TMA for effectiveness
40	C96	CNSC	Not good practice to burn unless scanned first
41	C97	SERM	Remove Carswell dock, fill basements, submit drillhole locations
41	C98	SERM	Removal of sewage treatment plant and field
41	C99	DFO	Source of till to backfill sewage lagoon
41	C100	SERM	Table of building areas vs. volume does not appear to line up
42	C103	DFO	Detailed procedures and timing for stream crossing removal
42	C104	DFO	Rationale for leaving concrete pads in place
42	C105	SERM	Preference that concrete pads be broken up
42	C106	SERM	Need for pipelines for longer term water treatment?
43	C107	SERM	Impacts on till borrow areas
43	C108	SERM	Map of borrow pit locations and depth of excavation
43	C109	SERM	Native species preference for seed mix
44	C110	SERM	Table of Contents for Section 3 missing page numbers
44	C112	EC and CNSC	D Pit waste pile - monitoring must be detailed enough to detect an emerging plume; geochemical data and long term predictions not provided
44	C113	DFO	Due to uncertainty of long term utility of wetlands, need a contingency plan; global warming should be considered
44	C114	DFO	Flooded pits should meet SSWQO; see C111 as well
45	C115	EC	Wetlands contingency from Claude pit susceptible to failure; consider active treatment
45	C115	EC	Describe robustness of the waste rock cover from burrowing animals and uprooting by vegetation
45	C116	CNSC	Discuss precedents for successful cover construction and performance of capillary break covers for ARD rock
45	C117	DFO	Contingency for Claude Lake sediments
45	C118	DFO	Water level in Claude pit maintained below Claude Lake
46	C119	SERM	DJN backfill placed in the bottom of DJX should have a 0.3 till cover
46	C120	DFO	Details of flooding DJX; same question as C80
46	C121	EC	Thicker composite cover for DJN pile

Table 1 - Summary of Initial Regulatory Comments

Page #	Comment #	Agency	Comment
46	C122	SERM	Details of purpose built pit for mill demolition waste
46	C123	SERM	Will mine water pipeline be retained?
47	C124	SERM	Groundwater monitoring of old dumpsites within TMA
47	C125 C126 C127	NRCAN and CNSC	Regional background in Wollaston from airborne survey? Need local background; Timing of the scan; D pit
48	C128	SERM	Radon levels; Change colors on Figure 4.4.2-2
48	C129	DFO	Groundwater discharge in LSP and Snake Lake
48	C130	SERM	Suggestion for Principal Components Analysis
48	C132	SERM	Source of predictions on water quality in Island Lake system
48	C133	SERM	Identify those parameters which currently exceed SSWQO in Snake Lake
48	C134	SERM	Identify those parameters which currently exceed SSWQO in Island Lake
48	C135	SERM	Fecal coliforms in Germaine
48	C136	SERM	Fish species in Island Lake
48	C137	SERM	Note that a new Human Resources Development Agreement is currently in preparation
48	C138	SERM	Impact communities clarification
48	C139	CNSC	Elevated natural background; further references required
50	C140	DFO	Flooded pits should meet SSWQO
50	C141	DFO	Show Snake Lake can assimilate future loadings
50	C142	DFO	Monitoring criteria to establish no adverse impacts
50	C144	DFO	Time frame to achieve 100 ug/L in Claude Creek
51	C146	DFO	Selenium at Cluff Lake
51	C147	DFO	Water quality in flooded pits
51	C148	DFO	Water quality in flooded pits
51	C150	NRCAN	Details on airborne or ground gamma surveys
51	C151	NRCAN	Differences in quoted background gamma levels
52	C152	DFO	Sediment values in Snake Lake
52	C153	DFO	Additional support for peat trench concept required
52	C154	DFO	Long term modelling for D Pit conducted?
52	C155	DFO	Cluff Lake sediment exceeds PEL values
52	C156	SERM	Predictions for north end or outlet of Cluff Lake?
53	C157	SERM	Identify timeframe for Island Lake water and sediment quality to return to SSWQO/PEL values
53	C158	SERM	Assess other options for Island Lake sediment (i.e. covering)
53	C159	SERM	Sediment concentrations in Cluff Lake
53	C160	CNSC	Ecological implications of Cluff Lake sediment predictions
54	C162	SERM	Acid rain and implications on TMA & waste rock modeling
54	C163	SERM	Control vegetation around mill during mothballing to prevent forest fires
54	C164	SERM	Effect of global warming on site vegetation or streamflow
54	C166	DFO	Concrete caps over surface raises vented?
54	C167	SERM	Concern about long term underground stability; monitoring may be required
55	C168	SERM	Backfilling 50 m below bulkhead; meet Golder recommendation?
55	C169	SERM	Request for some additional information in Table 5.6-1
55	C170	SERM	How will DJX be flooded?
55	C172	DFO	Timing and method of removal of water crossings along roadways
55	C173	DFO	Effectiveness of peat trench removal must be tested in advance
56	C175	DFO	Contingency plan if infiltration to the TMA is greater than anticipated
56	C176	DFO	Investigate appropriate ways to reduce waste rock cover permeability before problems are observed
56	C177	DFO	Evaluate the effectiveness of the wetland contingency for Claude Pit
57	C178	SERM	Passive removal ok for polishing but not for treatment
57	C179	SERM	Significance of not building the DJX dyke
57	C180	DFO	Selenium in Snake Lake and Snake Creek may be problematic
57	C182	DFO	Indicate the expected reduction in Phytoplankton in Cluff Lake due to elevated uranium
58	C183	SERM	Access to health information after closure
58	C184	SERM	Provide predicted annual monitoring costs once site has been released
58	C185	SERM	Evaluate the impacts and cost of removal of beaver dams in the diversion ditches
58	C186	CNSC	Long term institutional care and maintenance will be needed on TMA and waste rock areas; detail and cost
58	C188	SERM	Conduct a new ecological baseline, especially wildlife abundance at the end of the decommissioning period for future reference
59	C189	EC	General comments on requirements of the monitoring program
60	C192	SERM	Future claims for diability and health problems; need for insurance
61	C193	DFO	Consult DFO regarding plans for bridge and culvert removal on access road
	Section 5.2 - Comprehensive Study Report - Volume 1 of 2, Appendices A & B		
61	C195	NRCAN	Consider gamma data from Geological Survey of Canada
61 - 71	C196 C197 C230	NRCAN	Groundwater issues
62 -71	C198 C224	All Agencies	Pathways Analysis - Appendix B
	Section 5.3 - Comprehensive Study Report - Volume 2 of 2, Appendices C, D, E & F		
71 - 72	C224 C228	All Agencies	Underground Stability - Appendix C
	Section 5.4 - Supporting Document #1 - Tailings Management Area		
72 - 77	C231 C265	All Agencies	TMA Supporting Document + Appendices A, B and C
	Section 5.5 - Supporting Document #2 - Mines and Waste Rock		
77 - 80	C266 C277	All Agencies	Mines and Waste Rock + Appendix A
80	C278 C280	All Agencies	Source Term - Appendix B

Table 1 - Summary of Initial Regulatory Comments

Page #	Comment #	Agency	Comment
81 - 86	C281 C305	All Agencies	Transport Modeling - Appendix C
86 - 87	C306 C312	All Agencies	Soil Cover Modeling - Appendix D
87 - 88	C313 C322	All Agencies	D Pit - Appendix E

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
Claude Pit Backfilling					
	Modelling of sediment removal rates in Claude Lakeshould consider a variability in removal efficiency between 50 and 90 %	NRCan		Updated results from Claude Lake sediment column experiment were provided to all agencies to demonstrate that, after almost one year of operation, uranium removal still exceeded 99% and nickel and cobalt removal appeared to have stabilized at about 60%; committed to continued operation and monitoring of the columns	**Section 3.1**
	Provide the basis for the 90% removal assumption	SE			
	Must show that the capacity for nickel removal will re-establish with sulphate reduction	NRCan			
	Experimental data must demonstrate nickel removal	CNSC - WDD			
	Include dissolved sulphide species in test water quality	NRCan		Difficult to keep water samples in anaerobic conditions during transport to the lab; these products would tend to oxidize prior to analysis	
	Low winter temperatures in the sediment may retard the removal process	NRCan		May slow the rate of sulphate reduction slightly but will not reduce uranium removal by absorption	
	More detail for backfilling the bog area between the pit and lake	SE		The area between Claude Pit and Claude Lake was lake bottom prior to installation of the dikes. These areas will be backfilled to prevent surface seepage and push the groundwater into Claude lake where the sediments can effectively remove a significant portion of the contaminant load.	
	Fate of the contaminants if lake dries up	SE		Although Claude Lake may revert to a wetland over the next 50 years, it remains a groundwater discharge area and a headwater for local runoff collection. The current lake sediments will continue to be saturated and will retain the contaminants.	
	Will peak loadings increase after 1000 years?	SE		Table 7-2 on page A-26 of the "Response to Regulatory Comments" indicates that the maximum concentrations and peak loadings for Claude Lake will occur after 1000 years but indicates those peaks are only marginally higher than observed over the first 1000 years. Similar tables are offered for all other locations and indicate the same situation.	
DJX Backfilling					
	Should model after incorporating alkalinity and organic materials with waste rock	NRCan		Subsequent modelling showed DJX flooding provided acceptable water quality results for all surface water bodies with Claude waste rock remaining on surface; this option is economically superior	
	Treating of DJX water prior to final flooding; use of contaminated Claude pile groundwater to fill the DJX pit	SE	C60	The water management plan has not been finalized. The detailed plans will be submitted as part of the licencing process. The contaminated wells at the toe of Claude pile contain an insufficient volume of water to warrant pumping to DJX.	
	Model the long term water quality of a fully-flooded DJX Pit; CNSC expects water quality will be worse than anticipated by COGEMA modelling	CNSC - WDD		The modelling for the mining area was reviewed and upgraded following critical evaluation of source terms and other model inputs. The model was then applied to compare the backfilled versus flooded DJX scenarios. The result of the study confirmed that the flooding option was superior in terms of final water quality in Cluff Lake. Water quality in the flooded pit was improved as a result of removal of DJN backfill material to a level of 314 masl and addition of a till cap.	**Section 3.2**

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
	Remodel DJX contaminant transport using the leach test results from 1993	CNSC - WDD			**Section 3.2**
	Care required in flooding DJX to ensure not fish, sediment or aquatic life introduced	EC	C36, 39 & 40	COGEMA will attempt to do this through appropriate screening of the intake, however, it will be impossible not to introduce plankton.	
	DJX overflow should avoid the fish compensation agreement area	DFO	C80	The Fish Habitat Compensation area can be circumvented during construction of the emergency overflow ditch.	
	Total volume and schedule for pumping from Cluff to fill DJX should be provided	DFO	C80	The water management and flooding plan has not yet been completed. Water will be required from Cluff Lake to complete DJX flooding but this will be done at a rate which does not exceed the current rate for mill utilization. Details of the plan will be part of the licencing submission.	
	Details of water intake if DJX to be flooded from Cluff Lake	DFO	C120	Will use the same intake, infrastructure and maximum pumping rate as has been used for during operations to supply fresh water to the mill. There will be no further mill operation at this time.	
	Changes in phytoplankton species composition should be reviewed to confirm that predominant species will be palatable to zooplankton and forage fish	DFO	C182	The follow up monitoring program includes a baseline environmental evaluation of the Cluff and Island Lake systems at the time of closure. A Status of the Environment report will be undertaken five years thereafter. Changes to the phytoplankton population composition will be identified with these surveys. If these changes occur, the environmental significance will be evaluated.	
TMA Modelling					
	Modelling should be conducted to show that high arsenic near HYD197 will be averaged out and not constitute a highly contaminated plume	NRCan	C197	Further modelling indicated that a conservative estimate of the groundwater plume As concentration could reach 75 ug/L; this would marginally increase the Snake Lake concentration from 2 to 3 ug/L. HYD197 was added to the post closure monitoring program as requested.	**Section 3.3**
	Map showing sites of slimes and solid tailings sampling to prove representativeness	NRCan	C210	Provided in the follow up submission to NRCan	
	Run sensitivity on longitudinal dispersivity up to a value of 3.0 m	NRCan	C263	Further modelling indicated that the selected dispersivity values were appropriate.	**Section 3.3**
	Model using a distinct As source term for the slimes not blended with the rest of the tailings	NRCan	C262	The submission demonstrated that the borehole locations used in the source term calculation were sufficiently diverse to provide a good representation of coarse, fine and transitional tailings.	
	Final CSR should include the risks to ducks in the TMA	SE	C22 & C63	This is not an environmental assessment issue for decommissioning. A program has been developed for further investigation and will be conducted under the current operating approval.	
	Upon completion, submit gradation test results for the cover and results of piezo readings	CNSC - WDD	C242	COGEMA agree to provide this information	
	The discrepancy between predicted and observed Ra226 in porewater may be a result of colloidal resuspension during sampling	CNSC - WDD		This is exactly what we believe to be happening. However, rather than do a bounding calculation, our plan is to install piezos in the tailings after leveling course placement and monitor quiescent conditions to confirm the lower predicted value	

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
	Comment on long term impact of diversion ditches around TMA	CNSC - PFTSD		The North and South Diversion Ditches were constructed around the TMA to divert upstream and lateral drainage around rather than through the reclaimed tailings. The ditches are designed to handle a PMP event and can be expected to consolidate the drainage area of the TMA to the maximum extent possible.	
	Reliable estimates of infiltration needed for covers	CNSC - PFTSD		We recognize and agree with the importance of the infiltration rate. Rather then divert additional time and effort to modelling, we will install test plots to monitor the infiltration which actually occurs. This has been included within the monitoring program. As data is collected, our modelling will be refined using observed values.	
	Sulphate depletion tests done 16 years ago and didn't continue long enough to show Ra226 trends	DFO	C53	There have been no significant changes to tailings chemistry since the tests with the exception that radium-226 levels increased over the final year as a result of higher ore grade. We believe the results of the testing are still applicable.	
	Regular inspection of cover post decommissioning important to monitor effects from animals, erosion and tree toppling	EC	C60	Agree. Post closure monitoring will include daily inspections of the tailings area as well as annual evaluations of the revegetation.	
Waste Rock Piles					
	Discuss proven cases where covers are successful in minimizing oxygen diffusion	CNSC - WDD	C116	Any cover will reduce oxygen entry to some extent but a saturated layer will preclude entry for as long as the saturated condition exists. The MEND program has documented several Canadian examples where oxygen entry has been impeded by a dry cover approach.	
	Location of boreholes not shown on the drawing	CNSC - WDD	C284	These locations are shown on Figure 4 within Appendix D of Volume 2	
	Identify the percentage and spatial distribution of in situ and non-compacted waste rock	CNSC - WDD	C310	The soil cover modelling assumed uncompacted till over compacted waste rock over in situ waste rock. The category of non-compacted waste rock was developed in an earlier phase of the study but was not used in the modelling.	
	On Figure D4-3, the saturated permeability is 10-9, not 10-8	CNSC - WDD	C311	Agree	
	Re-model with both Claude and DJX backfilled and Claude above ground pile reduced to 20% of current volume	CNSC - WDD		The modelling for the mining area was reviewed and upgraded following critical evaluation of source terms and other model inputs. The model was then applied to compare the backfilled versus flooded DJX scenarios. The result of the study confirmed that the flooding option was superior in terms of final water quality in Cluff Lake.	**Section 3.2**
	Explain cessation of flow and concentration increases in groundwater	DFO	C75	The reduction in groundwater level is directly related to the lower-than-average annual precipitation which has occurred at Cluff Lake over 1999, 2000 and 2001. The reduced precipitation also results in reduced dilution of the portion of the groundwater originating from the waste rock pile, resulting in a corresponding increase in concentration of the contaminants.	

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
	Potential impacts of arsenic in Cluff Lake should be the subject of future sediment toxicity testing	DFO	C155	Based on the predicted arsenic values in Cluff Lake sediment, toxicity studies are not warranted at this time. In the event that monitoring indicates these levels are approaching a realistic toxicity potential, toxicity studies will be considered.	
	Lab tests for waste rock were not conducted at pH levels predicted for the piles	DFO	C292	The relocation of the DJN waste rock pile to Claude pit will remove the majority of the contaminant source to the Peter River.	
	Cover on Claude pile be routinely inspected to assess stability	EC	C115	Agree. The area will be inspected monthly and revegetation evaluations will be done annually.	
Water Quality Criteria					
	Use hardness of unimpacted water body	SE		The reduction in uranium toxicity is related to the hardness value in the water at the time of exposure. If hardness rises coincident with the uranium increase, an increasing portion of the uranium will be captured by the additional TDS and will not be bioavialable. The uranium objective must be determined based on the hardness at the time of measurement and will vary over time as the hardness value increases or decreases. This is no different than the current method within SSWQO for calculation of nickel.	
	Justify not achieving SSWQO in the full water column of flooded pits	SE	C23	Separate response provided to SE which details the reasons why achieving SSWQO in the upper portion of flooded pit water column is an acceptable decommissioning approach.	**Section 3.4**
	Selenium in sediments - request details on the teratogenic assessment for white sucker from Island Lake	SE	C33	A report on the white sucker tests will be provided to SE and DFO when it has been finalized.	
	Applying SSWQO for selenium and arsenic is hazardous and inappropriate	DFO	C1 & C23	These elements are to be evaluated under Regional Water and Sediment Quality Working Group (RW&SQWG) to define an appropriate level of protection for a Northern Saskatchewan situation. We would like to re-iterate once again that CWQG are derived from laboratory studies on most sensitive species (usually non-native) divided by a significant safety factor. Exceedance of these guidelines do not necessarily infer a hazardous situation.	
	Time period to achieve SSWQO in pits not clearly defined; use treatments to speed recovery	DFO	C36	COGEMA have committed to treating and monitoring in the flooded DJX pit until compliance is achieved (in the upper portion of the water column) or can be reasonably predicted. We would hope this would be achieved upon initial flooding but, if not, within one to two years.	
	Use Regional Water and Sediment Quality Objectives Committee to validate uranium close out objective	EC	C23	Agree	
	Use an interim close out objective for molybdenum in Island Lake of 0.5 mg/L	EC	C23	This is consistent with the CNSC position (Comment #79) and the objectives have been adjusted to reflect this preference. Whether this low value is appropriate for environmental protection will be a subject for the RW&SQWG.	

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
	Groundwater criteria should be developed during the licencing phase by back calculating from acceptable surface water criteria	EC	C60	Groundwater impacts are a function of concentration and flow rate. Accordingly, quality objectives would be highly variable from location to location and would offer limited benefit.	
	MMER will require EEM	EC	C189	We are currently in further discussions with EC regarding implementation of the MMER and associated EEM programs.	
	CNSC do not accept hardness relationship proposed for uranium toxicity; propose 23 ug/L	CNSC - EP & A	C23	Further discussions with CNSC have lead to the conclusion that the hardness-related uranium toxicity relationship developed by COGEMA will be permitted on an interim basis. In the event that the RW&SQWG, through future research and related studies, modify this value, Cluff Lake will further assess the implications on a site specific basis and work with the CNSC to take appropriate action.	**Section 3.6**
	Use 0.5 mg/L for Molybdenum in Island Lake and pit water and 0.073 mg/L for other drainages	CNSC - EP & A	C23	This is consistent with the EC position (Comment #65) and the objectives have been adjusted to reflect this preference. Whether these low values are appropriate for environmental protection will be a subject for the RW&SQWG.	
Sediment Quality					
	Cycling of contaminants between sediment and water; consider long term implications	DFO	C33 & 212	This was considered in the Pathways Analysis predictions of future water and sediment quality.	
	Replace sediment benchmarks with updated version	CNSC - EP & A	C139, 160, 212 & 213	Agree.	
Selenium					
	Assumption of acceptable upstream equals acceptable downstream may not be appropriate	DFO	C1	Studies on Se will consider existing conditions in Island Lake where downstream effects are higher due to sediment releases	
	Assess the development of embryos from fishes in Island Lake	DFO	C9	A study has been conducted on selenium effects to early life stages of white sucker from Island Lake. A copy of the final report will be provided to DFO and CNSC.	**Section 3.5**
	Characterize selenium in the waste rock	DFO	C34	Selenium has been added to the list of parameters for groundwater sampling. Several piezometers are installed in or adjacent to the Claude waste rock pile.	
	Retention of selenate in Claude Lake sediment re: potential for oxidation and uptake by benthics	DFO	C34 & C54	Groundwater enters the lake from the bottom up; sectioning of the columns at the conclusion of the test will determine the proportions near the water/sediment interface; these will likely be minimal	
	Additional detail to demonstrate that Se is not problematic to Snake Lake fish	DFO	C83 & 34	The discussion in Comment 83 of the REsponses to Regulatory Comments relates to Snake Creek below Snake Lake. Se values in Snake Lake have traditionally been below detection (< 1 ug/L). Movement by fish in and out of Snake Lake is difficult as a result of beaver activity and low flows.	
	CNSC must approve study design for selenium investigations; further assessment and close out objectives may be required depending on results	CNSC - EP & A	C34	Program developed and implemented in late May of 2002; reviewed with CNSC representatives on site on May 14, 2002	

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
Snake Lake/Island Lake					
	Provide estimates of long term flow from Snake Lake	SE	C17	Long term flow estimates are presented in Section 7.3.6.1 of Appendix A, Volume 1 of the CSR.. The total flow including STS discharge is anticipated to average 0.51 m3/s.	
	Potential for wetlands to dry up and release contaminants	SE	C55	For the Island Lake fen, a monitoring program has been designed and included in the follow up program to confirm that the water level in the area is groundwater controlled.	
	Complete mixing within Snake Lake to achieve SSWQO is unacceptable; demonstrate water quality in center is similar to outlet	DFO	C17	The RW&SQWG will be assessing the suitability of these SSWQO values. The details of the monitoring program will be worked out during the licencing period; the environmental assessment simply commits to monitoring Snake Lake, to which we all agree.	
	Designate wetlands as a "contaminated site"	DFO	C55	Disagree; if contaminants are permanently tied up, which is the case if they remain in a saturated condition, there is no long term hazard. The monitoring program includes collection of information at the Island Lake fen which will evaluate the probability of continued saturation.	
	Contingencies for Island Lake sediment and fen may invoke DFO as an RA; need to clarify the probability that these contingencies will be invoked	DFO		COGEMA has formally altered the contingency plan to one which specifies the pumping of fresh water from Cluff Lake (through existing intake facilities) to supplement inflows to Island Lake until a more permanent solution is identified. This will alleviate the DFO concerns regarding fish impacts as a result of interbasin water transfer.	**Section 3.5**
	Routine assessment of Island Lake sediments	EC	C35	Agree. A decommissioning baseline of the aquatic ecosystem in Island Lake will be conducted on closure to evaluate aquatic ecosystems, including sediments. A further follow up survey will be conducted five years thereafter and be reported in the Status of the Environment Report.	
	No contingency offered for the possibility that contaminants released from sediment to water	EC	C56	EIS predicts release but at rates which do not result in water quality problems; the fen will polish water quality if rates are higher than expected. Continued water and sediment quality monitoring in Island Lake and downstream will identify and quantify the problem.	
Radiological					
	Investigation of mill, DP and Claude sewage areas for radiological contamination and clean up plan	SE	C87	A gamma survey will be conducted over the entire reclaimed site to ensure that all areas are within accepted radiological criteria. This will include the sewage disposal area; if the criteria are not met, the options include excavation of the contaminated soil or covering with clean material. This will be a licencing issue.	

