Uranium Mine Reclamation - A Myriad of Extremes Politics, Perceptions and Long-Lived Radionuclides

M. Ross

Saskatchewan Environment
and Resource Management
Assessment Branch
3085 Albert Street
Regina, Saskatchewan
S4S 0BI

D.G.Hovdebo

Northern Mines Monitoring
Secretariat
Box 5000
La Ronge,
Saskatchewan
S0J 1L0

ABSTRACT

Decommissioning and reclamation of Saskatchewan uranium mines involves a number of "extremes" which range from the physical location and climatic conditions at the sites to the politics, perceptions and regulatory issues which surround the mineral itself.

This paper discusses a number of these extremes and explores how each is being dealt with by operating mines, the regulatory agencies and the "impact communities".

Uranium mining, because of the strategic nature of the mineral, falls under the jurisdiction of both the federal and provincial government. This results in a regime where all proposals, including decommissioning and reclamation plans, must be reviewed and approved by two separate and distinct agencies before licensing is provided. The regulatory regime is, in itself, an extreme.

The tailings and waste rock piles present a second extreme in that, not only are they composed of the chemical and heavy metal components normally identified with a mining operation, but also contain a radioactive component which requires special consideration in all reclamation activities. Recently, operations have been approved which employ an in-pit pervious surround system for tailings management. This involves the use of a mined out pit which is modified to receive tailings and operated in a manner which considers the final reclamation strategy for the area.

All uranium mines in Saskatchewan are located north of 57° latitude: in areas which experience short and cool growing seasons and extreme freeze-thaw cycles. This, combined with poor soils, does not allow for the implementation of traditional revegetation programs nor the easy management of tailings deposition. The physical location of the sites also presents an "extreme" when implementing monitoring programs required as follow-up to reclamation activities.

Public involvement, including First Nations, in the review of monitoring and reclamation plans is being addressed in Saskatchewan by the establishment of a Northern Mines Monitoring Secretariat and regional Environmental Quality Committees. Through this means, valid impact community input will be a consideration without restricting industry's ability to make operating decisions or the ability of the regulators to do their jobs.

In the Saskatchewan uranium mining industry, "Reclamation in Extreme Environments" is a given: however, the extremes are not limiting the ability of the industry to successfully achieve desired goals.

INTRODUCTION

Uranium ore was first discovered in Saskatchewan in the mineral pitchblende form on the north shore of Lake Athabasca in 1934. The mining and milling of ore began in 1953 with the start-up of Eldorado Mining and Refining Limited's Beaverlodge mine/mill near Uranium City. In 1955 and 1957 Gunnar Mines Limited and Lorado Mines Ltd., both privately owned companies began operations in the same area. By the end of 1957 there were a number of small mines operating in the Uranium City area which supplied ore to both the Eldorado and Lorado milling facilities. The Lorado mill closed in 1960 and was followed four years later by the closure of the Gunnar operation. In the case of both these mines, no decommissioning or reclamation took place and the sites remain today. By 1965 Eldorado's Beaverlodge site was the only operating uranium mine in Saskatchewan. It continued operations until June of 1982. At that tune, the site was decommissioned, and monitoring of the area continues today water with samples being collected at various locations on a monthly basis.

During the operation of these early mines, environmental protection was not a concern for either industry or the responsible governments. Environmental protection was limited to that which was provided by the natural assimilative capacity of the receiving environment. Deposition of wastes, particularly tailings, into nearby lakes was selected as the most economical and convenient waste management systems.

In 1975, the first specifically designed tailings management structure was built at a Saskatchewan uranium mine to coincide with the start-up of the Rabbit Lake mill. Today there are three active uranium mine and mills in northern Saskatchewan; Cluff Lake , Key Lake and Rabbit Lake with a fourth, the McClean Lake Project, having recently received regulatory approval, began construction in the first quarter of 1995.

Currently, Saskatchewan produces approximately 23 million pounds of uranium (U_3O_8) per year or approximately 26% of total world production. The Joint Federal/Provincial Panel on Uranium Developments in Northern Saskatchewan is scheduled to review three additional proposals for production mines in the near future; Midwest, Cigar Lake and McArthur River. The latter two projects are significant, being the world's two largest high-grade uranium deposits with combined reserves estimated at more than 600 million pounds of U_3O_8.

EXTREMES

There are a number of "extremes" in relation to uranium mining which are not experienced in other types of mineral developments, operations, or decommissioning and reclamation.

One of the most significant is the fact that, because uranium was considered a "strategic mineral" during the war years, the federal government passed a declaratory Act which placed uranium under federal jurisdiction. Today, both the federal and the provincial governments play an active role in regulating these mines. Operators must receive approval from both before embarking on any activity including the implementation of decommissioning and reclamation plans. They must also contend with dual inspections and a duplication in almost all areas of regulatory compliance.

In addition, since 1991, all proposals for new uranium mine and mill facilities have been referred to the Joint Federal-Provincial Panel on Uranium Mining Developments in Northern Saskatchewan for public review.

Currently, in Saskatchewan, the approval and regulatory regime is in itself an "extreme".

As most people are aware, the development of uranium mines generates heated debates within the general public, all levels of government, and First Nations, national and international interest groups. Uranium mining proposals and operations are also an issue in public discussions involving the end use of the mineral - nuclear power, export, diversion to military uses, nuclear non-proliferation treaties, and terrorism. Operating or decommissioning a uranium mine involves a great deal of public discussion.

Uranium mines in Saskatchewan are all located north of 57° latitude: in areas which experience short and cool growing seasons and extreme freeze-thaw cycles. This, combined with soils which are marginal to non-existent, does not allow for the implementation of traditional revegetation programs nor the easy management of tailings deposition. The physical location of the sites also presents an "extreme" when implementing monitoring programs required in follow-up to reclamation activities.

At Saskatchewan mines, as with any uranium mine worldwide, tailings management and the issues related to long term decommissioning of tailings areas have a dimension with which more conventional mines do not have to contend with. While the potential for environmental impact from mine effluents at conventional mines originates primarily from chemical toxicity, the potential for environmental impact from a uranium mine originates from both chemical and radiological toxicity. The half-lives of the radioactive contaminants of primary concern are: uranium-238, 4.5×10^9 years; thorium-234, 24 days; thorium-230, 8×10^s years; radon-222, 3.82 days; and radium-226, 1622 years. Consequently, the design of a uranium tailings management system and the post-operational monitoring program has to incorporate parameters from a risk management model in which time is function of these half-lives. Currently the Atomic Energy Control Board of Canada requests pathway analyses for radioactive contaminants to extend up to 10,000 years.

As a footnote, it is interesting to consider that, theoretically, over conceivable time, the potential for environmental impact by some radiological contaminants will decrease to zero, whereas the potential for chemical toxicity will remain constant.

The time factor in decommissioning coupled with the physical locations of Saskatchewan uranium mines naturally focus the majority of concern on tailings management facilities and the decommissioning and reclamation of these areas.

URANIUM TAILINGS MANAGEMENT IN SASKATCHEWAN

The Early Years

During the early years of uranium mining and milling in Saskatchewan environmental protection was not a priority for the industry or the responsible government. In the 1950's there were tailings management areas at the Gunnar, Lorado and Eldorado operations, all in the Uranium City area. Alternatives for tailings management was limited to topographical considerations. The most economical and convenient method of tailings management was deposition in existing lakes with no consideration given to environmental protection.