Table 2 - Responses to Supplementary Regulatory Comments

Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
Clarify gamma exposure levels from D-Pit and pile	SE	C127	SE is correct that Figure 4.4.2-1 indicates gamma levels in the D pit area between 1 and 5 uSv/h. This may be partially related to the relatively high background due to the natural boulder train materials in the area. As previously committed, a final gamma survey by ground methods will be completed on a tighter grid over all areas following decommissioning. If the criteria of 1 uSv/h for large areas and 2.5 uSv/h on a spot basis cannot be met, the options include further remediation or a confirmation that these elevated levels are background conditions which occur naturally in the area.	
Post closure monitoring of small burrowing animals in the TMA should be part of follow up	EC	C59	COGEMA do not agree that the terrestrial pathways have been identified within the EIS to be sufficiently significant to warrant follow up monitoring. However, if subsequent information confirms this issue needs to be addressed in the follow up monitoring program, the program will be revised.	
Wildlife/Human Impacts				
High risk quotients predicted for wildlife must be interpreted as to spatial and temporal extent of impacts	CNSC - EP & A	C64-67, 215 & 218	Elevated risk quotients for As, Mo, Se and U are often the result of questionable benchmark values. When factors such as residence time, size of affected population and scale of the effect are considered, the probability of risk is much reduced.	**Section 3.7**
Impacts on biota from flooded pits and waters between pits and Cluff Lake should be discussed	CNSC - EP & A	C64	Upper water columns in flooded pits will meet SSWQO or other post closure water quality objectives; no impacts are expected	
Examine the consequences of casual use of contaminated water in terms of human health risk	CNSC - EP & A	C65	The risk quotients quoted in Comment #65 of the Response to Regulatory Comments for flooded pits are < 1 for all parameters except U and As (& Mo for DJX). This was a conservative calculation based on human consumption of water from the pit exclusively over 6 months of the year. The conclusion of no consequence will also apply to Island Lake where water quality values are similar and Snake Lake where water quality will be significantly better.	
Additional tables and graphs to show time period where parameters with high RQ values remain above 1	CNSC - EP & A		Can be provided if necessary.	
Toxicity experiments with Island Lake media to determine impacts on terrestrial animals	CNSC - EP & A		Research should be concentrated on the aquatic pathway until sufficient scientific information is available to support development of realistic objectives.	
Underground Mine Closure				
Remedial measures taken in Upper DJ North to reduce or eliminate potential for surface subsidence	SE	C228	Additional filling has also been undertaken in Upper DJ North, however, subsidence is of reduced risk in this area due to substantially greater depths of overburden between the workings and the surface.	
General				
Identify the additional remedial actions that will be taken if tailings and waste rock measures are inadequate	SE	C44	Modify the cover design to decrease the rate of infiltration.	

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
	Potential impacts of borrow areas and reclamation plans; concern they may be a "conduit for contaminant migration"	SE	C107	Borrow areas are a source of well drained till material for cover construction. They are generally located on elevated ground well above the groundwater table. Reclamation will be accomplished by stripping topsoil and organics to the side and replacing the material after the borrow pit has been removed and the site recontoured.	
	Use of non-native species in reclamation not approved unless can demonstrate natives will not be effective	SE	C109	Selected area of the decommissioning require immediate erosion control and a comprehenisive root mass that will accelerate transpiration. These areas include the North and South Diversion ditches and the soil covers on the TMA and the Claude waste rock pile. COGEMA will consult SE in the selection of a final grass/legume mixture for these areas.	
	Explain how acid rain was considered in the tailings and waste rock modelling	SE	C234	Acid rain impacts were considered by starting the model calculations at a reduced pH.	
	Surface flow predictions - check the regression analysis for CFFHYD-1; check outliers in CFFHYD-3 and 4	CNSC - PFTSD		This has no direct bearing on the decommissioning plan. It is provided in order to develop long term flow comparisons between similar stations. COGEMA will check to ensure the calculations are correct	
	Develop contingency plan prior to decommissioning	DFO	C61	Contingency plans have been developed but further detail will be added as follow up monitoring is conducted	
	Identify and provide information on all stream crossings	DFO	C103	Design and approval of stream crossings is clearly a licencing issue. The removal of stream crossings will be one of the last tasks to be performed as it removes all further access; significant time is available for the permitting of this work. For purposes of the EA, our conceptual plan is that all stream crossings will be removed, habitat will be re-established and, because habitat will be created not destroyed, there will be no HADD	
	Criteria for determining whether water flow is an issue for concrete pads	DFO	C104	The water flow issue relates only to the potential for water ponding on a continuous basis within a localized area. There are no impacts on regional groundwater flow and recharge patterns.	
	The details of the proposed testing for the peat trench should be provided with mitigation techniques verified	DFO	C173	The approach will be to install the ditch and field monitor the results over subsequent years. It is important to point out that the peat trench is an auxiliary removal mechanism intended to pre-treat the Claude pile drainage prior to the principal removal mechanism, the sediment under Claude Lake.	
	Monitoring of other waste disposal sites must continue with a commitment to address if problems arise	EC	C58, 88, 89 & 90	Agree. The piezometers installed at the landfill sites will be monitored on a quarterly basis throughout the post closure period. Hydrocarbons will be included in the analytical parameters. If contamination is identified, follow up action will be taken.	
	General specification for the monitoring program; detailed program defined at licencing stage	EC	C189	The post closure and follow up monitoring programs include all the elements identified with exception of the terrestrial environment which we do not believe warrants follow up monitoring.	
	Report must be re-written as an integrated stand-alone document	CNSC - EP & A		An integrated executive summary will be prepared for submission to CEAA; the earlier seven documents will become a reference manual	

Table 2 - Responses to Supplementary Regulatory Comments

	Specific Comment (by Subject Category)	Agency	Relates to Previous Comment #	COGEMA Response	More Detail Provided In COGEMA, 2002b:
	Omissions on Table C199-1	CNSC - EP & A	C199	Two values to be added; information will be supplied	

CEAA EA DOCUMENT LISTING

FEAI Reference No: 18738

***Project Title**: Comprehensive Study Report, Cluff Lake Decommissioning Project*
Canadian Nuclear Safety Commission
December 2003

Document Title	Author	Document Date	No. of Pages	Subject (Letters)	File No.
	D. Myles	November 7, 2003	5	Cluff Lake Decommissioning Project CNSC Comprehensive Study Report (CSR)	17769 22-C1-123-5
	D. Munro	November 5, 2003	1	Cluff Lake Comprehensive Study Report Final Review of the Proposed Comprehensive Study Report (September 2003)	17505 22-C1-123-5
	R. Kidd	October 30, 2003	2	Comments on Comprehensive Study Report (CSR) for Cluff Lake	17470 22-C1-123-5
	R. Tupper	October 30, 2003	1	Cluff Lake Decommissioning - Comprehensive Study Report	17467 22-C1-123-5
	A. Merkowsky	October 31, 2003	1	Cluff Lake Project – Final Review of the Comprehensive Study Report	17477 22-C1-123-5
	J. Conrod	November 4, 2003	2	Comprehensive Study Report for Cluff Lake Decommissioning Project	17497 22-C1-123-5
	D. McClymont - Peace	October 29, 2003	1	Cluff Lake Decommissioning – Final Review of the Comprehensive Study Report	17435 22-C1-123-5

Note: Federal Authority Review Comments

Appendix B

CEAA EA Document Listing

Table 6.12

Comparison of Environmental Assessment Predicted Impacts and Realized Operational Impacts

Issue	Description	Reference*	Predicted Potential Operational Impact	Predicted Impact Classification	Observed Impact During Operations	Actual Impact Classification
Air Quality						
	Changes in air quality due to emissions of TSP, standard pollutants, radioactive dust and radon	2 and 1 - Sec 5.18	Increase in radioactive dust and radon levels due to mining and milling activities and ore, mineralized waste and tailings management activities	Minor to Negligible	Monitoring results indicate minor elevation of radon and dust levels which were restricted to the project area, primarily the TMA	Negligible (Adverse but not significant)
		2 and 1 - Sec 5.59	Increase in TSP, SO2 and NOx due to power generation products, use of sulphuric acid and vehicular activity during operations	Minor to Negligible	Atmospheric contaminants maintained below regulatory standards; no effect from SO$_2$ and NO$_X$ emissions observed; sulphuric acid not produced on site	Negligible (Adverse but not significant)
		2	Incremental dust, radioactive dust and radon after decommissioning	Negligible	Monitoring results indicate minor elevation of radon and dust levels which were restricted to the project area, primarily the TMA	Negligible (Adverse but not significant)
Vegetation						
	Construction activities	2	Disturbance of existing communities	Minor	Land disturbance limited to 418 ha; site reclamation progressive	Minor (Adverse but not significant)
		2 and 1 - Sec 5.57 & 5.58	Loss of rare or endangered communities	Minor	Primary locations near Germaine Camp and the Dolomites have remained undisturbed	Negligible (No adverse effects)
	Exposure to radionuclides	2 and 1 - Sec 5.55	Uptake of radionuclides by vegetation, and transfer to man via direct consumption and through the food chain	Minor	Vegetative monitoring indicated some elevation of radionuclides in near-field exposure areas; collective dose to workers and the public well within accepted standards	Negligible (No adverse effects)
	Erosion and flooding	2	Local loss of vegetation	Minor	Erosion and flooding controlled through infrastructure construction and maintenance	Negligible (No adverse effects)
Wildlife						
	Construction and operation activities	2 and 1 - Sec 5.69	Disturbance of existing communities	Minor	Monitoring results indicate no observable effect on wildlife diversity; minimal land disturbance; notable increases in black bear, ravens and waterfowl (Canada Geese, Mallards); trapping has continued during operations	Negligible (Adverse but not significant)
			Loss or alteration of habitat	Minor		
			Displacement of wildlife	Minor		
			Local reduction in numbers	Minor		
	Exploitation of wildlife	2	Regulated and unregulated harvest	Minor	Some additional harvest related increased accessibility to area and establishment of an outfitting operation at Carswell Lake	Negligible (Adverse but not significant)
	Exposure to radionuclides	2	Uptake of radionuclides by wildlife and transfer to man	Minor	Worker and Public dose well within accepted standards	Negligible (No adverse effects)
Surface Water Quality						
	Changes to water quality in Snake Lake	1 - Sec 5.42	Increases in gypsum and dissolved solids	Minor	Longterm monitoring has shown increases in TDS, SO$_4$ and Cl. Elevated radium-226 concentrations were detected and in 1998-2000 due to the inadvertent temporary use of a contaminated pipeline for freshwater diversion. Rectified	Minor (Adverse but not significant)
	Changes to water quality in Island Creek watershed	2	Higher flows of mine water containing elevated TDS and chloride to Tailings Management Area may lead to increased contaminant levels downstream of the treated effluent discharge	Moderate	Treated effluent discharge to Snake Creek - Island Lake has been maintained within regulatory limits but has resulted in elevated levels of Mo, U, TDS, SO$_4$ and Cl in Island Lake. Effective contaminant removal in the fen at the outflow of Island Lake minimized changes in water quality downstream of Island Lake	Moderate (Adverse but not significant)
		3 - Sec 2.4 & 3.5	Modelling predicts elevations of Mo, U, TDS, SO4 and Cl in Island Lake water	Moderate		
	Changes to water quality of Sandy Lake	2	Increase in contaminant levels due to combined input from the Island Creek system and the Cluff Lake system during operating phase and immediate post-operating phase	Minor	Slight increases in TDS, SO$_4$ and Cl observed	Negligible (Adverse but not significant)
		3 - Sec 2.4 & 3.5	Modelling predicts elevations of U, TDS, SO4 and Cl in Sandy Lake water	Minor		
	Placement of special waste in Claude pit will result in changes to water quality of Claude Lake	3 - Sec 3.5 & 3.39	Modelling predicts elevations of As, Ni, and U in Claude Lake water	Moderate	Claude pit maintained in a partially dewatered state throughout operations; hydrodynamic containment maintained	Minor (No adverse effects)

Table 6.12

Comparison of Environmental Assessment Predicted Impacts and Realized Operational Impacts

Issue	Description	Reference*	Predicted Potential Operational Impact	Predicted Impact Classification	Observed Impact During Operations	Actual Impact Classification
	Changes to water quality of Peter River	2	Inflow of seepage containing dissolved contaminants leached from existing waste rock piles	Negligible	Peter River at background levels with exception of a minor increase in SO_4; groundwater piezometers show no indication of contaminant plume beyond the toe of the waste rock piles; pit dewatering has prevented movement	Minor (Adverse but not significant)
	Changes to water quality of Cluff Lake	2	Siltation effects due to construction of berm	Not Classified	Berm construction not required with adoption of alternative mine development plan, DJ Pods construction with overburden in Cluff Lake limited to a small near shore area	No Impact (No adverse effects)
		2	Leaching of contaminants from the berm during operating phase	Moderate		
		2	Leaching of contaminants from the berm and special waste either in a till lined cell in the berm or a till covered deposit in the pit during post-operating phase	Minor		
		2	Changes to downstream water quality due to changes to water quality in Cluff Lake	Minor to Negligible		
		3 - Sec 3.5	Modelling predicts elevations of U in Cluff Lake water	Moderate	Monitoring has indicated that Cluff Lake U has remained near background levels (1 to 2 ug/L)	Minor (No adverse effects)
Aquatic Ecology						
	construction activities	2	Siltation effects on benthos in area of berm	Minor	The Cluff Lake shoreline was altered to enable testing at the DJ Pods; the small area of habitat lost was the subject of a Fisheries and Oceans habitat compensation agreement	Minor (Adverse but not significant)
		2	Permanent loss of habitat and loss of benthic invertebrates with accompanying loss of food resource for fish	Major		
	Access to creeks flowing into north end of Cluff Lake	2	Berm will alter access routes to spawning and nursery areas	Major		No Impact (No adverse effects)
	Exploitation of fish resources	2	Removal of older, larger fish; possible reduction in recruitment	Minor	Fishing by employees during the operational phase has been largely limited to Sandy and Carswell Lakes; catch and release techniques have been generally adopted by the workforce; removal has been limited	No Impact (No adverse effects)
	Water quality changes in Peter River from waste rock seepage	2	Sublethal toxicity or bioaccumulation	Negligible	Peter River at background levels with exception of a minor increase in SO_4; groundwater piezometers show no indication of contaminant plume beyond the toe of the waste rock piles; pit dewatering has prevented movement	Negligible (Adverse but not significant)
	Water quality changes in Cluff Lake and downstream	2	Sublethal toxicity or bioaccumulation; changes in species composition	Minor to Negligible	No observable changes in water quality during operations; mine drainage largely contained by pumping to the mill for treatment and release through the Island Creek watershed	Negligible (No adverse effects)
	Discharge of treated effluent from TMA	2 and 1 - Sec 5.62 & 5.63	Continued increase in major ions and some trace elements; accompanying change in species composition; bioaccumulation	Moderate	Discharge of treated effluent to Island Lake has resulted in changes in zooplankton, benthic and fish community composition	Moderate (Adverse but not significant)
Environmental Pathways						
	Release of radioactivity	2	Incremental radiation exposure of general public arising from releases of radioactivity to the air and water both during operation and after decommissioning	Minor	Monitoring results indicate minor elevation of radon and LLRD levels which were restricted to the project area, primarily the TMA; primary gamma sources include the mill and the TMA. Collective dose to workers and the public well within accepted standards	Negligible (Adverse but not significant)
*** Reference**						
1	**Final Report - Cluff Lake Board of Inquiry - May 1978**					
2	**Environmental Impact Statement - Dominique-Janine Extension - Main Document - Chapter 4 - Impact Prediction and Mitigation - February 1992**					
3	**Environmental Impact Statement - Dominique-Janine Extension - Addendum - January 1993**					
4	**Comprehensive Study for Decommissioning - December 2000 and all supplementary submissions up to November 2002**					

Table 9.1
Summary of Project Environmental Effects and Assessment of Significance

Environmental Component	Area or Category	Environmental Effects? Yes or No?	Basis for Decision	Are they Adverse? Yes or No?	Basis for Decision	Are they significant? Yes or No?	Basis for Decision				
							Below Accepted Objectives	Magnitude	Geographic Extent	Duration	Degree of Reversibility
Air Quality	Mill and TMA	No	Contaminated materials from the mill demolition will be buried; revegetated soil covers on the TMA and waste rock piles will prevent dust								
Surface Hydrology	Island Watershed	No	Upon cessation of effluent discharge, flows will revert to natural rates								
	Cluff Watershed	No	Flow rates will return to pre-mining conditions								
Groundwater	Island Watershed	Yes	TMA seepage will introduce contaminants into the groundwater flow for several years in the future	Yes	Negative effect on groundwater quality in relation to operational conditions	No	Will not cause an elevation of contaminant levels in surface water bodies above SSWQO or decommissioning objectives		Isolated to a very small area in the direct locality of the source		
	Cluff Watershed	Yes	Waste rock seepage will introduce contaminants into the groundwater flow for several years in the future	Yes	Negative effect on groundwater quality in relation to operational conditions	No	Will not cause an elevation of contaminant levels in surface water bodies above SSWQO or decommissioning objectives		Isolated to a very small area in the direct locality of the source		
Surface Water Quality	Snake Lake	Yes	Predicted water quality will be further impacted by seepage from TMA	No	Negative effect in water quality in relation to operational conditions.	No	predicted water quality is below accepted guidelines (SSWQO) for the protection of drinking water or aquatic life	Negligible. Ecological effects unlikely to be detectable	minimal: Snake Lake is 20 ha and averages about 1 m in depth		
	Island Lake	No	Water quality will improve from existing conditions once effluent discharge ceases.								
	Cluff Lake Watershed	Yes	Predicted water quality is elevated in comparison to existing conditions	Yes	predicted water quality is elevated in comparison to that experienced during the operational period	No	predicted water quality for Claude Lake, Peter River and Cluff Lake are all below SSWQO or accepted decommissioning objectives	Negligible to minor. Based on hardness amelioration of U toxicity.	Limited: Cluff Lake is 341 ha with maximum and mean depths of 52 and 20 m, respectively. No expectation that contaminants will be detectable beyond Cluff Lake.	Peak concentrations are predicted to occur within 150 years.	
	D Pit	No	Stable chemocline will no further deterioration in predicted water quality								
	DJX Pit	No	Water treatment will ensure water quality improves from existing conditions.								
Sediment Quality	Snake Lake	Yes	Actual and predicted sediment quality will be further impacted post-decommissioning	Yes	predicted sediment quality is elevated for some contaminants in comparison to that experienced during the operational period	No	median values fall below sediment benchmark values. Only 95th percentile for molybdenum and nickel exceed lower benchmarks or regional background, but do not exceed upper benchmark boundaries.	Effects predicted to be minor based on field evidence from U mining areas with greater sediment concentrations.	limited to a very small area of minimal ecological significance in the region (20 ha and 1.8 m average depth)		reversible through passive, natural recovery; recovery further accelerated as it is a very shallow lake with relatively high rates of sedimentation and organic deposition.
	Island Lake	No	Sediment quality will improve as a result of cessation of effluent discharges								
	Cluff Lake	Yes	Predicted contaminant concentrations in sediment are expected to increase post-decommissioning	Yes	predicted sediment quality is elevated for some contaminants in comparison to that experienced during the operational period	No	median values fall below sediment benchmark values. Only 95th percentile for Ni and U exceed lower benchmarks and/or regional background but are well below upper threshold boundaries calculated for uranium bearing regions	Effects predicted to be minor based on field evidence from U mining areas with greater sediment concentrations	Limited: Cluff Lake is 341 ha with maximum and mean depths of 52 and 20 m, respectively		reversible through passive, natural recovery
Aquatic Organisms	Island Lake	No	Some impact to fish population as a result of cessation of discharge of oxygen rich effluent. Fish population expected to stabilize to pre-mining levels. Aquatic organisms expected to recover as result of cessation in effluent discharge								
	Cluff Lake	Yes	Potential for effects due to copper and uranium	Yes	predicted water and sediment quality is elevated in comparison to that experienced during the operational period	No	benchmark values for uranium and copper are conservatively low	minor: natural lakes in the area exceed benchmark values for copper; uranium under review by a joint industry/government working group			

Table 9.1
Summary of Project Environmental Effects and Assessment of Significance

Environmental Component	Area or Category	Environmental Effects? Yes or No?	Basis for Decision	Are they Adverse? Yes or No?	Basis for Decision	Are they significant? Yes or No?	Basis for Decision			
							Below Accepted Objectives	Magnitude	Geographic Extent	Duration	Degree of Reversibility
Terrestrial Organisms	Island Lake	No	Potential for effects due to molybdenum, selenium and uranium as a result of operational impacts. No additional impacts resulting from decommissioning.								
	Cluff Lake	Yes	Changes in water and sediment quality predicted	Yes	Increased potential for contaminant uptake.	No	screening indices for all metals and radionuclides below 1				
	Incremental effects of drinking flooded pit water	Yes	Flooded pit waters will become more readily accessible to terrestria organisms post-decommissioning	Yes	Increased potential for contaminant uptake.	No	screening indices for all metals and radionuclides still below 1				
Human Health	Cluff and Sandy Lakes	Yes	Changes in water and sediment quality predicted	Yes	Increased potential for contaminant uptake.	No	screening indices for all metals and radionuclides below 1				
	Incremental effects of drinking Snake, Island or flooded pit water	Yes	Flooded pit waters will become more readily accessible to humans post-decommissioning	Yes	Ingestion of contaminated waters presents increased health risk	No	screening indices for all metals and radionuclides still below 1				
Land Reclamation	Disturbed lands	No	Reclamation will improve on current site conditions								
	Ambient radiologocial levels	No	Decommissioning activities will result in significant reductions in existing ambient radiological levels								
Socio Economics	Employment	No	Negative impacts on employment are from cessation of operations, not decommissioning								
	Land use	No	Return to traditional land use.								

Table 9.1
Summary of Project Environmental Effects and Assessment of Significance

Ecological Context
No impact on the ecological communities in downstream surface water receptors
No impact on the ecological communities in downstream surface water receptors
Ecological effects likely to be undetectable
Effects should be limited to minor shifts in pelagic community composition. Based on hardness amelioration of U toxicity.
effects are limited to common species primarily benthic invertebrates. Result in shift in community composition with no predicted effect on total abundance. No effect on regional populations, nor endangered or threatened species.
effects are limited to common species primarily benthic invertebrates. May result in minor shift in community composition with no predicted effect on total abundance or benthic foraging fish population. No effect on regional populations, nor endangered or threatened species.

Table 9.1
Summary of Project Environmental Effects and Assessment of Significance

Ecological Context

Table 9.2: Volume of Treated Water Discharged To Snake Creek (m^3)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Year													
2002	0	0	88,629	101,772	91,022	89,267	65,327	13,968	55,931	112,985	0	0	618,901
2001	37,725	33,986	80,196	87,469	105,576	43,132	59,945	119,986	145,868	51,135	0	0	765,018
2000	71,483	72,086	126,010	77,674	81,547	115,813	133,271	122,780	167	80,086	60,209	32,271	973,397
1999	87,884	92,895	133,214	143,680	143,493	93,801	87,110	96,732	71,700	61,769	60,700	74,248	1,147,226
1998	92,129	95,526	112,284	192,088	175,929	134,752	177,382	151,110	64,029	102,689	98,516	84,954	1,481,388
1997	83,607	126,706	78,077	82,583	164,493	138,034	172,955	177,087	195,816	182,190	103,455	91,775	1,596,778
1996	31,158	60,520	67,338	105,161	132,324	136,644	137,514	116,380	106,740	149,544	56,215	55,807	1,155,345
1995	42,668	52,117	97,051	71,894	110,921	133,903	34,203	126,205	181,707	66,035	77,406	69,803	1,063,913
1994	67,167	61,385	65,156	99,664	123,566	162,398	86,553	88,576	41,914	61,664	44,638	58,967	961,648
1993	2,167	0	67,179	108,220	104,314	108,241	42,549	30,730	97,625	60,155	61,423	61,523	744,126
1992	67,303	54,217	57,947	97,756	112,721	130,953	139,521	144,928	103,090	58,988	61,629	63,027	1,092,080
1991	85,610	84,147	43,393	137,095	151,999	75,936	0	84,342	23,146	98,861	67,432	67,640	919,601
1990	38,879	33,138	35,761	52,186	126,106	132,319	0	0	0	40,371	78,961	93,546	631,267
1989	76,328	62,151	56,839	89,348	112,396	111,128	136,277	100,491	136,820	103,996	50,280	40,272	1,076,326
1988	43,976	47,526	77,100	92,387	92,530	118,319	138,323	118,144	63,517	42,423	71,641	76,214	982,100
1987	88,715	74,124	86,301	86,576	94,594	103,325	123,680	119,302	113,472	119,784	92,290	80,916	1,183,079
1986	109,895	50,227	47,956	117,942	121,720	119,733	115,327	58,446	123,090	37,395	107,673	114,735	1,124,139
1985	125,908	115,650	123,924	117,714	122,000	95,657	127,192	130,858	119,832	127,601	130,316	134,486	1,471,138
1984	94,837	40,414	72,450	97,894	50,069	116,654	124,662	117,779	116,947	123,905	117,549	118,168	1,191,328
1983	93,402	105,800	121,602	115,563	177,051	118,064	122,209	107,890	57,438	116,749	85,558	118,859	1,340,185
1982	0	0	26,275	97,332	124,891	110,669	106,371	118,690	108,280	88,888	109,893	7,472	898,761
Average	63,850	60,125	79,271	103,428	119,965	113,750	101,446	102,115	91,768	89,867	73,133	68,794	1,067,512

Average Flow Rate:	0.0339 m3/s	
Average Natural Flow at Node 4:	0.0673 m3/s	(Node 4 is Island Lake Outlet; see page A-34 of Volume 1, Appendix A)
Total Average Flow:	0.1012 m3/s	

% Flow which is Treated Effluent: 33.47%

Table 9.3: Estimated Treated Effluent Flows – 2003 through 2009

Year	DJ Pit	DP U/G	DJ U/G	Claude Pit	Cluff Lake	TMA Consolidation	Total
1999	53,316	102,442	71,901	312,162	607,405	0	1,147,226
2000	82,815	0	51,230	277,112	562,240	0	973,397
2001	133,629	0	0	0	631,389	0	765,018
2002	81,101	0	-68,189	0	588,211	17,778	618,901
2003	0	0	0	400,000	0	30,000	430,000
2004	0	0	0	340,000	0	10,000	350,000
2005	0	0	0	0	0	5,000	5,000
2006	0	0	0	0	0	3,000	3,000
2007	0	0	0	0	0	1,000	1,000
2008	0	0	0	0	0	1,000	1,000
2009	0	0	0	0	0	0	0

Assumptions:

- Total water to pump from Claude pit is 740,000 m3 at a rate of 70 m3/hr; will start May 2003 and continue to completion

Table 9.7: Screening Index Values for Non-Radionuclide Contaminants to Aquatic Species – Island Lake

	Simulated Background		Island Lake Outlet 2000		Island Lake Outlet 2009		Island Lake Outlet 2050	
Ammonia	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-	-	-	-	-
Primary Producers	< 0.001	0.001	0.016	0.031	0.011	0.017	0.003	0.005
Benthic Invertebrates	0.001	0.001	0.026	0.051	0.018	0.028	0.004	0.008
Zooplankton	< 0.001	0.001	0.019	0.038	0.013	0.021	0.003	0.006
Northern Pike	0.001	0.002	0.044	0.088	0.030	0.047	0.007	0.013
White Sucker	< 0.001	0.001	0.024	0.047	0.016	0.025	0.004	0.007

	Simulated Background		Island Lake Outlet 2000		Island Lake Outlet 2009		Island Lake Outlet 2050	
Arsenic	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	< 0.001	0.001	0.003	0.001	0.002	< 0.001	0.0009
Primary Producers	0.005	0.020	0.052	0.145	0.042	0.092	0.021	0.045
Benthic Invertebrates	< 0.001	0.001	0.003	0.009	0.003	0.006	0.001	0.003
Zooplankton	< 0.001	0.001	0.002	0.005	0.001	0.003	0.001	0.001
Northern Pike	< 0.001	0.002	0.005	0.013	0.004	0.008	0.002	0.004
White Sucker	0.001	0.003	0.007	0.018	0.005	0.012	0.003	0.006

	Simulated Background		Island Lake Outlet		Island Lake Outlet 2009		Island Lake Outlet 2050	
Cobalt	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-	-	-	-	-
Primary Producers	0.004	0.004	0.003	0.004	0.003	0.004	0.003	0.004
Benthic Invertebrates	0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Zooplankton	0.209	0.226	0.160	0.207	0.158	0.207	0.150	0.207
Northern Pike	0.004	0.005	0.003	0.004	0.003	0.004	0.003	0.004
White Sucker	0.003	0.003	0.002	0.003	0.002	0.003	0.002	0.003

Table 9.7: Screening Index Values for Non-Radionuclide Contaminants to Aquatic Species – Island Lake (Cont'd)

	Simulated Background		Island Lake Outlet 2000		Island Lake Outlet 2009		Island Lake Outlet 2050	
Copper	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.011	0.064	0.024	0.062	0.020	0.060	0.012	0.0558
Primary Producers	0.457	**2.550**	0.973	**2.473**	0.797	**2.387**	0.473	**2.233**
Benthic Invertebrates	0.004	0.024	0.009	0.023	0.007	0.022	0.004	0.021
Zooplankton	0.009	0.051	0.019	0.049	0.016	0.048	0.009	0.045
Northern Pike	0.343	**1.913**	0.730	**1.855**	0.598	**1.790**	0.355	**1.675**
White Sucker	0.010	0.055	0.021	0.053	0.017	0.051	0.010	0.048

	Simulated Background		Island Lake Outlet		Island Lake Outlet 2009		Island Lake Outlet 2050	
Lead	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Primary Producers	< 0.001	0.018	0.011	0.021	0.008	0.020	0.002	0.016
Benthic Invertebrates	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Zooplankton	0.025	0.733	0.449	0.883	0.328	0.830	0.103	0.675
Northern Pike	0.013	0.400	0.245	0.482	0.179	0.453	0.056	0.368
White Sucker	< 0.001	0.013	0.008	0.016	0.006	0.015	0.002	0.012

	Simulated Background		Island Lake Outlet 2000		Island Lake Outlet 2009		Island Lake Outlet 2050	
Molybdenum	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-	-	-	-	-
Primary Producers	< 0.001	0.002	0.160	0.234	0.071	0.100	0.004	0.021
Benthic Invertebrates	-	-	-	-	-	-	-	-
Zooplankton	0.007	0.028	**2.225**	**3.250**	0.986	**1.383**	0.052	0.294
Northern Pike	0.009	0.034	**2.762**	**4.034**	**1.224**	**1.717**	0.064	0.366
White Sucker	< 0.001	< 0.001	0.033	0.049	0.015	0.021	0.001	0.004

Table 9.7: Screening Index Values for Non-Radionuclide Contaminants to Aquatic Species – Island Lake (Cont'd)

	Simulated Background		Island Lake Outlet		Island Lake Outlet 2009		Island Lake Outlet 2050	
Nickel	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.007	0.027	0.035	0.053	0.026	0.042	0.014	0.030
Primary Producers	0.238	0.988	**1.266**	**1.910**	0.928	**1.496**	0.498	**1.072**
Benthic Invertebrates	0.001	0.006	0.007	0.011	0.005	0.009	0.003	0.006
Zooplankton	0.026	0.110	0.141	0.212	0.103	0.166	0.055	0.119
Northern Pike	0.019	0.080	0.102	0.154	0.075	0.121	0.040	0.086
White Sucker	0.001	0.005	0.006	0.009	0.004	0.007	0.002	0.005

	Simulated Background		Island Lake Outlet 2000		Island Lake Outlet 2009		Island Lake Outlet 2050	
Selenium	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	0.001	0.005	0.011	0.004	0.007	0.002	0.003
Primary Producers	0.001	0.007	0.035	0.075	0.028	0.047	0.011	0.017
Benthic Invertebrates	0.001	0.004	0.019	0.042	0.016	0.026	0.006	0.009
Zooplankton	0.004	0.022	0.117	0.250	0.095	0.155	0.036	0.056
Northern Pike	0.003	0.016	0.088	0.187	0.071	0.116	0.027	0.042
White Sucker	< 0.001	< 0.001	0.001	0.003	0.001	0.002	< 0.001	0.001

	Simulated Background		Island Lake Outlet		Island Lake Outlet 2009		Island Lake Outlet 2050	
Uranium	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-	-	-	-	-
Primary Producers	0.046	0.078	**16.273**	**28.727**	**12.000**	**18.091**	**3.355**	**6.027**
Benthic Invertebrates	< 0.001	< 0.001	0.053	0.094	0.039	0.059	0.011	0.020
Zooplankton	0.046	0.078	**16.273**	**28.727**	**12.000**	**18.091**	**3.355**	**6.027**
Northern Pike	0.001	0.001	0.289	0.510	0.213	0.321	0.060	0.107
White Sucker	0.003	0.005	**1.119**	**1.975**	0.825	**1.244**	0.231	0.414

Table 9.7: Screening Index Values for Non-Radionuclide Contaminants to Aquatic Species – Island Lake (Con't)

	Simulated Background		Island Lake Outlet 2000		Island Lake Outlet 2009		Island Lake Outlet 2050	
Zinc	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	< 0.001	0.001	0.002	0.001	0.002	< 0.001	0.001
Primary Producers	0.076	0.423	0.211	0.470	0.169	0.447	0.082	0.350
Benthic Invertebrates	0.005	0.028	0.014	0.031	0.011	0.030	0.005	0.023
Zooplankton	0.057	0.318	0.158	0.353	0.127	0.335	0.062	0.263
Northern Pike	0.048	0.265	0.132	0.294	0.106	0.279	0.051	0.219
White Sucker	0.003	0.016	0.008	0.018	0.007	0.017	0.003	0.013

Table 9.8: Screening Index Values for Non-Radionuclide Contaminants to Aquatic Species – Cluff Lake

	Background		Cluff Lake Outlet	
Ammonia	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	< 0.001	0.001	< 0.001	0.001
Benthic Invertebrates	0.001	0.001	0.001	0.001
Zooplankton	< 0.001	0.001	< 0.001	0.001
Northern Pike	0.001	0.002	0.001	0.002
Lake Whitefish	0.002	0.004	0.002	0.004
White Sucker	0.001	0.001	0.001	0.001

	Background		Cluff Lake Outlet	
Arsenic	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	< 0.001	0.002	0.002
Primary Producers	0.005	0.022	0.088	0.118
Benthic Invertebrates	< 0.001	0.001	0.005	0.007
Zooplankton	< 0.001	0.001	0.003	0.004
Northern Pike	< 0.001	0.002	0.008	0.011
Lake Whitefish	< 0.001	< 0.001	0.001	0.001
White Sucker	0.001	0.003	0.011	0.015

	Background		Cluff Lake Outlet	
Cobalt	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	0.004	0.004	0.010	0.012
Benthic Invertebrates	0.001	0.001	0.001	0.002
Zooplankton	0.232	0.246	0.545	0.638
Northern Pike	0.005	0.005	0.011	0.013
Lake Whitefish	0.001	0.001	0.003	0.003
White Sucker	0.003	0.003	0.007	0.008

	Background		Cluff Lake Outlet	
Copper	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.013	0.070	0.015	0.071
Primary Producers	0.527	**2.783**	0.603	**2.853**
Benthic Invertebrates	0.005	0.026	0.006	0.027
Zooplankton	0.011	0.056	0.012	0.057
Northern Pike	0.395	**2.088**	0.453	**2.140**
Lake Whitefish	0.198	**1.044**	0.226	**1.070**
White Sucker	0.011	0.060	0.013	0.061

	Background		Cluff Lake Outlet	
Lead	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	< 0.001	< 0.001	< 0.001
Primary Producers	< 0.001	0.021	0.001	0.021
Benthic Invertebrates	< 0.001	< 0.001	< 0.001	< 0.001
Zooplankton	0.027	0.858	0.055	0.875
Northern Pike	0.015	0.468	0.030	0.477
Lake Whitefish	< 0.001	0.006	< 0.001	0.006
White Sucker	< 0.001	0.016	0.001	0.016

	Background		Cluff Lake Outlet	
Molybdenum	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	< 0.001	0.002	0.001	0.003
Benthic Invertebrates	-	-	-	-
Zooplankton	0.007	0.029	0.015	0.037
Northern Pike	0.009	0.036	0.019	0.046
Lake Whitefish	< 0.001	< 0.001	< 0.001	< 0.001
White Sucker	< 0.001	< 0.001	< 0.001	0.001

Table 9.8: Screening Index Values for Non-Radionuclide Contaminants to Aquatic Species – Cluff Lake (Con't)

	Background		Cluff Lake Outlet	
Nickel	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.007	0.032	0.027	0.052
Primary Producers	0.260	**1.146**	0.962	**1.878**
Benthic Invertebrates	0.002	0.007	0.006	0.011
Zooplankton	0.029	0.127	0.107	0.209
Northern Pike	0.021	0.092	0.078	0.151
Lake Whitefish	0.004	0.020	0.017	0.032
White Sucker	0.001	0.006	0.005	0.009

	Background		Cluff Lake Outlet	
Selenium	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.000	0.001	0.000	0.001
Primary Producers	0.001	0.008	0.001	0.008
Benthic Invertebrates	0.001	0.004	0.001	0.004
Zooplankton	0.005	0.026	0.005	0.026
Northern Pike	0.004	0.019	0.004	0.019
Lake Whitefish	0.001	0.003	0.001	0.003
White Sucker	5.07E-05	2.67E-04	5.07E-05	2.67E-04

	Background		Cluff Lake Outlet	
Uranium	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	0.051	0.087	**1.809**	**2.209**
Benthic Invertebrates	< 0.001	< 0.001	0.006	0.007
Zooplankton	0.051	0.087	**1.809**	**2.209**
Northern Pike	0.001	0.002	0.032	0.039
Lake Whitefish	0.004	0.006	0.124	0.152
White Sucker	0.004	0.006	0.124	0.152

	Background		Cluff Lake Outlet	
Zinc	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	0.002	< 0.001	0.002
Primary Producers	0.088	0.490	0.127	0.533
Benthic Invertebrates	0.006	0.033	0.008	0.036
Zooplankton	0.066	0.368	0.095	0.400
Northern Pike	0.055	0.306	0.079	0.333
Lake Whitefish	0.028	0.155	0.040	0.168
White Sucker	0.003	0.019	0.005	0.021

Note: Predicted peak year water concentrations were used in the calculation of the screening index values.

Table 9.9: Screening Index Values for Non-Radioactive Contaminants to Aquatic Species – Sandy Lake

	Background		Sandy Lake Outlet	
Ammonia	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	< 0.001	< 0.001	< 0.001	< 0.001
Benthic Invertebrates	0.001	0.001	0.001	0.001
Zooplankton	< 0.001	0.001	< 0.001	0.001
Northern Pike	0.001	0.001	0.001	0.001
Lake Whitefish	0.002	0.003	0.002	0.003
White Sucker	0.001	0.001	0.001	0.001

	Background		Sandy Lake Outlet	
Arsenic	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	0.001	0.001	0.001
Primary Producers	0.028	0.035	0.032	0.038
Benthic Invertebrates	< 0.001	0.002	0.002	0.002
Zooplankton	< 0.001	0.001	0.001	0.001
Northern Pike	0.003	0.003	0.003	0.003
Lake Whitefish	< 0.001	< 0.001	< 0.001	< 0.001
White Sucker	0.004	0.004	0.004	0.005

	Background		Sandy Lake Outlet	
Cobalt	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	0.001	0.002	0.001	0.002
Benthic Invertebrates	< 0.001	< 0.001	< 0.001	< 0.001
Zooplankton	0.055	0.086	0.069	0.114
Northern Pike	0.001	0.002	0.001	0.002
Lake Whitefish	< 0.001	< 0.001	< 0.001	0.001
White Sucker	0.001	0.001	0.001	0.001

	Background		Sandy Lake Outlet	
Copper	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.020	0.036	0.020	0.036
Primary Producers	0.790	**1.433**	0.790	**1.437**
Benthic Invertebrates	0.007	0.013	0.007	0.013
Zooplankton	0.016	0.029	0.016	0.029
Northern Pike	0.593	**1.075**	0.593	**1.078**
Lake Whitefish	0.296	0.538	0.296	0.539
White Sucker	0.017	0.031	0.017	0.031

	Background		Sandy Lake Outlet	
Lead	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	< 0.001	< 0.001	< 0.001	< 0.001
Primary Producers	< 0.001	0.010	0.004	0.010
Benthic Invertebrates	< 0.001	< 0.001	< 0.001	< 0.001
Zooplankton	0.181	0.405	0.182	0.410
Northern Pike	0.099	0.221	0.099	0.224
Lake Whitefish	< 0.001	0.003	< 0.001	0.003
White Sucker	0.003	0.007	0.003	0.007

	Background		Sandy Lake Outlet	
Molybdenum	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	< 0.001	0.001	0.001	0.002
Benthic Invertebrates	-	-	-	-
Zooplankton	0.012	0.019	0.014	0.021
Northern Pike	0.015	0.023	0.017	0.026
Lake Whitefish	< 0.001	< 0.001	< 0.001	< 0.001
White Sucker	< 0.001	< 0.001	< 0.001	< 0.001

Table 9.9: Screening Index Values for Non-Radioactive Contaminants to Aquatic Species – Sandy Lake (Con’t)

	Background		Sandy Lake Outlet	
Nickel	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.007	0.015	0.008	0.015
Primary Producers	0.254	0.526	0.288	0.534
Benthic Invertebrates	0.001	0.003	0.002	0.003
Zooplankton	0.028	0.058	0.032	0.059
Northern Pike	0.020	0.042	0.023	0.043
Lake Whitefish	0.004	0.009	0.005	0.009
White Sucker	0.001	0.003	0.001	0.003

	Background		Sandy Lake Outlet	
Selenium	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.002	0.002	0.002	0.002
Primary Producers	0.013	0.016	0.013	0.016
Benthic Invertebrates	0.007	0.009	0.007	0.009
Zooplankton	0.044	0.055	0.044	0.055
Northern Pike	0.033	0.041	0.033	0.041
Lake Whitefish	0.006	0.007	0.006	0.007
White Sucker	< 0.001	< 0.001	< 0.001	< 0.001

	Background		Sandy Lake Outlet	
Uranium	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	-	-	-	-
Primary Producers	0.072	0.090	0.176	0.229
Benthic Invertebrates	< 0.001	< 0.001	0.001	0.001
Zooplankton	0.072	0.090	0.176	0.229
Northern Pike	0.001	0.002	0.003	0.004
Lake Whitefish	0.005	0.006	0.012	0.016
White Sucker	0.005	0.006	0.012	0.016

	Background		Sandy Lake Outlet	
Zinc	50th Percentile	95th Percentile	50th Percentile	95th Percentile
Pond-lily	0.001	0.001	0.001	0.001
Primary Producers	0.185	0.290	0.186	0.291
Benthic Invertebrates	0.012	0.019	0.012	0.019
Zooplankton	0.139	0.218	0.140	0.219
Northern Pike	0.116	0.181	0.116	0.182
Lake Whitefish	0.059	0.092	0.059	0.092
White Sucker	0.007	0.011	0.007	0.011

Note: Predicted peak year water concentrations were used in the calculation of the screening index values.

Table 9.10: Screening Index Values for Non-Radioactive Contaminants for Terrestrial Ecological Receptors – Island Lake

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Arsenic	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	0.015	0.029	0.015	0.030	0.014	0.029	0.012	0.026	0.010	0.025
Eagle	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001
Mallard	0.002	0.009	0.015	0.035	0.009	0.020	0.005	0.011	0.005	0.013
Scaup	0.001	0.007	0.010	0.022	0.006	0.015	0.003	0.008	0.003	0.008
Merganser	< 0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002
Bear	0.049	0.121	0.056	0.125	0.056	0.127	0.046	0.125	0.039	0.125
Ptarmigan	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002
Caribou	0.029	0.064	0.029	0.064	0.028	0.063	0.024	0.062	0.021	0.061
Moose	0.010	0.057	0.018	0.066	0.014	0.062	0.010	0.051	0.009	0.045
Hare	0.076	0.203	0.076	0.203	0.075	0.203	0.065	0.200	0.054	0.197
Muskrat	0.004	0.021	0.011	0.035	0.011	0.038	0.013	0.043	0.014	0.044
Otter	0.010	0.057	0.038	0.114	0.045	0.124	0.050	0.135	0.061	0.154

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Cobalt	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Eagle	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.009	0.041	0.008	0.031	0.008	0.034	0.007	0.036	0.007	0.036
Scaup	0.005	0.032	0.004	0.024	0.004	0.027	0.004	0.031	0.003	0.030
Merganser	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Bear	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Moose	0.001	0.005	0.001	0.005	0.001	0.005	0.001	0.004	0.001	0.004
Hare	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Muskrat	0.014	0.078	0.011	0.073	0.011	0.072	0.012	0.065	0.012	0.065
Otter	0.002	0.006	0.002	0.004	0.002	0.005	0.002	0.004	0.002	0.004

Table 9.10: Screening Index Values for Non-Radioactive Contaminants for Terrestrial Ecological Receptors – Island Lake (Cont'd)

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Copper	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	0.002	0.006	0.002	0.007	0.002	0.006	0.001	0.005	0.001	0.004
Eagle	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.002	0.017	0.005	0.017	0.003	0.016	0.003	0.014	0.002	0.013
Scaup	0.002	0.011	0.003	0.011	0.002	0.010	0.002	0.010	0.002	0.010
Merganser	< 0.001	0.003	0.001	0.003	0.001	0.003	< 0.001	0.003	< 0.001	0.003
Bear	0.019	0.076	0.020	0.076	0.018	0.074	0.010	0.045	0.005	0.035
Ptarmigan	0.001	0.002	0.001	0.002	0.001	0.002	< 0.001	0.001	< 0.001	0.001
Caribou	0.002	0.006	0.002	0.006	0.002	0.005	0.002	0.004	0.001	0.004
Moose	0.005	0.016	0.006	0.019	0.005	0.016	0.004	0.014	0.003	0.013
Hare	0.024	0.131	0.024	0.131	0.019	0.110	0.011	0.088	0.006	0.059
Muskrat	0.020	0.241	0.051	0.260	0.037	0.239	0.025	0.221	0.022	0.194
Otter	0.006	0.029	0.010	0.030	0.008	0.029	0.006	0.025	0.005	0.024

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Lead	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	0.002	< 0.001	0.002	< 0.001	0.002	< 0.001	0.001	< 0.001	0.001
Eagle	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002
Mallard	0.002	0.092	0.024	0.146	0.004	0.038	0.002	0.029	0.001	0.027
Scaup	0.001	0.046	0.008	0.059	0.001	0.011	0.001	0.009	< 0.001	0.008
Merganser	< 0.001	0.004	0.001	0.007	0.001	0.006	< 0.001	0.005	< 0.001	0.004
Bear	< 0.001	< 0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002
Ptarmigan	0.003	0.012	0.003	0.012	0.003	0.012	0.003	0.012	0.003	0.012
Caribou	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001
Moose	0.001	0.004	0.001	0.004	0.001	0.004	0.001	0.003	0.001	0.003
Hare	0.001	0.003	0.001	0.003	0.001	0.003	0.001	0.003	0.001	0.003
Muskrat	< 0.001	0.017	0.008	0.021	0.005	0.019	0.002	0.016	0.001	0.015
Otter	< 0.001	0.002	0.001	0.006	0.001	0.005	0.001	0.004	0.001	0.005