At the Gunnar (1995) mining/milling operation on the north shore of Lake Athabasca, tailings were literally pumped over the hill and into Mudford (Blair) Lake. When this area reached capacity, a channel was blasted out of bedrock at the lowest end of the lake to allow the tailings to flow out. Eventually the tailings filled in a low area north of Mudford Lake, overtopped this area and continued to flow down hill, eventually entering Langley Bay, Lake Athabasca. During operations neither the discharged tailings, the liquid effluent nor the displaced lake water was treated to reduce contaminant loadings to the receiving environment. At the end of mining in the early 1960's no decommissioning or reclamation was done at the site.

The Lorado site (1957) was operated in a similar manner although the tailings were initially deposited on the shore of Nero Lake, formed a beach and eventually entered the Lake. This site was not decommissioned at the end of operations in 1964.

The Eldorado mining/milling operation north-east of Uranium City, also known as Beaverlodge (1953), began at approximately the same time as Gunnar, was modified in 1975-7 for effluent treatment purposes, and continued operations into the early 1980's. Initially, tailings were handled in a manner very similar to that at Gunnar. The bulk of the tailings generated over the lifetime of the operation were deposited in Marie and Fookes Lakes and during the early years no effluent treatment systems were in place.

In 1977, in response to environmental concerns raised by the Province, Eldorado's tailings management system was upgraded by the installation of control structures and chemical treatment facilities on the lake system handling the tailings effluent. The removal of radium and heavy metals from the effluent was facilitated by treatment with barium chloride and ferric sulphate. Effluent quality monitoring also began at this time.

In essence, tailings management in the early 1970's was still based on deposition in existing lakes, with the main difference being that the discharges from the lakes now were being monitored and the removal of radium was taking place before final discharge.

At the cessation of operations the Beaverlodge site was totally decommissioned and is currently in the seventh year of a post-decommissioning monitoring schedule with Cameco Corporation retaining responsibility for the site.

Transition Years

In the 1970's and early 80's, specially constructed tailings facilities were built at the Rabbit, Cluff and Key Lake mining and milling operations. These facilities were constructed above ground, with tailings decant water containment and treatment facilities.

The first appearance of a specially constructed uranium tailings containment structure in Saskatchewan occurred in 1975 at the Rabbit Lake operation on the west side of Wollaston Lake. The tailings management system involved the construction of two engineered earthen dams at the north and south ends of a natural topographic depression near the mill. The tailings were pumped from the mill to the tailings facility. Tailings decant water then was pumped from the tailings area, treated with barium chloride to remove radium, and allowed to settle in a precipitation pond. In 1977, this system was improved by the installation of a second precipitation pond and the addition of flocculant to aid in the settling. A further improvement in 1980-81 was achieved with the installation of a sand filtering system to treat the final effluent immediately prior to discharge to the environment.

The Rabbit Lake mill is still in operation, however, the original tailings area is no longer in use and a decommissioning plan for the area has been submitted to regulatory agencies for review. The plan consists of three elements; consolidation of the tailings mass, capping with a multi-layered cap for run-off and infiltration control and on-going monitoring.

After a detailed review by the Cluff Lake Board of Inquiry (Bayda, 1978), Phase I of the Cluff Lake mining operation instituted a complex waste handling strategy. Tailings, other mill wastes and contaminated water reported to an engineered tailings pond constructed in a muskeg lined topographical depression. Containment is provided by a dyke constructed of a local till and incorporating a soil-bentonite cut-off wall to reduce permeability.

Throughout it's operation considerable emphasis has been placed on effluent quality, with extensive secondary treatment and polishing of the effluent prior to discharge to the environment. In addition, uncontaminated surface water is diverted around the area and water usage is reduced by recirculating contaminated water back to the mill.

This tailings management facility is still in operation today.

The Key Lake tailings management facility, using sub-aerial deposition, was subject to a detailed review during the Key Lake Board of Inquiry in 1980-81 during which very specific objectives were outlined for the facility. The result is a totally engineered, designed and constructed above-ground-facility. No topographical features were incorporated in the design.