Table 9.10: Screening Index Values for Non-Radioactive Contaminants for Terrestrial Ecological Receptors – Island Lake (Cont'd)

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Molybdenum	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	< 0.001	0.014	0.060	0.006	0.022	0.001	0.004	< 0.001	0.001
Eagle	< 0.001	< 0.001	0.001	0.013	< 0.001	0.006	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.005	0.056	**1.646**	**3.822**	0.577	**1.656**	0.056	0.322	0.038	0.113
Scaup	0.005	0.061	**1.679**	**3.789**	0.594	**1.648**	0.057	0.255	0.037	0.110
Merganser	< 0.001	0.001	0.022	0.206	0.007	0.099	0.001	0.014	< 0.001	0.005
Bear	0.001	0.014	0.191	**1.400**	0.074	0.639	0.008	0.088	0.005	0.037
Ptarmigan	< 0.001	< 0.001	0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	See text for discussion. Ruminants are sensitive to molybdenosis which is highly dependent on copper and sulphur bioavailability in forage, hence, does not fit well into a simple risk assessment methodology. This is discussed in greater detail in the text.									
Moose										
Hare	< 0.001	0.001	0.050	0.075	0.020	0.028	0.002	0.006	0.001	0.002
Muskrat	0.008	0.039	**1.612**	**4.344**	0.712	**1.741**	0.057	0.372	0.036	0.143
Otter	0.029	0.229	**7.790**	**22.339**	**2.797**	**10.237**	0.270	**1.445**	0.159	0.521

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Nickel	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Eagle	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.001	0.005	0.003	0.010	0.002	0.006	0.002	0.006	0.002	0.005
Scaup	< 0.001	0.002	0.001	0.003	0.001	0.002	0.001	0.002	0.001	0.002
Merganser	< 0.001	0.002	0.001	0.004	0.001	0.003	0.001	0.002	0.001	0.002
Bear	0.002	0.004	0.002	0.004	0.002	0.004	0.002	0.004	0.002	0.003
Ptarmigan	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	< 0.001
Caribou	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001
Moose	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Hare	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001
Muskrat	< 0.001	0.002	0.001	0.006	0.001	0.004	0.001	0.004	0.001	0.004
Otter	0.001	0.006	0.004	0.014	0.003	0.010	0.002	0.008	0.002	0.008

Table 9.10: Screening Index Values for Non-Radioactive Contaminants for Terrestrial Ecological Receptors – Island Lake (Cont'd)

	Background		**Year 2000**		**Year 2009 (Post-Decommissioning)**		**Year 2050 (Post-Decommissioning)**		**Year 2100 (Post-Decommissioning)**	
Selenium	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	0.006	0.013	0.115	0.008	0.072	0.003	0.034	0.001	0.016
Eagle	< 0.001	0.003	0.010	0.032	0.006	0.019	0.002	0.007	0.001	0.004
Mallard	0.019	0.134	0.420	**1.781**	0.230	**1.102**	0.105	0.375	0.050	0.206
Scaup	0.009	0.115	0.191	**1.840**	0.105	**1.007**	0.048	0.373	0.026	0.191
Merganser	0.005	0.041	0.139	0.526	0.077	0.301	0.035	0.115	0.016	0.068
Bear	0.017	0.070	0.139	0.420	0.080	0.257	0.042	0.119	0.024	0.081
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	< 0.001	0.001	0.002	0.004	0.001	0.003	0.001	0.001	< 0.001	0.001
Moose	0.002	0.015	0.048	0.128	0.030	0.078	0.014	0.036	0.007	0.021
Hare	< 0.001	< 0.001	0.001	0.002	0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001
Muskrat	0.011	0.097	0.304	**1.952**	0.171	**1.089**	0.079	0.412	0.037	0.235
Otter	0.056	0.384	**1.358**	**4.009**	0.808	**2.427**	0.336	0.870	0.149	0.549

	Background		**Year 2000**		**Year 2009 (Post-Decommissioning)**		**Year 2050 (Post-Decommissioning)**		**Year 2100 (Post-Decommissioning)**	
Uranium	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Eagle*	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	0.000
Mallard*	0.002	0.009	0.612	**1.422**	0.337	0.612	0.125	0.344	0.040	0.182
Scaup*	0.001	0.003	0.207	0.436	0.110	0.195	0.040	0.097	0.012	0.057
Merganser*	< 0.001	< 0.001	0.005	0.027	0.003	0.013	0.001	0.004	< 0.001	0.002
Bear	0.003	0.010	0.022	0.055	0.010	0.021	0.005	0.012	0.004	0.011
Ptarmigan*	< 0.001	0.001	0.001	0.003	0.001	0.001	< 0.001	0.001	< 0.001	0.001
Caribou	0.057	0.315	0.083	0.328	0.063	0.297	0.060	0.286	0.058	0.277
Moose	0.003	0.008	0.082	0.188	0.046	0.094	0.021	0.036	0.009	0.017
Hare	0.003	0.007	0.011	0.019	0.006	0.011	0.003	0.008	0.002	0.007
Muskrat	0.004	0.012	0.372	**1.138**	0.211	0.605	0.074	0.241	0.028	0.100
Otter	0.003	0.010	0.183	0.593	0.102	0.277	0.040	0.085	0.015	0.046

* See text for additional information relating to the uranium toxicity benchmark for birds.

Table 9.10: Screening Index Values for Non-Radioactive Contaminants for Terrestrial Ecological Receptors - Island Lake (Cont'd)

	Background		Year 2000		Year 2009 (Post-Decommissioning)		Year 2050 (Post-Decommissioning)		Year 2100 (Post-Decommissioning)	
Zinc	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	0.003	< 0.001	0.004	< 0.001	0.003	< 0.001	0.002	< 0.001	0.002
Eagle	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001
Mallard	0.041	0.240	0.107	0.263	0.072	0.246	0.044	0.215	0.037	0.202
Scaup	0.048	0.243	0.111	0.260	0.079	0.243	0.051	0.210	0.042	0.201
Merganser	0.002	0.010	0.005	0.012	0.004	0.011	0.002	0.008	0.002	0.008
Bear	< 0.001	0.002	0.001	0.002	0.001	0.002	< 0.001	0.002	< 0.001	0.001
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Moose	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001	< 0.001	0.001
Hare	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Muskrat	0.001	0.015	0.003	0.018	0.002	0.016	0.001	0.013	0.001	0.012
Otter	0.005	0.023	0.012	0.025	0.008	0.023	0.005	0.020	0.004	0.019

Table 9.11: Screening Index Values for Non-Radioactive Contaminants to Terrestrial Ecological Receptors – Cluff Lake

	Background		Maximum	
Arsenic	**50th**	**95th**	**50th**	**95th**
Wolf	0.013	0.029	0.013	0.029
Eagle	< 0.001	0.001	< 0.001	0.001
Mallard	0.005	0.017	0.025	0.056
Scaup	0.004	0.011	0.019	0.035
Merganser	< 0.001	0.002	0.002	0.008
Bear	0.046	0.107	0.057	0.130
Ptarmigan	0.001	0.002	0.001	0.002
Caribou	0.029	0.062	0.029	0.063
Moose	0.010	0.058	0.021	0.066
Hare	0.071	0.191	0.071	0.191
Muskrat	0.010	0.037	0.055	0.140
Otter	0.040	0.103	0.211	0.429

	Background		Maximum	
Cobalt	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	< 0.001	< 0.001	< 0.001
Eagle	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.008	0.037	0.019	0.085
Scaup	0.004	0.034	0.010	0.076
Merganser	0.001	0.001	0.001	0.003
Bear	< 0.001	< 0.001	< 0.001	0.001
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	< 0.001	< 0.001	< 0.001	< 0.001
Moose	0.001	0.006	0.002	0.013
Hare	< 0.001	< 0.001	< 0.001	< 0.001
Muskrat	0.013	0.080	0.029	0.175
Otter	0.002	0.005	0.004	0.008

	Background		Maximum	
Copper	**50th**	**95th**	**50th**	**95th**
Wolf	0.002	0.007	0.002	0.007
Eagle	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.004	0.017	0.004	0.018
Scaup	0.003	0.010	0.003	0.010
Merganser	0.001	0.003	0.001	0.003
Bear	0.018	0.071	0.018	0.071
Ptarmigan	0.001	0.002	0.001	0.002
Caribou	0.002	0.005	0.002	0.005
Moose	0.005	0.016	0.005	0.016
Hare	0.023	0.101	0.023	0.101
Muskrat	0.035	0.240	0.038	0.247
Otter	0.008	0.032	0.008	0.032

Table 9.11: Screening Index Values for Non-Radioactive Contaminants to Terrestrial Ecological Receptors – Cluff Lake (Cont'd)

	Background		**Maximum**	
Lead	**50th**	**95th**	**50th**	**95th**
Wolf	0.001	0.003	0.001	0.003
Eagle	0.001	0.001	0.001	0.001
Mallard	0.008	0.150	0.010	0.152
Scaup	0.003	0.047	0.004	0.047
Merganser	< 0.001	0.006	0.001	0.006
Bear	0.001	0.002	0.001	0.002
Ptarmigan	0.003	0.011	0.003	0.011
Caribou	< 0.001	0.001	< 0.001	0.001
Moose	0.001	0.004	0.001	0.004
Hare	0.001	0.003	0.001	0.003
Muskrat	0.002	0.018	0.003	0.018
Otter	< 0.001	0.004	0.000	0.004

	Background		**Maximum**	
Molybdenum	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	0.001	0.004	0.007
Eagle	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.011	0.049	0.018	0.058
Scaup	0.011	0.061	0.019	0.075
Merganser	< 0.001	0.002	< 0.001	0.002
Bear	0.002	0.016	0.095	0.781
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	0.001	0.003	0.045	0.072
Moose	0.002	0.009	0.003	0.010
Hare	< 0.001	0.001	0.001	0.001
Muskrat	0.010	0.047	0.016	0.058
Otter	0.050	0.251	0.080	0.324

	Background		**Maximum**	
Nickel	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	< 0.001	< 0.001	< 0.001
Eagle	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.001	0.005	0.003	0.009
Scaup	< 0.001	0.002	0.001	0.003
Merganser	< 0.001	0.002	0.001	0.004
Bear	0.002	0.004	0.002	0.004
Ptarmigan	< 0.001	0.001	< 0.001	0.001
Caribou	< 0.001	0.001	< 0.001	0.001
Moose	< 0.001	< 0.001	< 0.001	< 0.001
Hare	< 0.001	0.001	< 0.001	0.001
Muskrat	< 0.001	0.002	0.001	0.005
Otter	0.001	0.006	0.003	0.013

Table 9.11: Screening Index Values for Non-Radioactive Contaminants to Terrestrial Ecological Receptors – Cluff Lake (Cont'd)

	Background		**Maximum**	
Selenium	**50th**	**95th**	**50th**	**95th**
Wolf	0.003	0.029	0.003	0.030
Eagle	0.002	0.006	0.002	0.006
Mallard	0.093	0.368	0.093	0.368
Scaup	0.051	0.360	0.051	0.360
Merganser	0.030	0.087	0.030	0.087
Bear	0.029	0.092	0.081	0.247
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	< 0.001	0.001	0.001	0.002
Moose	0.011	0.038	0.011	0.038
Hare	< 0.001	< 0.001	< 0.001	< 0.001
Muskrat	0.071	0.430	0.071	0.430
Otter	0.309	0.828	0.309	0.828

	Background		**Maximum**	
Uranium	**50th**	**95th**	**50th**	**95th**
Wolf	0.001	0.001	0.001	0.004
Eagle	< 0.001	< 0.001	< 0.001	< 0.001
Mallard	0.003	0.015	0.071	0.219
Scaup	0.001	0.004	0.026	0.070
Merganser	< 0.001	< 0.001	< 0.001	0.002
Bear	0.003	0.011	0.016	0.037
Ptarmigan	< 0.001	0.001	0.001	0.002
Caribou	0.075	0.212	0.323	0.745
Moose	0.002	0.006	0.009	0.019
Hare	0.003	0.006	0.003	0.007
Muskrat	0.002	0.006	0.043	0.112
Otter	0.001	0.003	0.017	0.050

	Background		**Maximum**	
Zinc	**50th**	**95th**	**50th**	**95th**
Wolf	< 0.001	0.003	< 0.001	0.003
Eagle	< 0.001	0.001	< 0.001	0.001
Mallard	0.067	0.277	0.081	0.287
Scaup	0.084	0.294	0.096	0.316
Merganser	0.004	0.012	0.004	0.012
Bear	< 0.001	0.002	0.001	0.002
Ptarmigan	< 0.001	< 0.001	< 0.001	< 0.001
Caribou	< 0.001	< 0.001	< 0.001	< 0.001
Moose	< 0.001	0.001	< 0.001	0.001
Hare	< 0.001	< 0.001	< 0.001	< 0.001
Muskrat	0.002	0.018	0.002	0.019
Otter	0.008	0.025	0.010	0.026

Table 9.12: Screening Index Values for Radioactive Contaminants to Terrestrial Ecological Receptors in the Island Creek Watershed

Based on Absorbed Dose

	Simulated Background		Max Conc.		Year 2009	
	50th	95th	50th	95th	50th	95th
Ptarmigan	0.007	0.010	0.007	0.010	0.007	0.010
Moose	0.007	0.007	0.007	0.008	0.007	0.008
Caribou	0.008	0.009	0.008	0.009	0.008	0.009
Black Bear	0.007	0.008	0.007	0.008	0.007	0.008
Snowshoe Hare	0.009	0.019	0.009	0.019	0.009	0.018
Otter	0.007	0.007	0.007	0.007	0.007	0.007
Eagle	0.002	0.003	0.002	0.004	0.002	0.003
Wolf	0.002	0.003	0.002	0.003	0.002	0.003
Mallard	0.004	0.015	0.027	0.414	0.016	0.191
Merganser	0.004	0.004	0.005	0.015	0.004	0.010
Scaup	0.004	0.011	0.012	0.111	0.008	0.063
Muskrat	0.007	0.007	0.007	0.007	0.007	0.007

Based on Equivalent Dose (RBE=5)

	Simulated Background		Max Conc.		2009	
	50th	95th	50th	95th	50th	95th
Ptarmigan	0.008	0.022	0.008	0.022	0.008	0.020
Moose	0.007	0.009	0.008	0.011	0.008	0.009
Caribou	0.010	0.018	0.010	0.018	0.010	0.018
Black Bear	0.007	0.012	0.007	0.012	0.007	0.011
Snowshoe Hare	0.015	0.066	0.015	0.066	0.014	0.063
Otter	0.007	0.007	0.007	0.008	0.007	0.007
Eagle	0.002	0.009	0.003	0.011	0.003	0.009
Wolf	0.003	0.009	0.003	0.009	0.003	0.009
Mallard	0.006	0.058	0.118	**2.056**	0.065	0.940
Merganser	0.004	0.006	0.010	0.062	0.007	0.038
Scaup	0.005	0.039	0.045	0.541	0.027	0.303
Muskrat	0.007	0.007	0.007	0.008	0.007	0.007

Note: All screening index values include the contribution due to background and are based on predicted radionuclide levels in the Island Creek watershed, where most species were assumed to spend a majority of their time.

Table 9.16: Hazard Quotients and Risk Values for Human Receptors

	50th Percentile						95th Percentile					
	Background			Maximum			Background			Maximum		
	Total Dose		Risk	Total Dose		Risk	Total Dose		Risk	Total Dose		Risk
Arsenic	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	$2.15x10^{-3}$	$8.41x10^{-5}$	$1.26x10^{-4}$	$3.78x10^{-3}$	$1.48x10^{-4}$	$2.22x10^{-4}$	$4.40x10^{-3}$	$1.72x10^{-4}$	$1.89x10^{-4}$	$8.29x10^{-3}$	$3.24x10^{-4}$	$3.33x10^{-4}$
2 - Cluff Lake Trapper	$7.93x10^{-4}$	$3.10x10^{-5}$	$4.66x10^{-5}$	$6.59x10^{-3}$	$2.58x10^{-4}$	$3.87x10^{-4}$	$2.37x10^{-3}$	$9.28x10^{-5}$	$6.98x10^{-5}$	$1.58x10^{-2}$	$6.18x10^{-4}$	$5.80x10^{-4}$

	50th Percentile						95th Percentile					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Cobalt	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	$1.49x10^{-3}$	$5.83x10^{-5}$	0.001	$2.40x10^{-3}$	$9.39x10^{-5}$	0.002	$3.01x10^{-3}$	$1.18x10^{-4}$	0.002	$4.05x10^{-3}$	$1.59x10^{-4}$	0.003
2 - Cluff Lake Trapper	$3.01x10^{-3}$	$1.18x10^{-4}$	0.002	$6.30x10^{-3}$	$2.47x10^{-4}$	0.004	$4.69x10^{-3}$	$1.84x10^{-4}$	0.003	$9.97x10^{-3}$	$3.90x10^{-4}$	0.007

	50th Percentile						95th Percentile					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Copper	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	$2.79x10^{-2}$	$1.09x10^{-3}$	0.029	$2.96x10^{-2}$	$1.16x10^{-3}$	0.031	$6.44x10^{-2}$	$2.52x10^{-3}$	0.068	$6.77x10^{-2}$	$2.65x10^{-3}$	0.071
2 - Cluff Lake Trapper	$2.65x10^{-2}$	$1.04x10^{-3}$	0.028	$2.83x10^{-2}$	$1.11x10^{-3}$	0.030	$7.31x10^{-2}$	$2.86x10^{-3}$	0.077	$7.43x10^{-2}$	$2.91x10^{-3}$	0.078

	50th Percentile						95th Percentile					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Lead	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	$9.38x10^{-3}$	$3.67x10^{-4}$	0.010	$1.22x10^{-2}$	$4.77x10^{-4}$	0.013	$5.99x10^{-2}$	$2.34x10^{-3}$	0.063	$7.90x10^{-2}$	$3.09x10^{-3}$	0.083
2 - Cluff Lake Trapper	$8.25x10^{-3}$	$3.23x10^{-4}$	0.009	$1.26x10^{-2}$	$4.93x10^{-4}$	0.013	$6.04x10^{-2}$	$2.36x10^{-3}$	0.064	$7.90x10^{-2}$	$3.09x10^{-3}$	0.083

Table 9.16: Hazard Quotients and Risk Values for Human Receptors (Cont'd)

	50th Percentile						**95th Percentile**					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Molybdenum	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	3.81×10^{-3}	1.49×10^{-4}	0.004	2.32×10^{-1}	9.08×10^{-3}	0.245	1.41×10^{-2}	5.52×10^{-4}	0.015	3.00×10^{-1}	1.17×10^{-2}	0.316
2 - Cluff Lake Trapper	2.59×10^{-3}	1.01×10^{-4}	0.003	5.47×10^{-2}	2.14×10^{-3}	0.058	1.66×10^{-2}	6.50×10^{-4}	0.018	2.98×10^{-1}	1.17×10^{-2}	0.314

	50th Percentile						**95th Percentile**					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Nickel	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	2.37×10^{-2}	9.28×10^{-4}	0.025	2.64×10^{-2}	1.03×10^{-3}	0.028	6.41×10^{-2}	2.51×10^{-3}	0.068	6.53×10^{-2}	2.56×10^{-3}	0.069
2 - Cluff Lake Trapper	2.50×10^{-2}	9.78×10^{-4}	0.026	2.75×10^{-2}	1.08×10^{-3}	0.029	7.32×10^{-2}	2.86×10^{-3}	0.077	7.94×10^{-2}	3.11×10^{-3}	0.084

	50th Percentile						**95th Percentile**					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Selenium	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	8.86×10^{-3}	3.47×10^{-4}	0.009	1.63×10^{-2}	6.38×10^{-4}	0.017	1.94×10^{-2}	7.59×10^{-4}	0.020	9.01×10^{-2}	3.53×10^{-3}	0.095
2 - Cluff Lake Trapper	1.65×10^{-3}	6.46×10^{-5}	0.002	7.54×10^{-3}	2.95×10^{-4}	0.008	9.02×10^{-3}	3.53×10^{-4}	0.010	8.54×10^{-2}	3.34×10^{-3}	0.090

	50th Percentile						**95th Percentile**					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Uranium	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	1.76×10^{-3}	6.89×10^{-5}	0.002	1.32×10^{-2}	5.17×10^{-4}	0.014	5.84×10^{-3}	2.29×10^{-4}	0.006	9.39×10^{-2}	3.68×10^{-3}	0.099
2 - Cluff Lake Trapper	1.61×10^{-3}	6.30×10^{-5}	0.002	1.46×10^{-2}	5.71×10^{-4}	0.015	5.80×10^{-3}	2.27×10^{-4}	0.006	9.42×10^{-2}	3.69×10^{-3}	0.099

	50th Percentile						**95th Percentile**					
	Background			Maximum			Background			Maximum		
	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ	Total Dose		HQ
Zinc	(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))		(g/y)	(mg/(kg d))	
1 - Sandy Lake Trapper	1.61×10^{-1}	6.30×10^{-3}	0.170	2.32×10^{-1}	9.08×10^{-3}	0.245	8.01×10^{-1}	3.14×10^{-2}	0.845	$1.01\times10^{+0}$	3.95×10^{-2}	**1.066**
2 - Cluff Lake Trapper	1.13×10^{-1}	4.42×10^{-3}	0.119	2.03×10^{-1}	7.95×10^{-3}	0.214	8.11×10^{-1}	3.17×10^{-2}	0.856	$1.10\times10^{+0}$	4.31×10^{-2}	**1.160**

Table 9.17: Incremental Dose Estimates to Human Receptors

	50th Percentile		
	Post Decommissioning Incremental Dose (μSv/yr)		
	Year 2009	Year 2050	Year 2100
1 - Sandy Lake Trapper	70	55	43
2 - Cluff Lake Trapper	100	83	65

	95th Percentile		
	Post Decommissioning Incremental Dose (μSv/yr)		
	Year 2009	Year 2050	Year 2100
1 - Sandy Lake Trapper	150	60	50
2 - Cluff Lake Trapper	170	90	90

Table 9.21
Summary of Cumulative Effects and Assessment of Significance

Environmental Component	Area or Category	Residual Effects? Yes or No?	Basis for Decision	Are they Adverse? Yes or No?	Basis for Decision	Are they significant? Yes or No?	Basis for Decision				
							Below Accepted Objectives	Magnitude	Geographic Extent	Duration	Degree of Reversibility
Air Quality	Mill and TMA	**No**	Post-decommissioning air quality is predicted to be near background levels								
Surface Hydrology	Island Watershed	**No**	Return to pre-mining conditions								
	Cluff Watershed	**No**	Return to pre-mining conditions								
Groundwater	Island Watershed	**Yes**	TMA seepage will introduce contaminants into the groundwater flow for several years in the future	**Yes**	Negative effect on groundwater quality from pre-mining conditions.	**No**	Will not cause an elevation of contaminant levels in surface water bodies above SSWQO or decommissioning objectives		Isolated to a very small area in the direct locality of the source		
	Cluff Watershed	**Yes**	Waste rock seepage will introduce contaminants into the groundwater flow for several years in the future	**Yes**	Negative effect on groundwater quality from pre-mining conditions.	**No**	Will not cause an elevation of contaminant levels in surface water bodies above SSWQO or decommissioning objectives		Isolated to a very small area in the direct locality of the source		
Surface Water Quality	Snake Lake	**Yes**	predicted water quality is elevated in comparison to reference lakes	**Yes**	Predicted water quality is elevated in comparison to pre-mining conditions	**No**	predicted water quality is below accepted guidelines (SSWQO) for the protection of drinking water or aquatic life	Negligible. Ecological effects unlikely to be detectable	minimal: Snake Lake is 20 ha and averages about 1 m in depth		
	Island Lake	**Yes**	predicted water quality is elevated in comparison to reference lakes	**Yes**	Predicted water quality is elevated in comparison to pre-mining conditions	**No**	Slightly elevated uranium, molybdenum, ammonia and major ions; latter two parameters recovering quickly.	Minor: Shift in pelagic community composition. Based on hardness amelioration of toxicity.	limited: Island Lake is 181 ha and averages about 1.5 m in depth. Based on suitability of sediment contaminant remobilization modelling and continued Island Lake stability.	recovery to natural background levels expected within 100 years	initial recovery will occur almost immediately after effluent cessation secondary recovery more slowly as contaminated sediments buried
	Cluff Lake Watershed	**Yes**	predicted water quality is elevated in comparison to reference lakes	**Yes**	Predicted water quality is elevated in comparison to reference lakes	**No**	predicted water quality for Claude Lake, Peter River and Cluff Lake are all below SSWQO or accepted decommissioning objectives	Negligible to minor. Based on hardness amelioration of U toxicity.	Limited: Cluff Lake is 341 ha with maximum and mean depths of 52 and 20 m, respectively. No expectation that contaminants will be detectable beyond Cluff Lake.	Peak concentrations are predicted to occur within 150 years.	
	D Pit	**Yes**	predicted water quality is elevated in comparison to reference lakes and deep water chemocline has developed.	**Yes**	Source of contaminated surface water	**No**	predicted water quality is below SSWQO and accepted decommissioning objectives, except for iron which is naturally elevated in the area.	minor: pit has already naturally established a pelagic and epibenthic aquatic community.	minimal: about 2 ha and totally isolated from natural surface water systems.		
	DJX Pit	**Yes**	predicted water quality is elevated in comparison to reference lakes and deep water chemocline has developed.	**Yes**	Source of contaminated surface water	**No**	predicted water quality is below SSWQO and accepted decommissioning objectives, except for iron which is naturally elevated in the area.		minimal: small area and isolated from natural surface water systems.		
Sediment Quality	Snake Lake	**Yes**	actual and predicted sediment quality is elevated in comparison to reference lakes	**Yes**	Negative effect on sediment quality from pre-mining conditions	**No**	median values fall below sediment benchmark values. Only 95th percentile for molybdenum and nickel exceed lower benchmarks or regional background, but do not exceed upper benchmark boundaries.	Effects predicted to be minor based on field evidence from U mining areas with greater sediment concentrations.	limited to a very small area of minimal ecological significance in the region (20 ha and 1.8 m average depth)		reversible through passive, natural recovery; recovery further accelerated as it is a very shallow lake with relatively high rates of sedimentation and organic deposition.
	Island Lake	**Yes**	actual and predicted sediment quality is elevated in comparison to reference lakes	**Yes**	Negative effect on sediment quality from pre-mining conditions	**No**	Initial sediment concentrations (primarily Mo, Ni and U) will exceed low effects benchmarks but not upper benchmarks. Sediment quality improves over time.	Benthic invertebrate community presently exhibiting some impairment (normal abundance but change in community composition). Expected to recover as sediment quality improves over time	limited to a very small area of minimal ecological significance in the region (181 ha) but with some uncertainty in potential for release of contaminants to the larger downstream watershed	recovery to natural background levels expected within 50 - 100 years	reversible through passive, natural recovery; recovery further accelerated as it is a very shallow lake with relatively high rates of sedimentation and organic deposition.
	Cluff Lake	**Yes**	predicted sediment quality is elevated in comparison to reference lakes	**Yes**	predicted sediment quality is elevated for some contaminants in comparison to that experienced during the operational period	**No**	median values fall below sediment benchmark values. Only 95th percentile for Ni and U exceed lower benchmarks and/or regional background but are well below upper threshold boundaries calculated for uranium bearing regions	Effects predicted to be minor based on field evidence from U mining areas with greater sediment concentrations	Limited: Cluff Lake is 341 ha with maximum and mean depths of 52 and 20 m, respectively		reversible through passive, natural recovery

Table 9.21
Summary of Cumulative Effects and Assessment of Significance

Environmental Component	Area or Category	Residual Effects? Yes or No?	Basis for Decision	Are they Adverse? Yes or No?	Basis for Decision	Are they significant? Yes or No?	Basis for Decision				
							Below Accepted Objectives	Magnitude	Geographic Extent	Duration	Degree of Reversibility
Aquatic Organisms	Island Lake	**Yes**	potential for effects due to copper, molybdenum and uranium	**Yes**	the quality of the aquatic environment will improve with the cessation of effluent release, however, recovery of the aquatic community will not be detectable in the early post-decommissioning period (5 - 10 years)	**No**	benchmark values for uranium and copper are conservatively low	minor; minimal risks associated with copper, molybdenum and uranium	limited: Island Lake is 181 ha and averages about 1.5 m in depth	potential effects possible until year 2050	
	Cluff Lake	**Yes**	potential for effects due to copper and uranium	**Yes**	Predicted water and sediment quality may affect aquatic organisms	**No**	benchmark values for uranium and copper are conservatively low	minor: natural lakes in the area exceed benchmark values for copper; uranium under review by a joint industry/government working group			
Terrestrial Organisms	Island Lake	**Yes**	potential for effects due to molybdenum, selenium and uranium	**Yes**	Effects exceed benchmarks for many species with diverse diets and ecological characteristics	**No**	benchmarks for some species may not be met until far into the future	effects are large for waterfowl and mammalian carnivores and herbivores with aquatic diets	limited to a very small area of minimal ecological significance in the region (181 ha) but with some uncertainty in potential for release of contaminants to the larger downstream watershed	screening indices improve rapidly during initial years but do not fall below benchmarks for certain species during the expected period of monitoring and observation9	reversible through passive, natural recovery of watersheds; returning to background conditions after perhaps 100+ years for key contaminants
	Cluff Lake	**Yes**	Changes in water and sediment quality predicted	**Yes**	Increased potential for contaminant uptake.	**No**	screening indices for all metals and radionuclides below 1				
	Incremental effects of drinking flooded pit water	**Yes**	Flooded pit waters are a source of surface contaminated water	**Yes**	Increased potential for contaminant uptake.	**No**	screening indices for all metals and radionuclides still below 1				
Human Health	Cluff and Sandy Lakes	**Yes**	Changes in water and sediment quality predicted	**Yes**	Increased potential for contaminant uptake.	**No**	screening indices for all metals and radionuclides below 1				
	Incremental effects of drinking Snake, Island or flooded pit water	**Yes**	Contaminated pit waters are accessible to humans for drinking post-decommissioning	**Yes**	Ingestion of contaminated waters presents increased health risk	**No**	screening indices for all metals and radionuclides still below 1				
Land Reclamation	Disturbed lands	**Yes**	Flooded pits and waste rock piles will remain in the longterm	**Yes**	Transformation in natural landscape	**No**	Reclamation will ensure areas are esthetically pleasing and allow for traditional uses.		Pits and waste rock pile represent a small portion of the site study area.	recontouring to be complete during decommissioning; revegetation will establish within 30 years	
	Ambient radiologocial levels	**Yes**	Localized areas may be marginally higher than natural background	**Yes**	Some potential for increased radiological exposures to land users	**No**	will meet generally accepted criteria for protection of the public		most of the above area will meet background levels; some localized areas may be marginally higher but will meet criteria for the public		
Socio Economics	Employment	**No**	negative impacts on employment are from cessation of operations, not decommissioning								
	Land use	**Yes**	Need for long term institutional control and some care and maintenance	**Yes**	Some burden on future generations and some restrictions on possible land use for select areas	**No**	will meet decommissioning objective of continued traditional land uses	Decommissioning approach will minimize requirement for care and maintenance	Land use restrictions are over a very small area within the site study area		

Table 9.21
Summary of Cumulative Effects and Assessment of Significance

Ecological Context
No impact on the ecological communities in downstream surface water receptors
No impact on the ecological communities in downstream surface water receptors
Ecological effects likely to be undetectable
substantial improvement from licenced operational water quality. Ecosystem effects resulting from operational activities expected to recover.
Effects should be limited to minor shifts in pelagic community composition. Based on hardness amelioration of U toxicity.
minor: pit has already naturally established a pelagic and epibenthic aquatic community.
minor: pit is expected to establish a pelagic and epibenthic aquatic community similar to D pit.
effects are limited to common species primarily benthic invertebrates. Result in shift in community composition with no predicted effect on total abundance. No effect on regional populations, nor endangered or threatened species.
effects are limited to common species primarily benthic invertebrates. Result in shift in community composition with no predicted effect on total abundance. This altered benthic community is presently supporting benthic foraging fish population. No effect on regional populations, nor endangered or threatened species.
effects are limited to common species primarily benthic invertebrates. May result in minor shift in community composition with no predicted effect on total abundance or benthic foraging fish population. No effect on regional populations, nor endangered or threatened species.

Table 9.21
Summary of Cumulative Effects and Assessment of Significance

Ecological Context
substantial improvement from licenced operational water and sediment quality
effects are limited to common species and are not expected to impact regional populations. No endangered or threatened species are effected. Aboriginal use of impacted species in the specifically affected area is minimal
natural revegetation strategy for most areas will re-establish land use capability similar to what existed prior to mining

FIGURE 6.1 Aerial Photo of the Claude Open Pit and Associated Infrastructure.
(Photo taken in 1999)

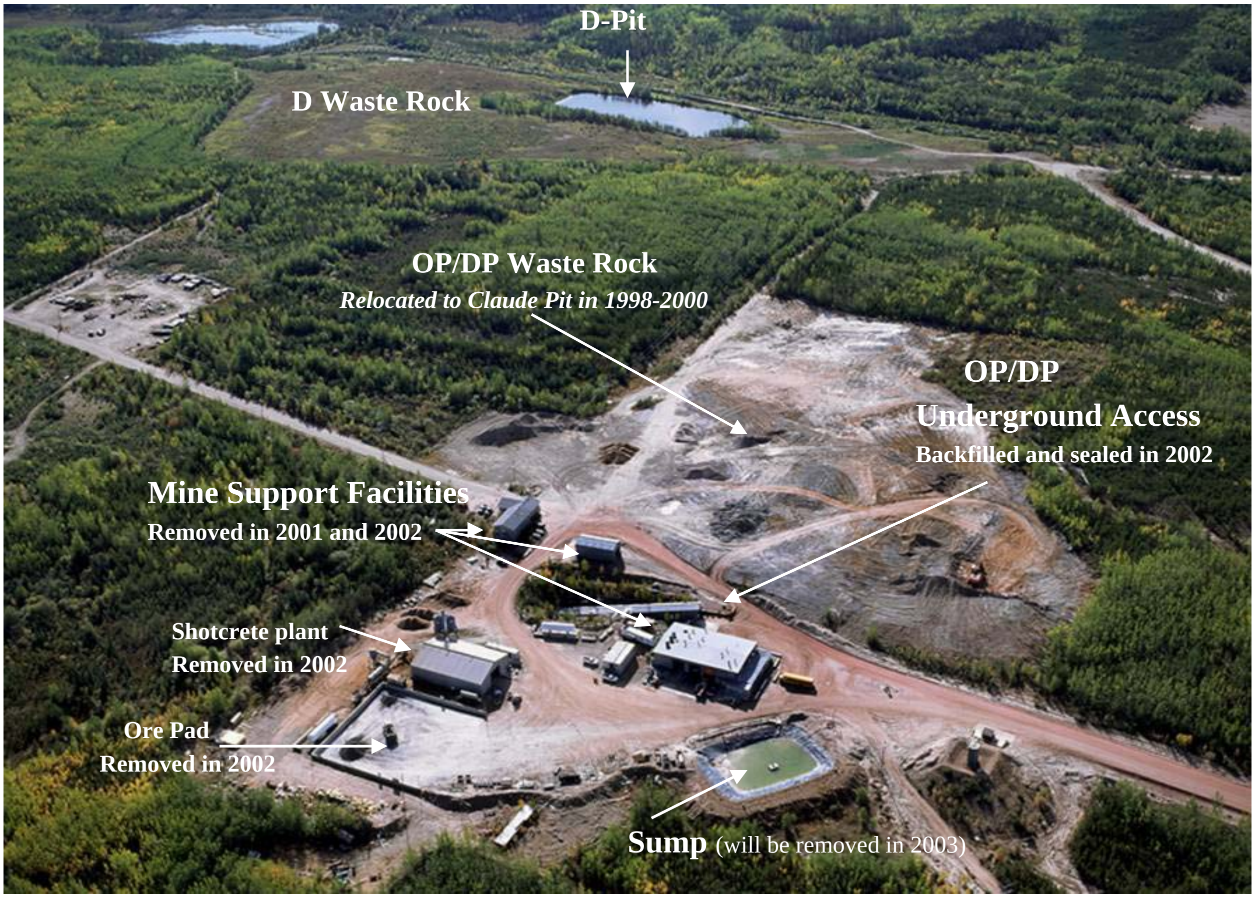


FIGURE 6.2 Aerial Photo of D-Pit and OP/DP Surface Facilities.
(Photo taken in 1999)

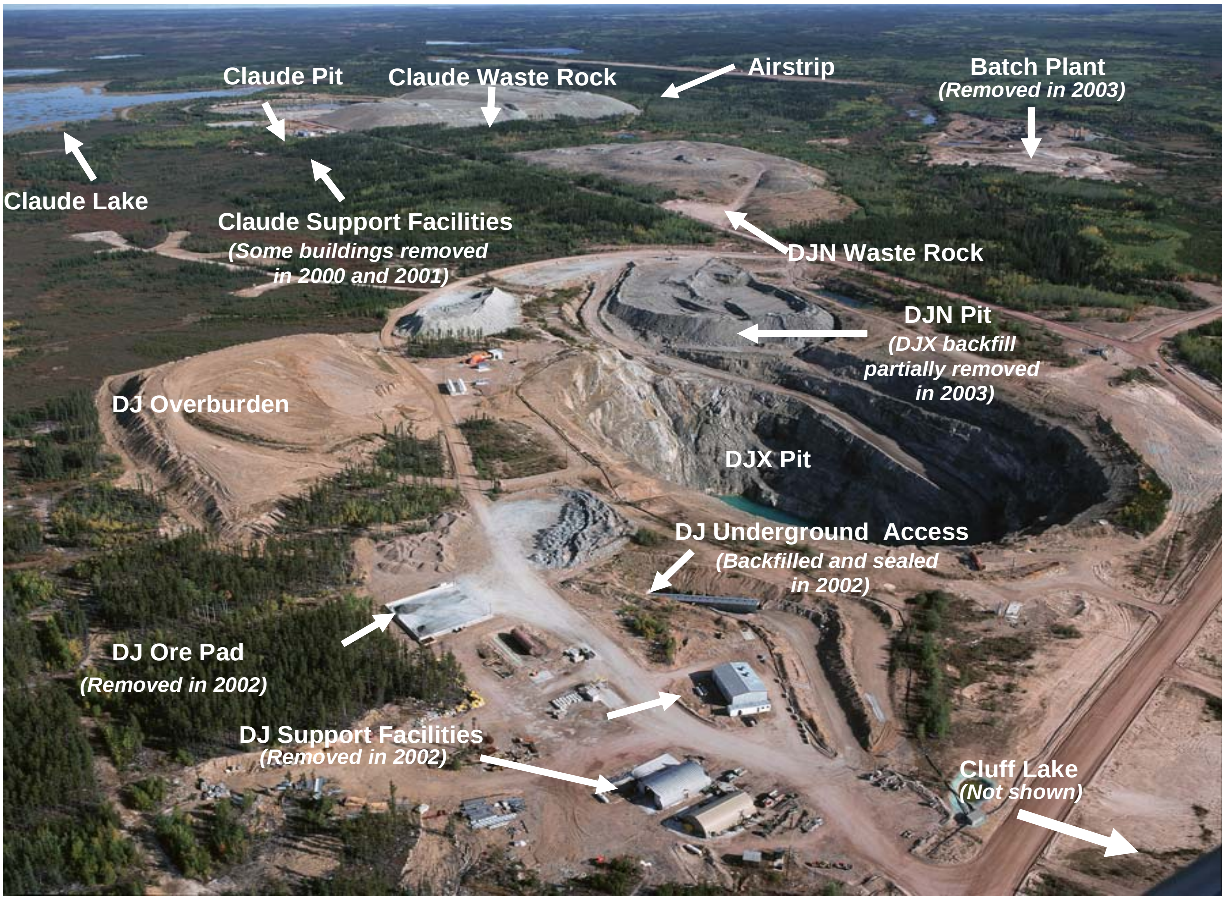


FIGURE 6.3. Aerial Photo of Claude and DJ Operations.
(Photo taken in 1999)

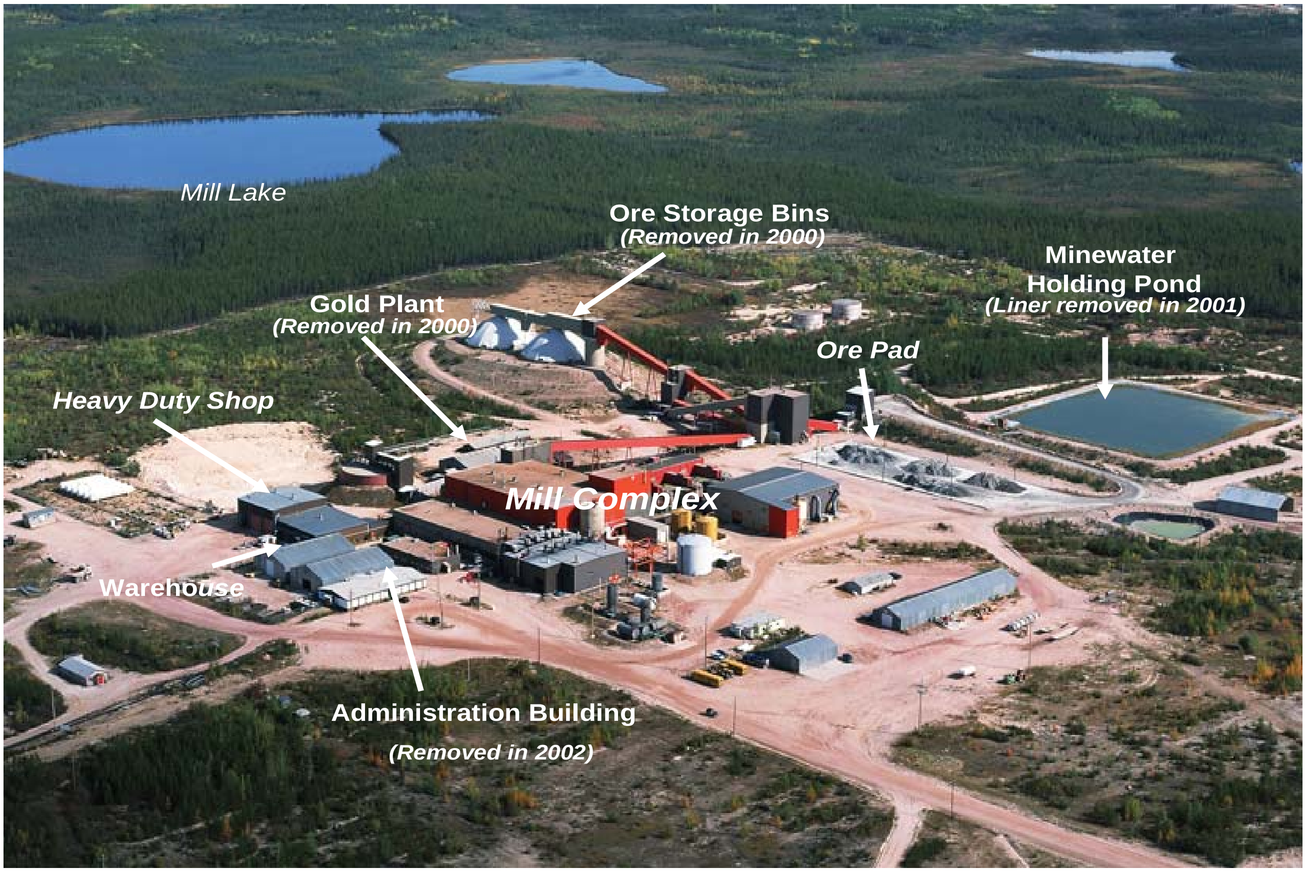


FIGURE 6.4 Aerial Photo of Mill Complex and Support Facilities.
(Photo taken in 1999)

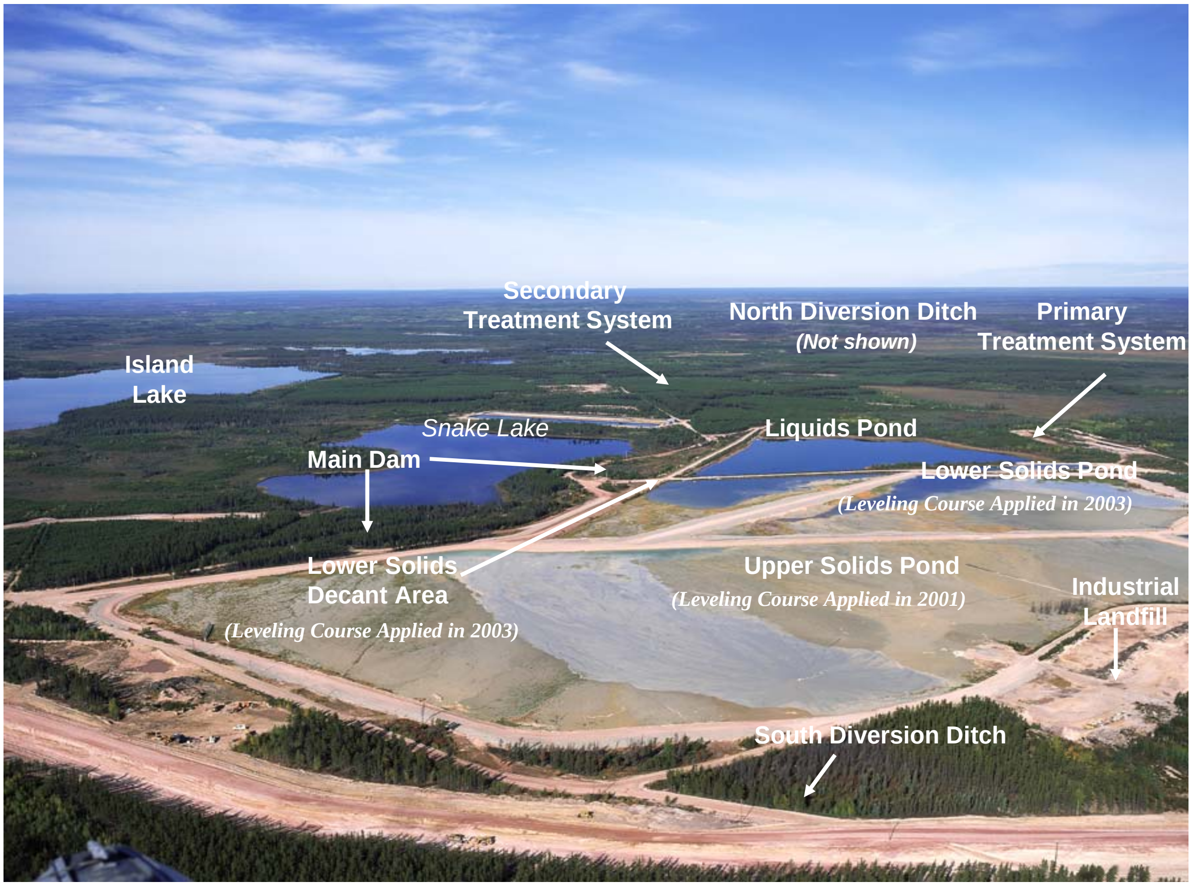


FIGURE 6.5 Aerial Photo of Tailings Management Area.
(Photo taken in 1999)