The Key lake tailings are contained within above ground, engineered and constructed embankments and base designed to achieve a drained and consolidated deposit of tailings. The tailings storage facility incorporates a filter blanket under the entire area of the stored tailings which is designed for the continuous collection of all free draining liquid in the tailings; a bentonite layer in the embankments and under the filter blanket to confine seepage and direct it to the seepage collection system; and deposition of the tailings in a. semi-dry form intended to achieve the maximum possible loss of retained liquid and minimum separation of fines to yield tailings a high density and low permeability. All seepage from the area is collected and directed back to the mill area for treatment before release to the environment.

This facility is still in operation today.

The conceptual decommissioning plan is to totally encapsulate the consolidated tailings by placing an engineered cap over the tailings area to direct surface runoff away from the tailings mass and to reduce infiltration rates.

Modern Era

In the mid-1980's, a below ground, and below water table, tailings facility was constructed at the Rabbit Lake site (1982) which offered many environmental advantages over previous designs.

The Rabbit Lake operations commenced with the mining of the Rabbit Lake orebody by open pit methods. Once that orebody was depleted, mining at the site continued with the development of the B-Zone orebody. As part of the continued mining and milling operations, tailings deposition into the original tailings management area ceased and the mined out Rabbit Lake open pit was converted into a tailings management system. A drift (tunnel) was mined out horizontally from the bottom of the pit and connected to a vertical raise (shaft) ascending to the surface near the edge of the pit. The drift was filled with crushed rock and layers of crushed rock and sand were placed on the bottom and sides of the pit. Tailings are placed within this layer and onto the crushed rock. Because the crushed rock is far more permeable than the rock of the pit wall tailings water follows the path of least resistance and flows through the crushed rock to the drift at the base of the pit. The contaminated water is then pumped up the raise and to the mill where it is reused in the milling process. Groundwater which may be flowing into the pit from the surrounding area also takes the path of least resistance, the crushed rock, and flows to the drift where it mixes with the decanted pore water and is pumped to the mill.

In this way, as long as the pumps are dewatering the tailings pit, the system is inherently safe because all natural water flows toward the pit, into the pervious surround and into the raise where it is pumped to the mill. Similarly, all contaminated water flows to the pervious surround and is likewise recovered and pumped to the mill.

At the end of milling, and after placement of the tailings is completed, the pumping and treatment of contaminated water will be maintained for a sufficient length of time to allow the tailings to consolidate into a relatively impermeable mass and the maximum amount of water removed. The original modelling for the decommissioning of the tailings area predicted a 25 year time period to totally decommission the area. Subsequent field measurements of consolidation rates of tailings within the operating pit show that the time period may be substantially less.

When optimum consolidation has been achieved the tailings will be covered with a layer of sand, followed by either a layer of rock or water cover, and the natural ground water system will be allowed to re-establish. The consolidated tailings will then be more resistant to water flow then the sand and gravel layer surrounding them. Natural groundwater flow will take the path of least resistance and bypass the tailings through the pervious surround material rather than flowing through the tailings and flushing contaminants from them. A simple analogy is that the consolidated tailings will be like a ball of plasticine within a layer of sand. Water will flow through the sand and around the plasticine (tailings).

Tailing management facilities incorporating in-pit pervious surround technology have become the preferred design alternative for new uranium mining operations in Saskatchewan.

Mining at the McClean Lake project, approved in 1993, will commence with the rapid mining of the JEB orebody with the ore being be stockpiled until the mill is constructed. The JEB open pit will be converted to a tailing management facilities incorporating in-pit pervious surround technology.

Currently, federal and provincial approval agencies are reviewing a proposal to convert the existing Deilmann open pit at the Key Lake operations into an in-pit pervious surround tailings management facility. In this case, the operator had identified that remaining capacity in the existing above-ground tailings management facility would be insufficient to accommodate the tailings from the milling of the remaining Key Lake ore.