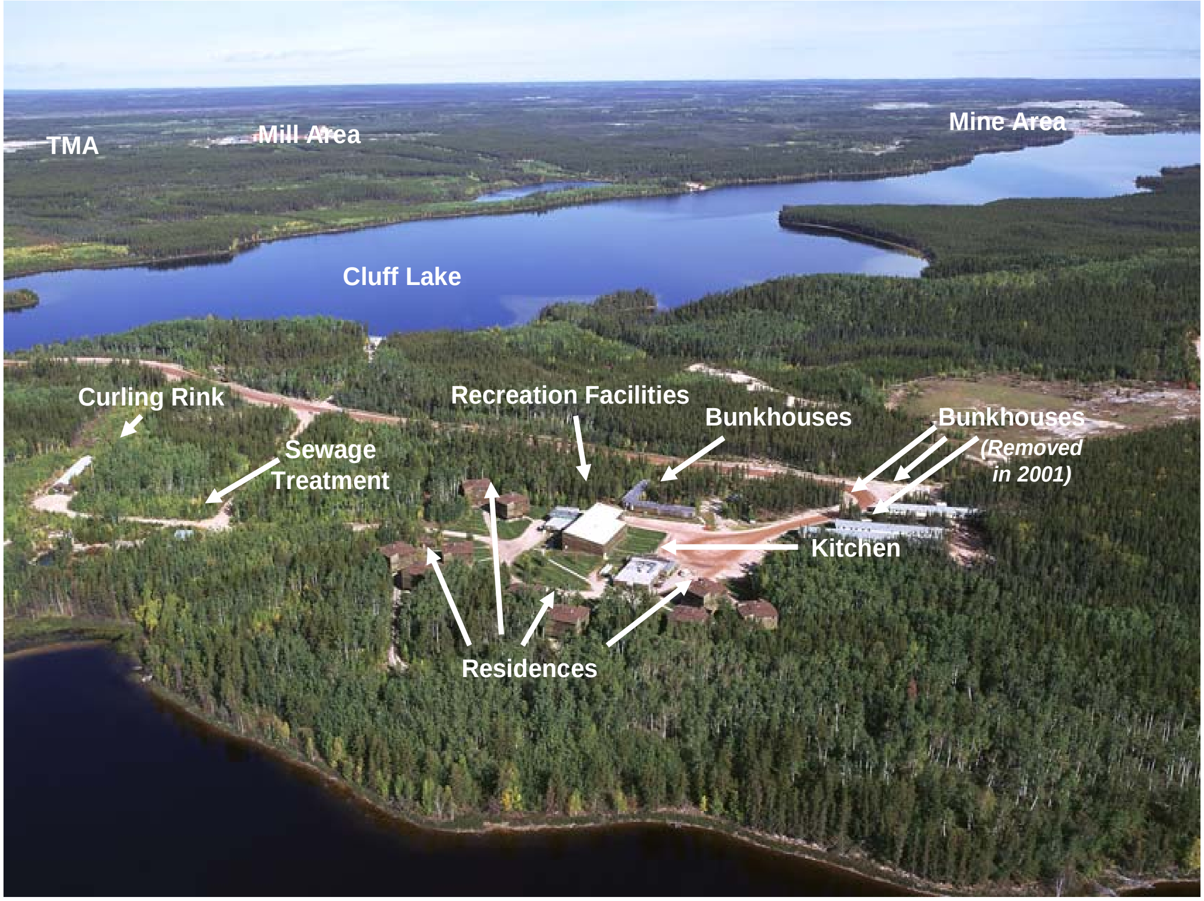


FIGURE 6.6 Aerial Photo of Germaine Camp.
(Photo taken in 1999)

Figure 8.1
Conceptual Decommissioning Schedule - Cluff Lake Mine

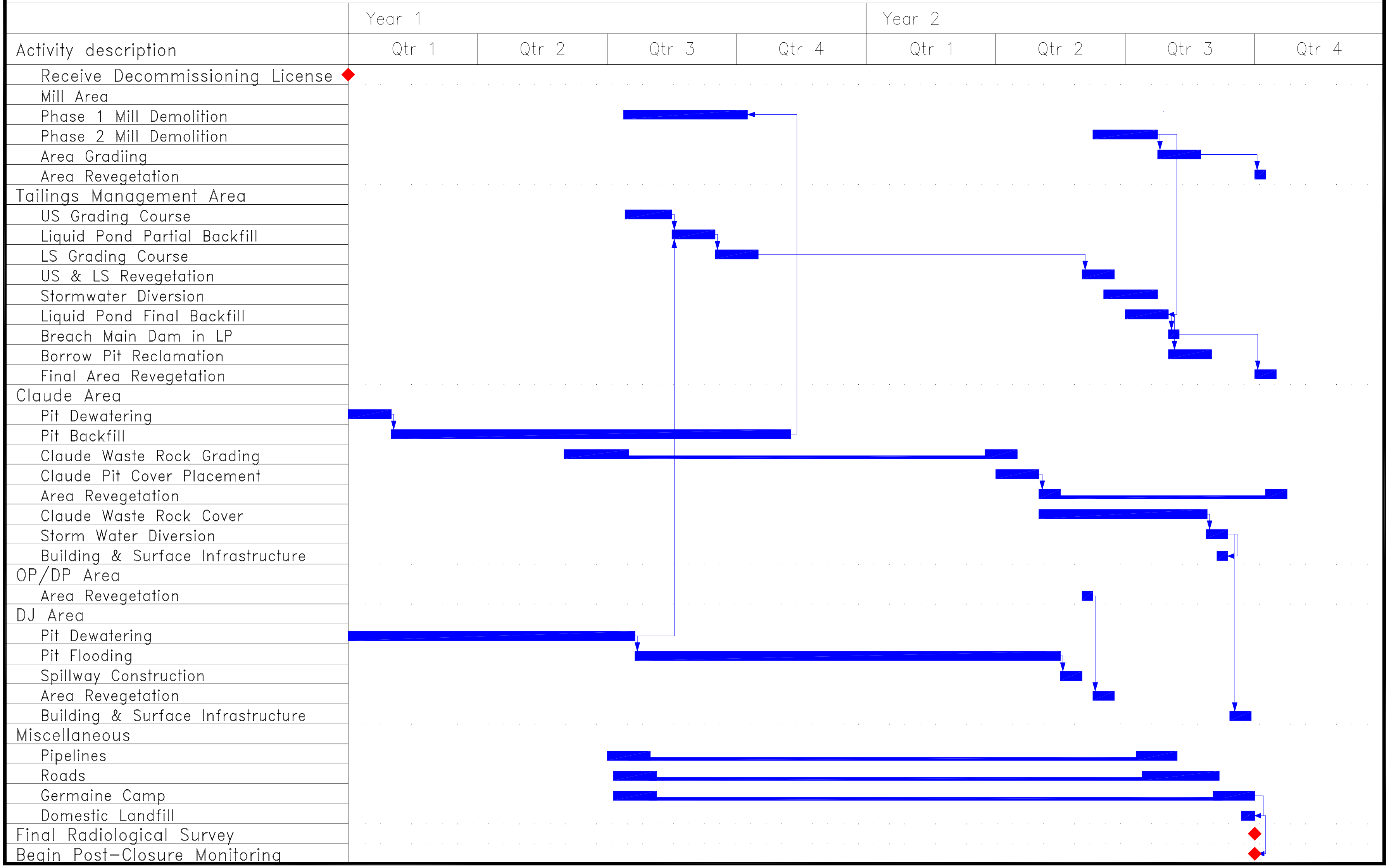


Figure 9.1: Predicted Water Quality in Island Lake

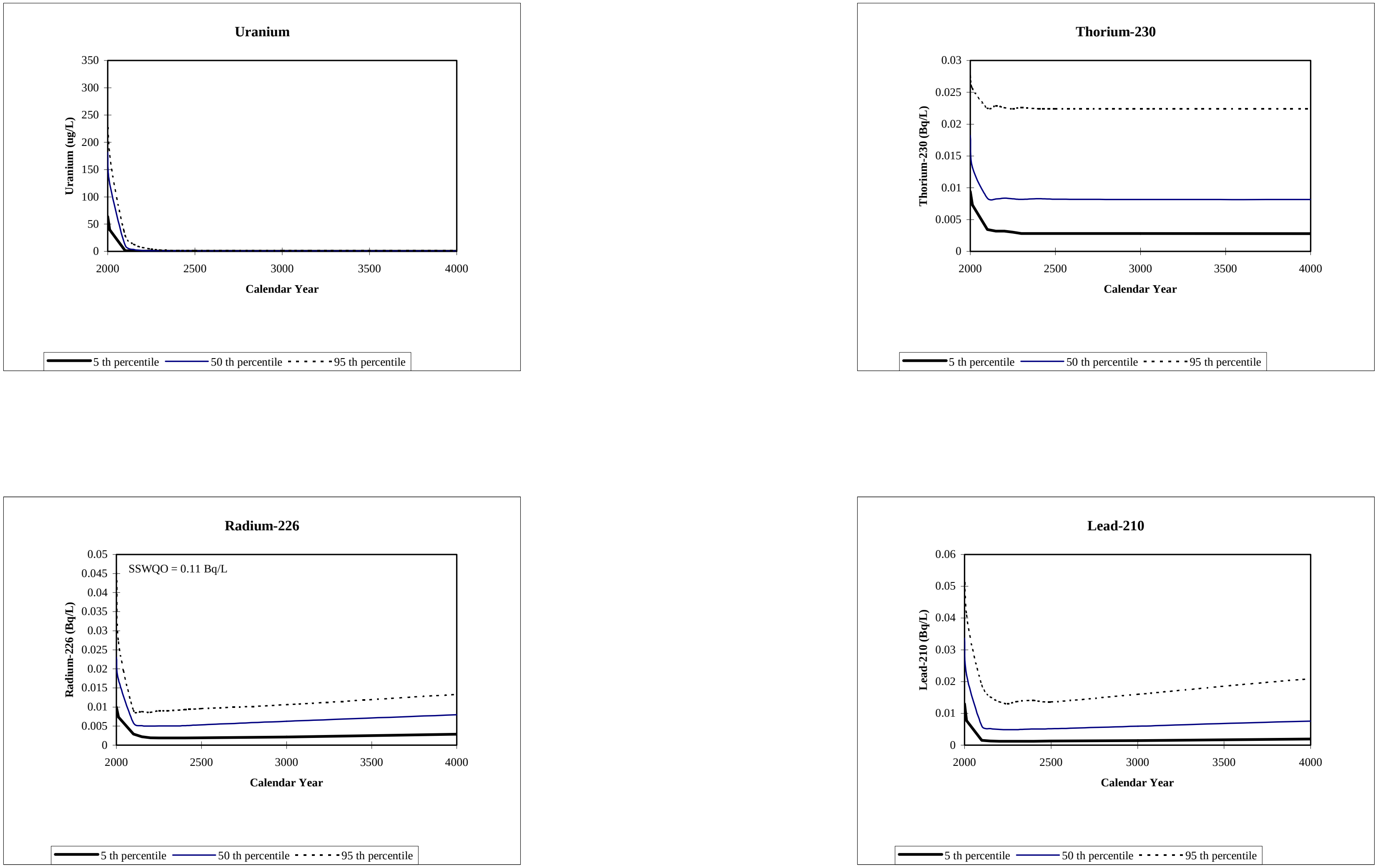


Figure 9.1: Predicted Water Quality in Island Lake (Cont'd)

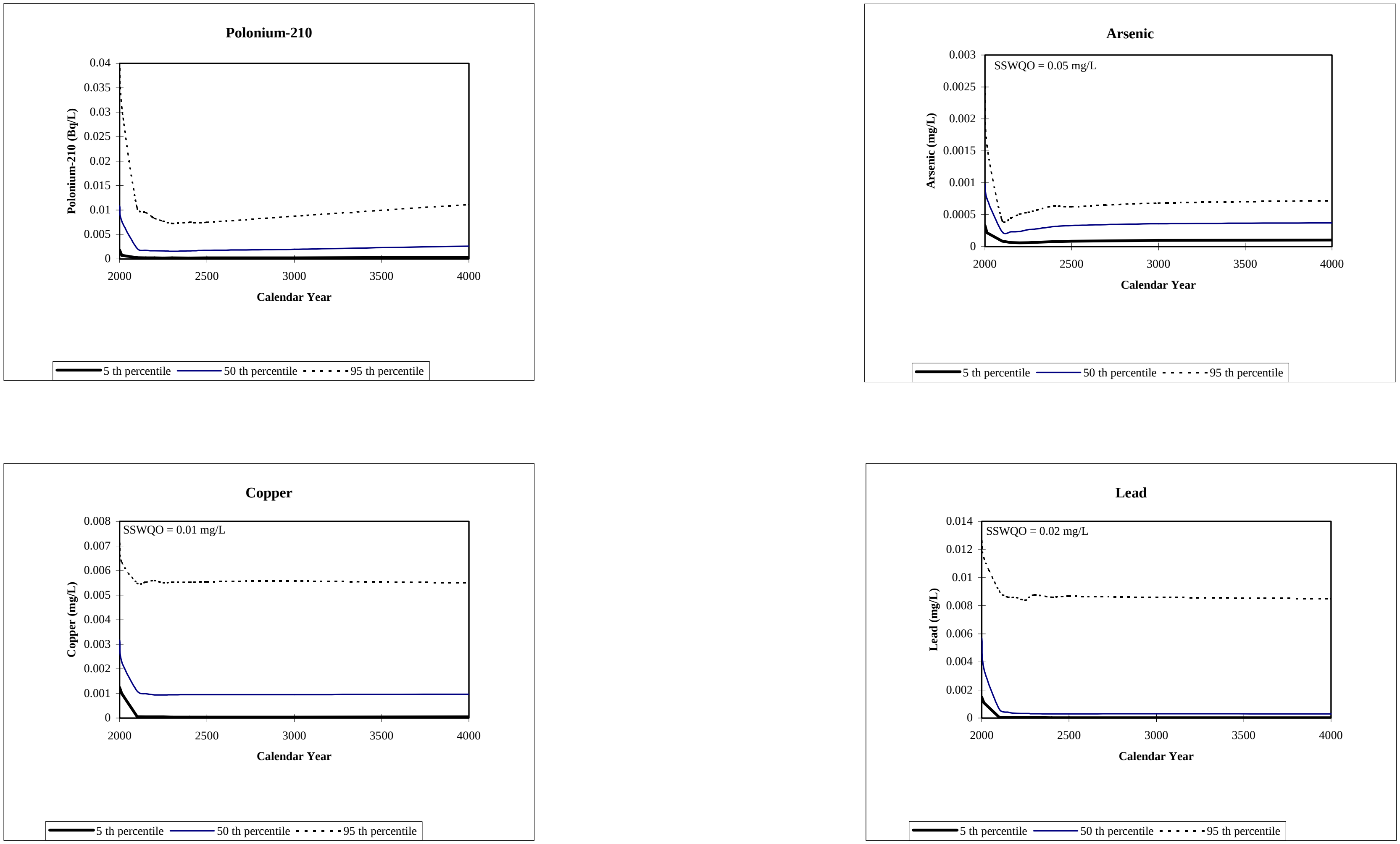


Figure 9.1: Predicted Water Quality in Island Lake (Cont'd)

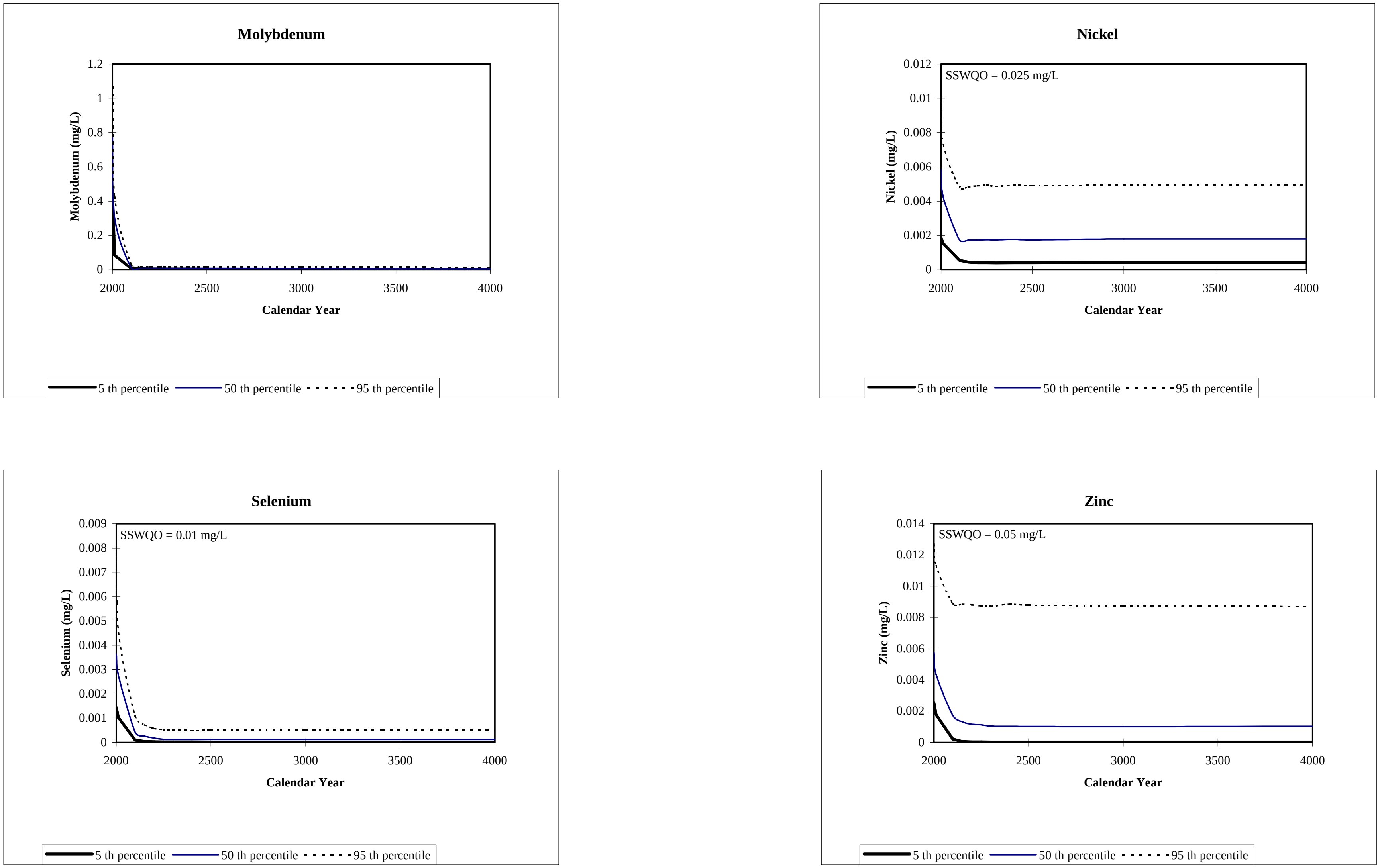


Figure 9.1: Predicted Water Quality in Island Lake (Cont'd)

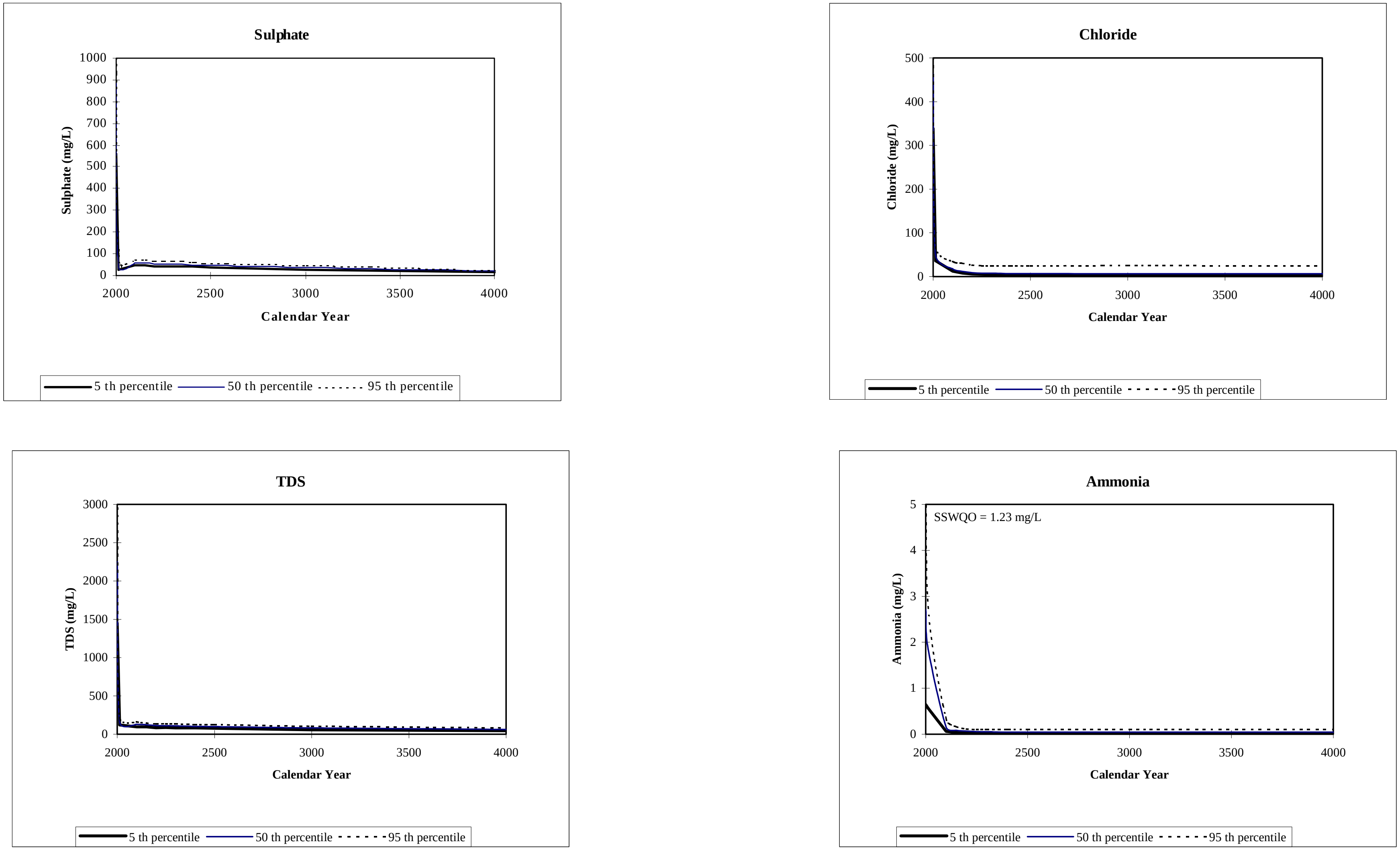
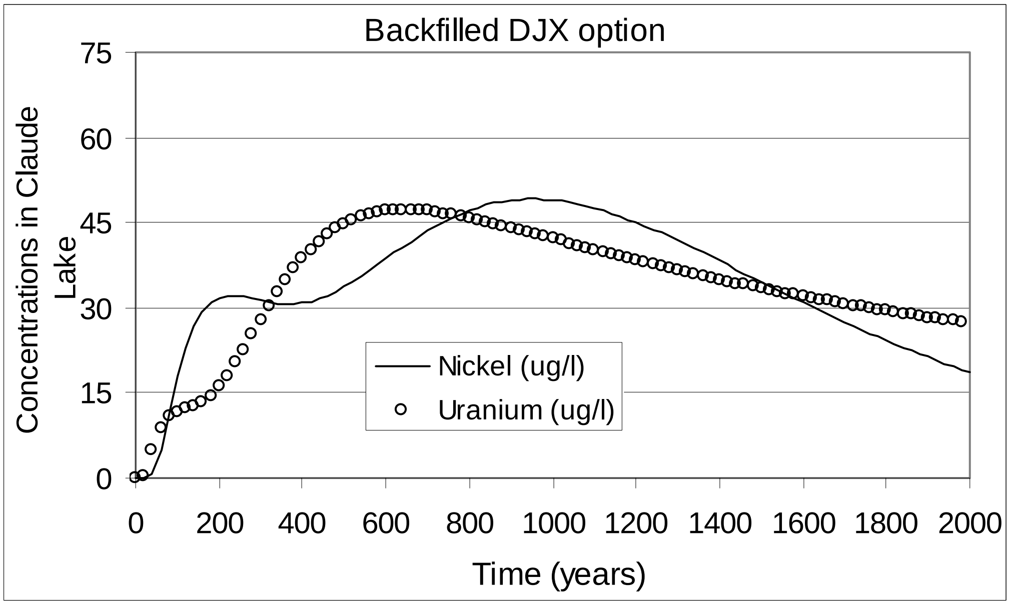


Figure 9.2: Predicted Uranium and Nickel Concentrations in Claude Lake for the Backfilled and Flooded DJX Pit Scenarios



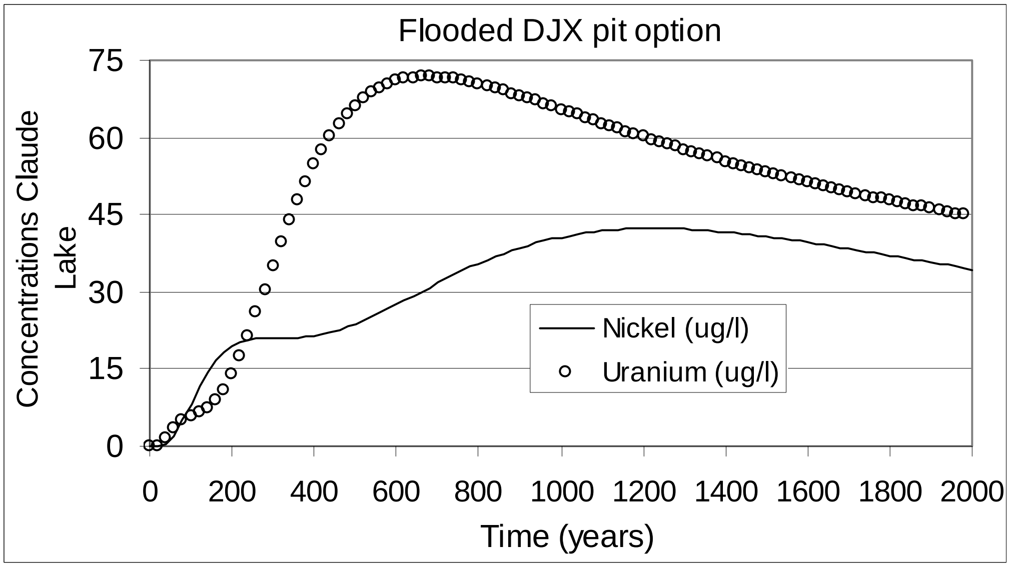
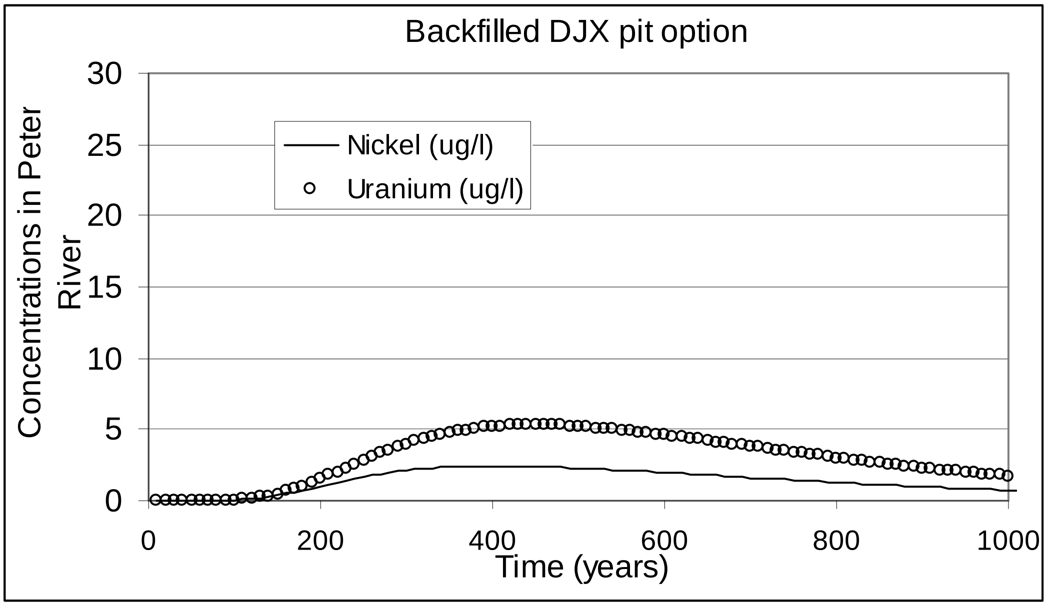


Figure 9.3: Predicted Uranium and Nickel Concentrations in Peter River for the Backfilled and Flooded DJX Pit Scenarios



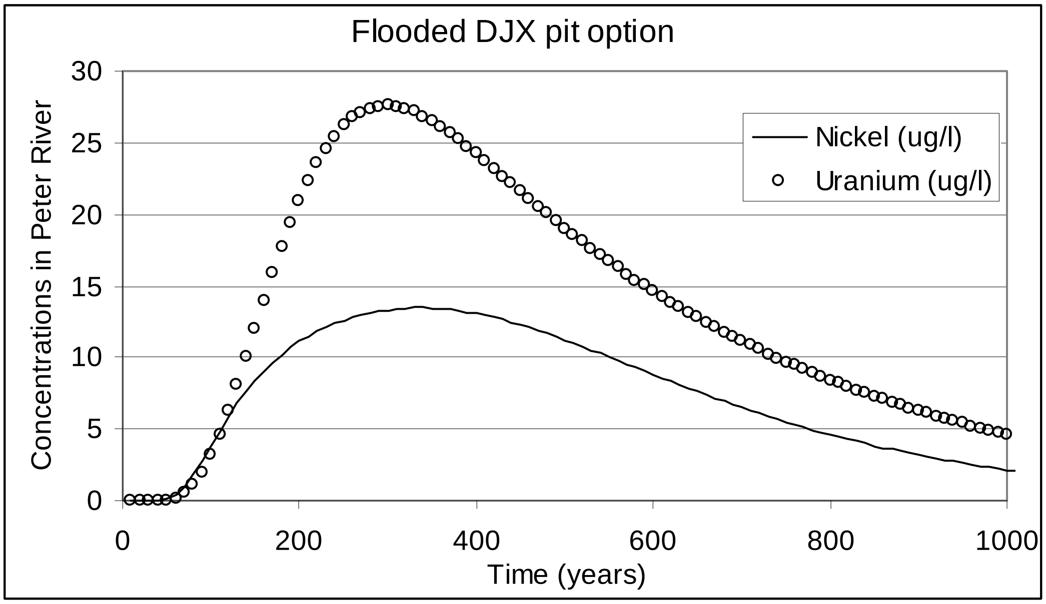
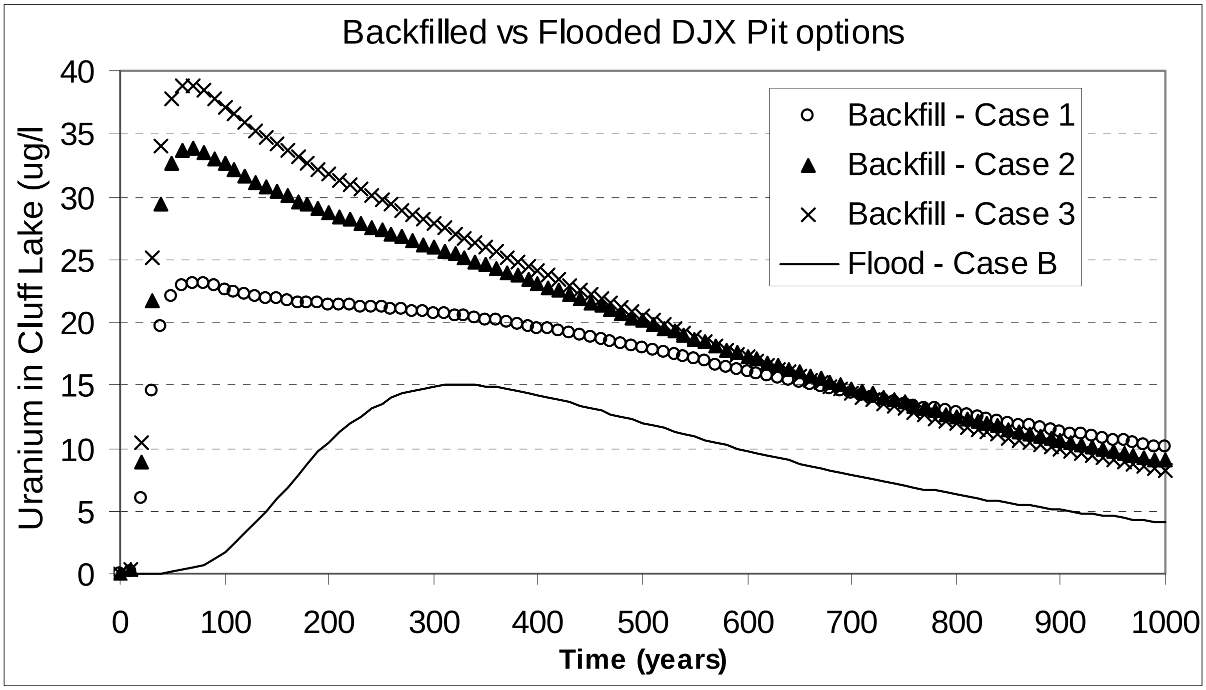


Figure 9.4: Predicted Uranium and Nickel Concentrations in Cluff Lake for the Backfilled and Flooded DJX Pit Scenarios



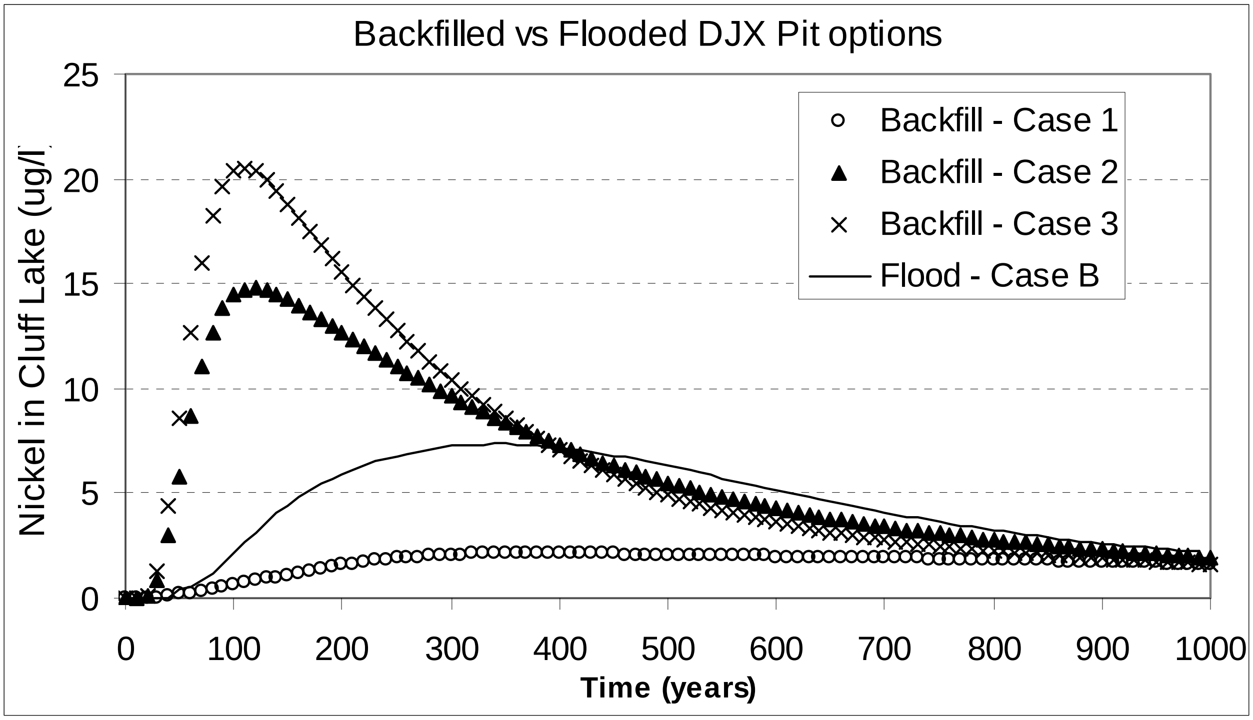
Backfill – Case 1 - The source term for the waste rock to be placed in the DJX Pit (oxidized Claude waste rock, DJN waste rock and DJN special waste) is based on the 1993 saturated leaching tests for the fresh DJN waste rock.

Backfill – Case 2 - For the first pore volume, the source term for the waste rock to be placed in the DJX pit is based on the average between the 1993 saturated leaching test results for the DJN fresh waste rock and the 1999 modified BC SWEP test results for the oxidized Claude waste rock, DJN waste rock and DJN special waste. For the other pore volumes, the source term is based on the 1993 saturated leaching tests for the fresh DJN waste rock.

Backfill – Case 3 - The source term for the waste rock to be placed in the DJX Pit (oxidized Claude waste rock, DJN waste rock and DJN special waste) is based on the 1999 modified BC SWEP tests for the oxidized Claude waste rock, DJN waste rock and DJN special waste.

Flood – Case B - The post-treatment DJX pit lake quality is considered to be 87 µg/L and 54 µg/L for uranium and nickel, respectively.

Figure 9.4: Predicted Uranium and Nickel Concentrations in Cluff Lake for the Backfilled and Flooded DJX Pit Scenarios (continued)



Backfill – Case 1 - The source term for the waste rock to be placed in the DJX Pit (oxidized Claude waste rock, DJN waste rock and DJN special waste) is based on the 1993 saturated leaching tests for the fresh DJN waste rock.

Backfill – Case 2 - For the first pore volume, the source term for the waste rock to be placed in the DJX pit is based on the average between the 1993 saturated leaching test results for the DJN fresh waste rock and the 1999 modified BC SWEP test results for the oxidized Claude waste rock, DJN waste rock and DJN special waste. For the other pore volumes, the source term is based on the 1993 saturated leaching tests for the fresh DJN waste rock.

Backfill – Case 3 - The source term for the waste rock to be placed in the DJX Pit (oxidized Claude waste rock, DJN waste rock and DJN special waste) is based on the 1999 modified BC SWEP tests for the oxidized Claude waste rock, DJN waste rock and DJN special waste.

Flood – Case B - The post-treatment DJX pit lake quality is considered to be 87 µg/L and 54 µg/L for uranium and nickel, respectively.

Figure 9.5: Predicted Contaminant Levels in Sediment of Snake Lake

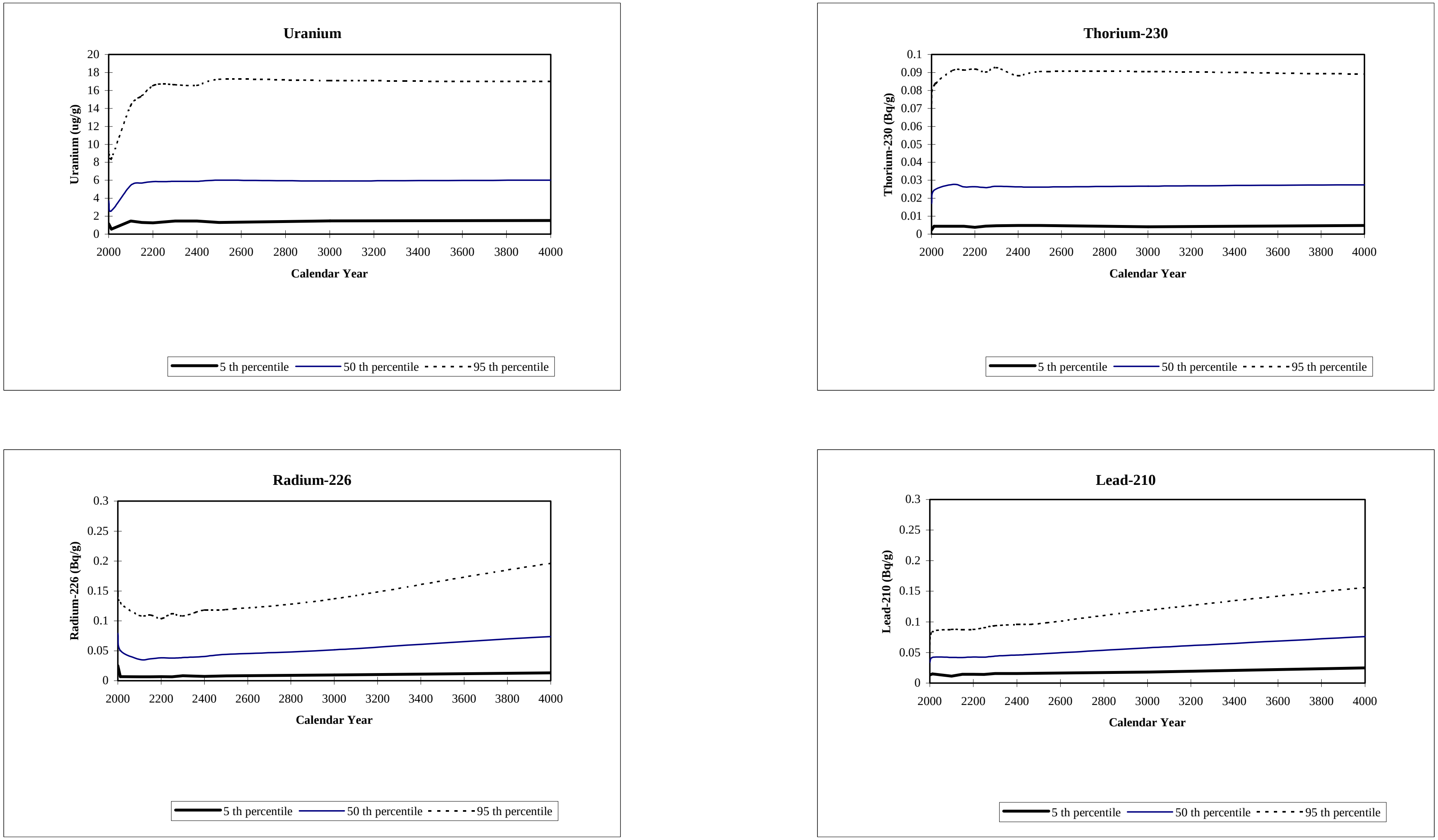


Figure 9.5: Predicted Contaminant Levels in Sediment of Snake Lake (Cont'd)

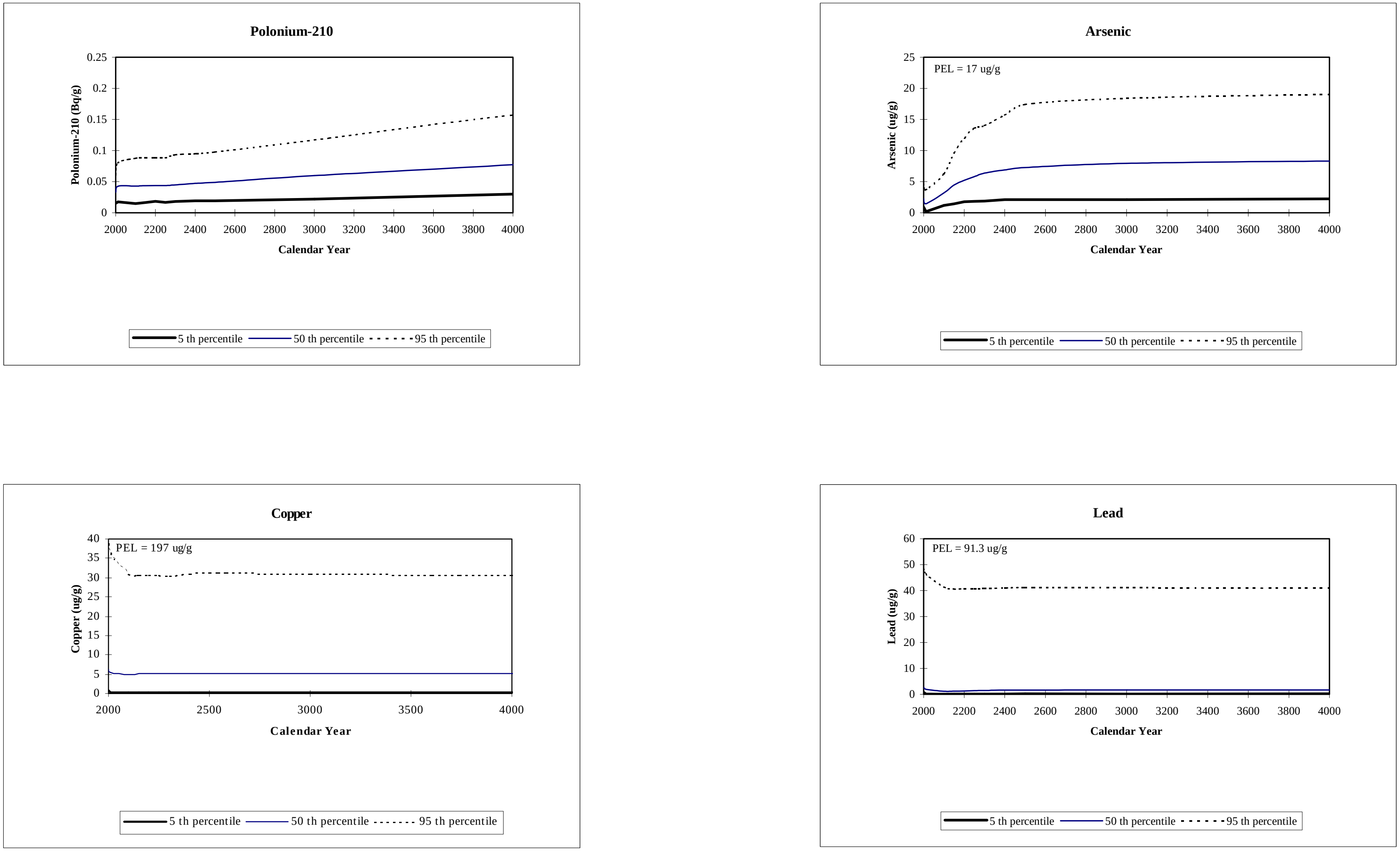


Figure 9.5: Predicted Contaminant Levels in Sediment of Snake Lake (Cont'd)