ISSUES

Inherent in a discussion of reclamation and decommissioning in an extreme environment, or reclamation in any environment for that matter, is the assumption that the land forms and bio-physical systems which are constructed during reclamation and decommissioning will sustain a desired post-mining land use over time. There are two aspects to consider (i) difficulty of establishment, and (ii) difficulty of maintenance over time.

The land forms and bio-physical systems are constructed to;

(i) to render land disturbed by mining productive and compatible with the surrounding landscape/ecosystem; and

(ii) to mitigate the potential for mine effluents contained in engineered systems to enter the landscape/ecosystem.

Over time, the potential for natural physical and chemical forces to erode or destroy these man-made land forms and bio-physical systems increases. The public's concern is reflected in the increasing regulatory emphasis being placed on financial assurance/bonding mechanisms that are intended to minimize financial risk to the public purse should these man-made structures fail or deteriorate in the future.

Until recently environmental monitoring of uranium mines was conducted on a site-specific basis. As a consequence of issues raised during the Joint Panel review of proposed uranium mine developments, Saskatchewan has initiated a cumulative effects monitoring program to integrate the site-specific monitoring data into a single database. The province has established selected monitoring stations which will provide information to link the site-specific databases. Saskatchewan Environment and Resource Management has obtained the IMPACT model (Integrated Model for the Probabilistic Assessment of Contaminant Transport) and is currently working with the federal Atomic Energy Control Board to accurately calibrate and test the model for use in Saskatchewan. Data from existing operations as well as that which is currently being collected by the Cumulative Effects Monitoring Program is being used to calibrate the IMPACT model for Saskatchewan.

Public awareness of proposed uranium developments was another issue raised during the Joint Panel review of proposed uranium mine developments. In response to this issue, and in conjunction with the initiation of the cumulative effects monitoring program, the province has established a Northern Mines Monitoring Secretariat which co-ordinates information flow through Environmental Quality Committees to northern communities and First Nations. The Environmental Quality Committee consist of representatives from impacted northern communities and Indian Bands. Identification of "valued ecosystem components" is being conducted both through the use of the IMPACT model and through discussions with impact community representatives on the Environmental Quality Committees.

Industry has agreed to participate in the establishment of the Environmental Quality Committees which will meet regularly and review reports addressing the environmental status of developments, the status of construction and operation of developments, compliance with the terms and conditions of approvals and research activities concerning mine, mill and waste management issues.

As more decommissioning takes place at Saskatchewan uranium mines, the role of the Environmental Monitoring Committees will focus much more onto the issues of decommissioning reclamation and eventual approval for mining companies to abandon stewardship of the various properties.

SUMMARY AND CONCLUSIONS

Few examples of completed decommissioning and reclamation exist in uranium mining in Saskatchewan. This is in part due to the length of time uranium mines operate and to the issue of long-term containment of radionuclides.

The stability of a tailings management system is critical for long term environmental protection. Consequently the emphasis placed on system design during the pre-operational planning phase and on decommissioning and reclamation during the post-operational phase is paramount. The ultimate objective of tailings management is to achieve isolation of the tailings material within a confined space and, ideally, total elimination of both water and airborne contaminant emissions for a substantial length of time.

In practice, very small amounts of emissions are unavoidable. These emissions must be maintained at levels below the assimilative capacity of the receiving environment.

Realistically stated, therefore, uranium tailings management systems must use the best available technology to limit emissions to achievable minimum levels; levels which are comparable to the background emissions occurring in nature.

As can be seen in this brief description, tailings management has evolved over the past 40 years. Coupled with the development of new technology and improved management strategies for tailings is the extremely important enhancement of environmental protection that the new technology affords.

Today, before a facility is approved it receives a detailed regulatory review including an assessment of the ability to successfully decommission the area in the long term. During operations it is rigorously monitored with instrumentation and regular inspections by company officials and regulatory agencies. This monitoring continues for years after the facility has been decommissioned to ensure that it does not adversely affect the ecosystem or residents of the area.