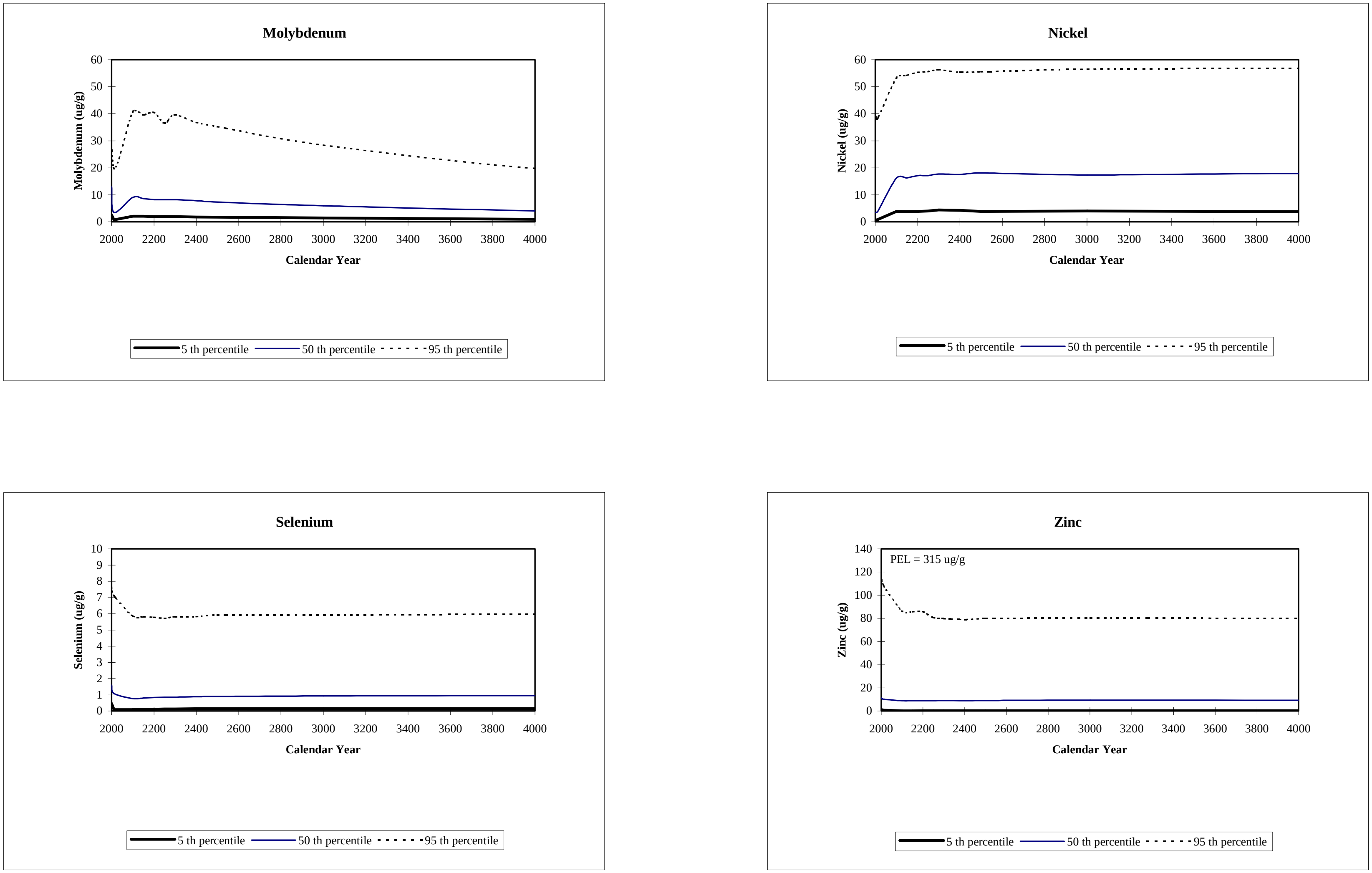


Figure 9.6: Predicted Contaminant Levels in Sediment of Island Lake

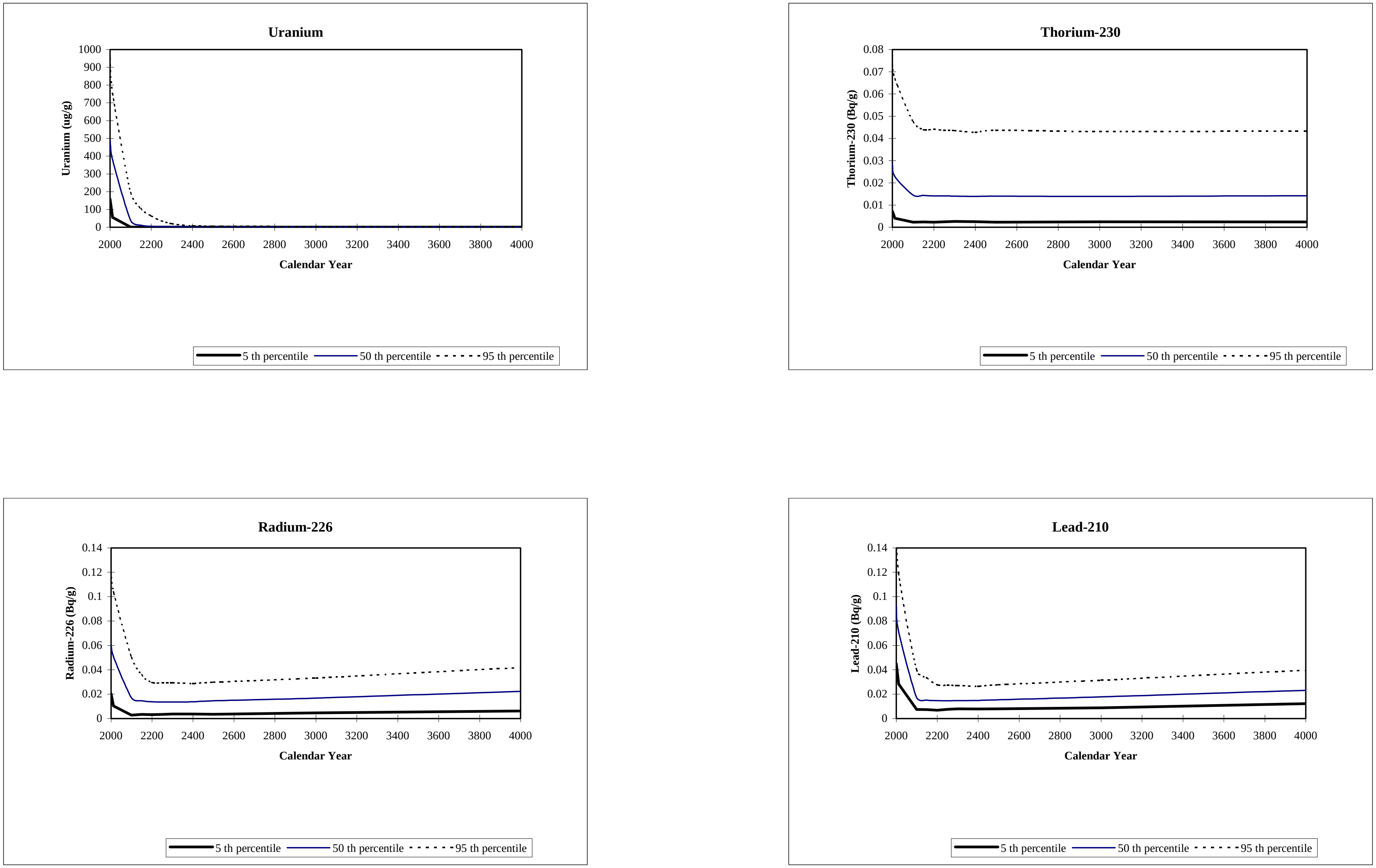


Figure 9.6: Predicted Contaminant Levels in Sediment of Island Lake (Cont'd)

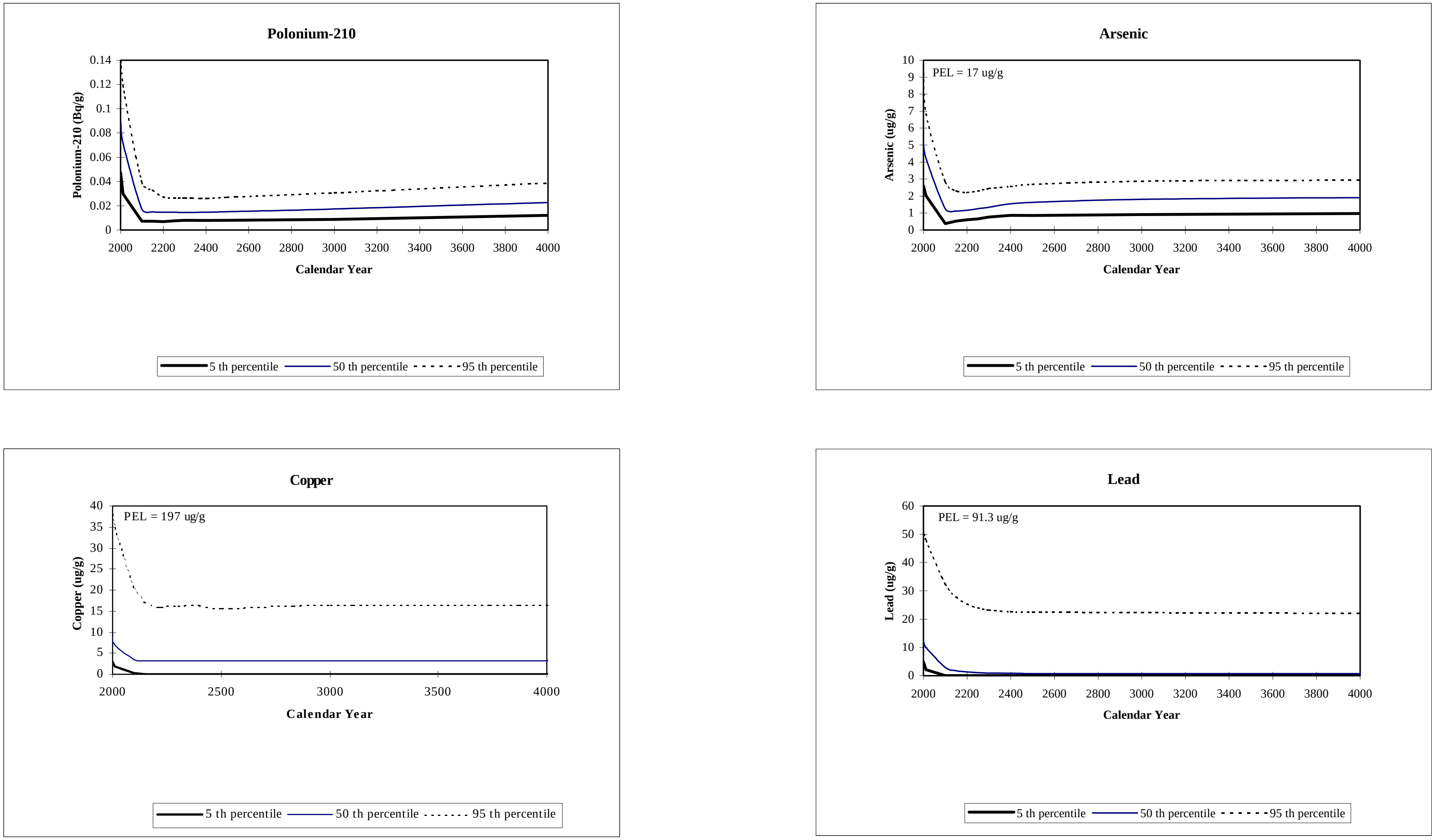


Figure 9.6: Predicted Contaminant Levels in Sediment of Island Lake (Cont'd)

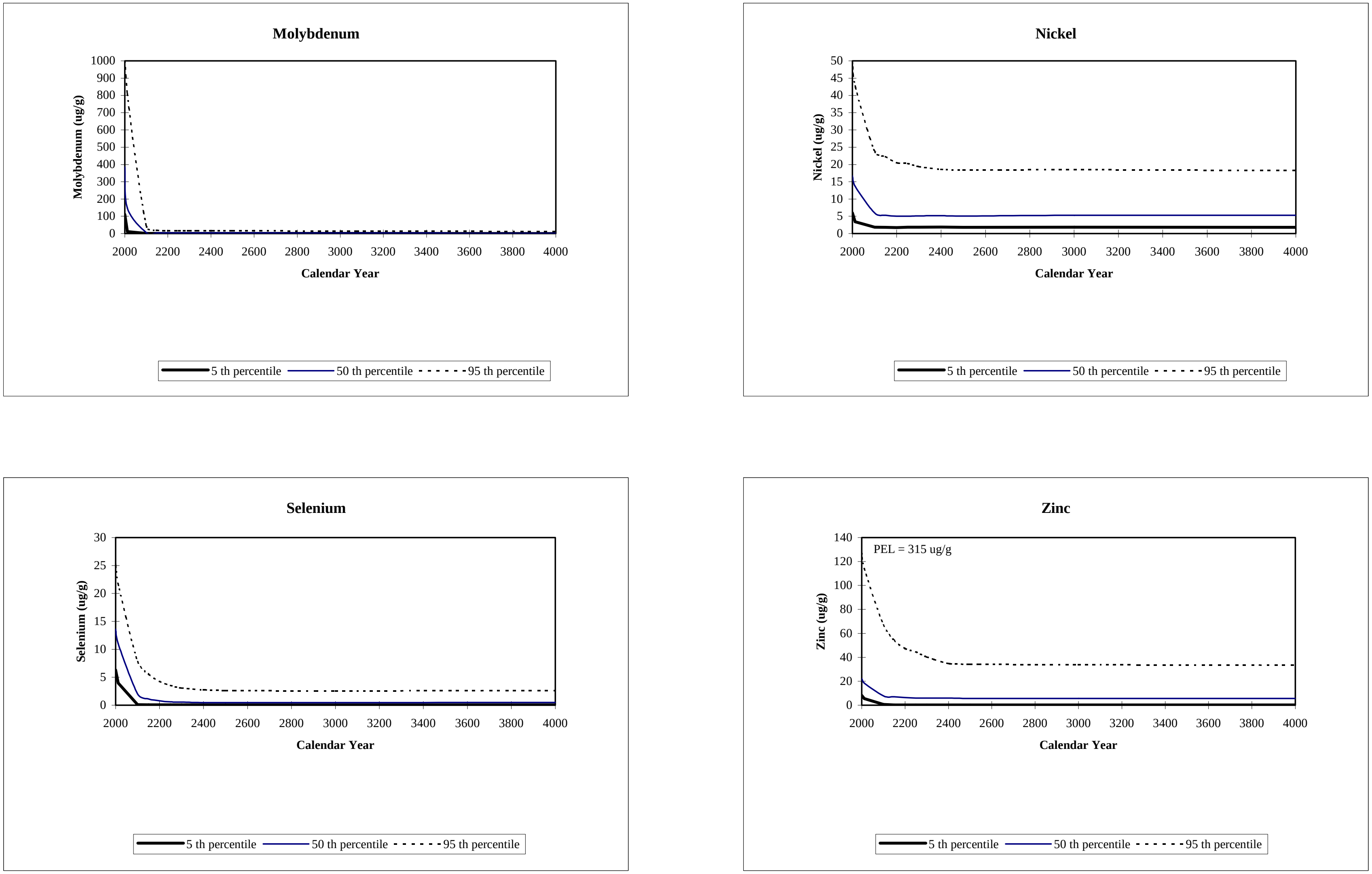


Figure 9.7: Predicted Contaminant Levels in Cluff Lake Sediment First 2000 Years Following Decommissioning

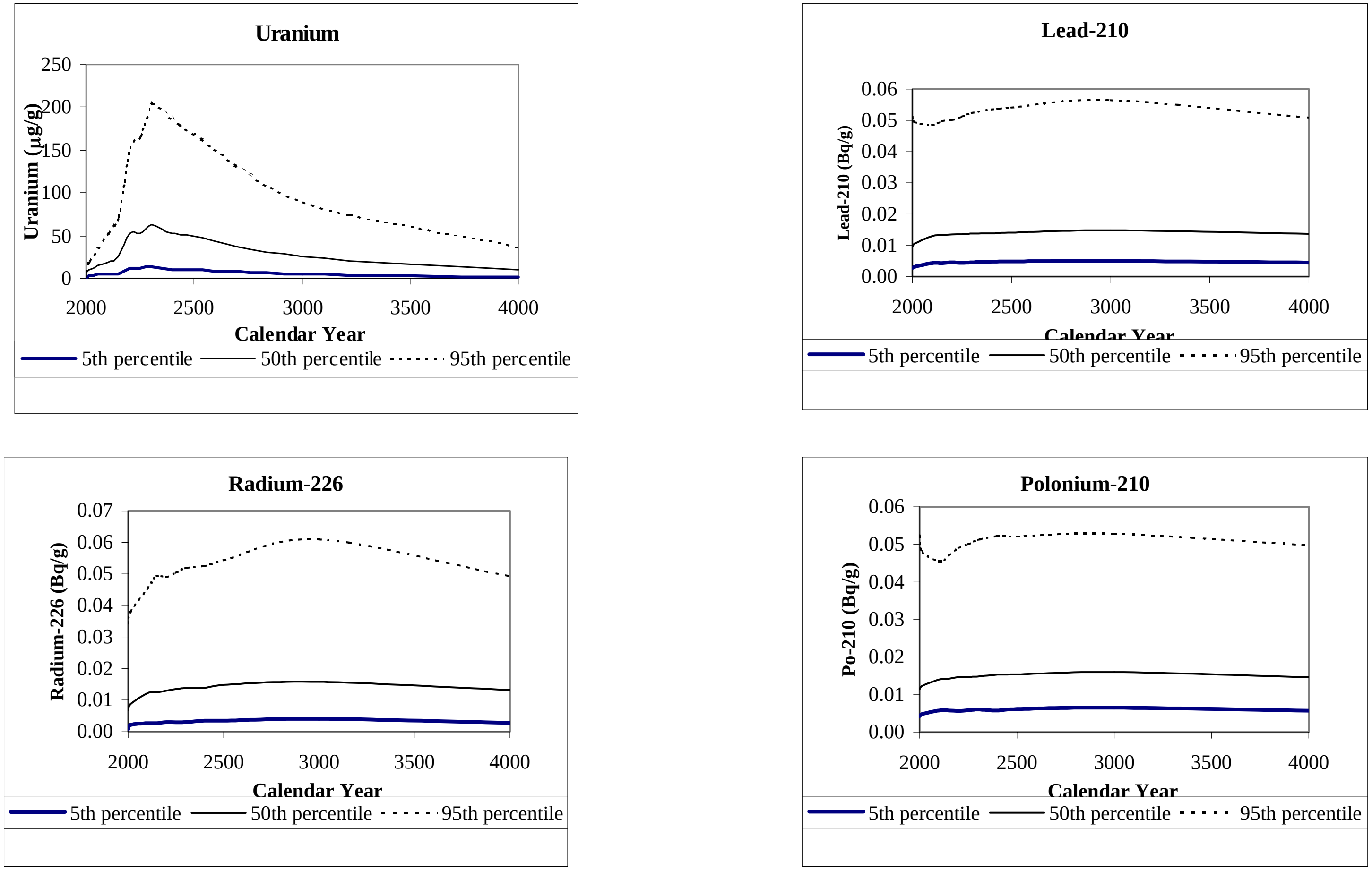


Figure 9.7: Predicted Contaminant Levels in Cluff Lake Sediment First 2000 Years Following Decommissioning (Cont'd)

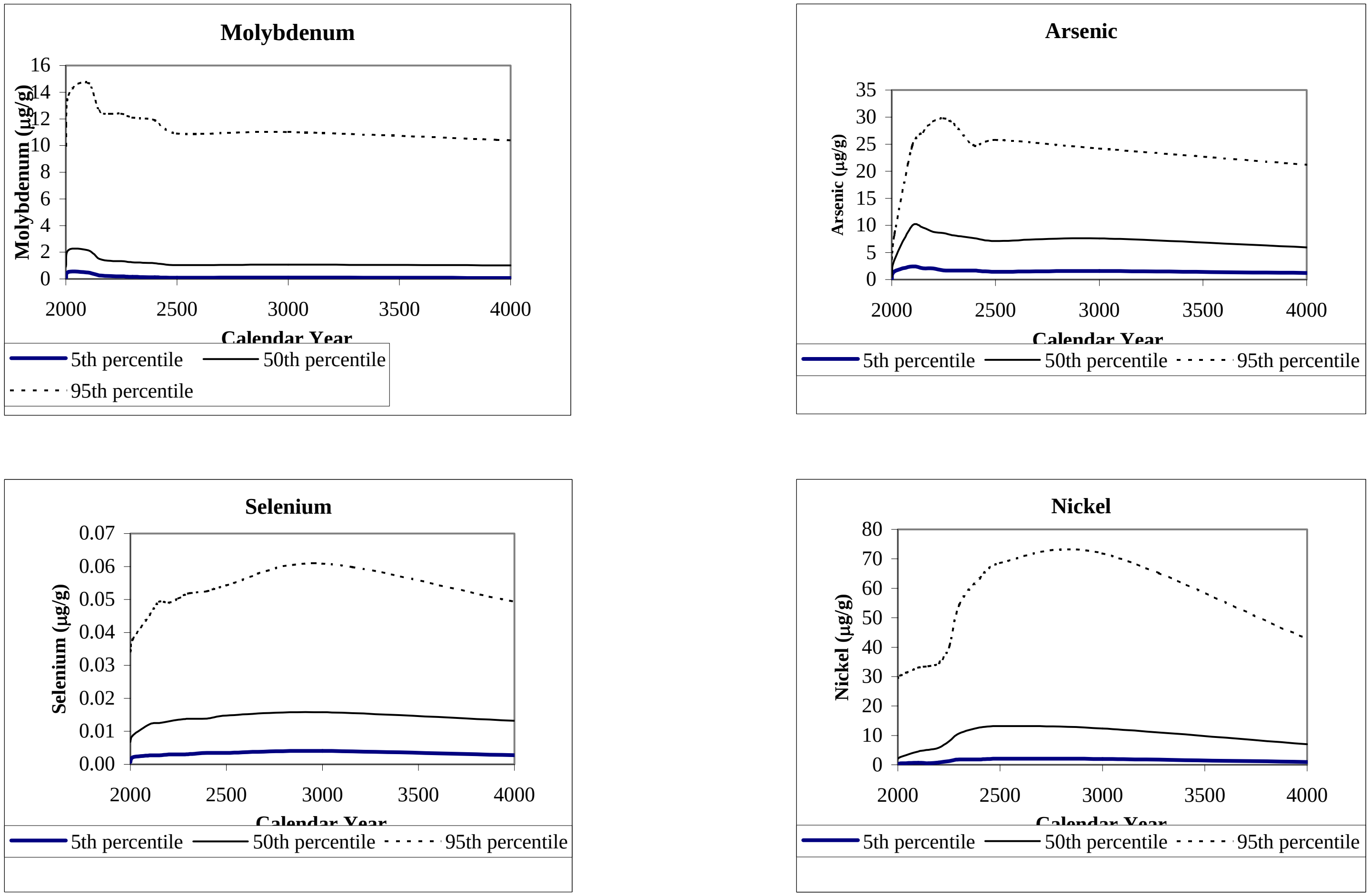


Figure 9.7: Predicted Contaminant Levels in Cluff Lake Sediment First 2000 Years Following Decommissioning