AN OVERVIEW OF SASKATCHEWAN'S PROGRAM FOR THE ENVIRONMENTAL REGULATION OF URANIUM MINING

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INTRODUCTION

In 1977 the Cluff Lake Board of Inquiry was assigned the task of conducting a public assessment into the then proposed Amok Ltd. Cluff Lake project and on a more general scale the future expansion of the Uranium Industry in Saskatchewan. The terms of reference directed the Board to "review all available information" and to "receive public comment" in relation to the relevant questions. Consequently, the Cluff Lake Inquiry extensively examined both the technical and non-technical aspects of uranium mining in Saskatchewan. The Inquiry process was completed in May of 1978 with the issuance of the Cluff Lake Board of Inquiry Final Report. (3)

In summary the Board felt that uranium mining and milling could be pursued at Cluff Lake specifically and that the uranium industry could be allowed to expand in the province of Saskatchewan if adequate controls were instituted. From an environmental perspective the Board recommended that "The administration of the Pollution Prevention Regulations for the Mineral Industry, 1970, be transferred from the Department of Mineral Resources to the Department of Environment, which should be provided with sufficient field staff to perform compliance monitoring, inspections and evaluations". Consequently, the Mines Pollution Control Branch of Saskatchewan Environment was established in Prince Albert.

GEOGRAPHY

The major belt of uranium mineralization occurs in northern Saskatchewan, generally north of 57 degrees latitude. The area is remote, being more than 600 km north of Saskatoon. The mines are served primarily by air, with low standard roads serving the more recently developed mines.

Northern Saskatchewan lies in the Boreal or sub-arctic climatic region of Canada, typified by extreme temperatures and relatively low precipitation. Meterological data have been recorded at Cree Lake (57° 22'N. Lat., 106° 50 'W. Long.) since 1970. Extreme temperatures of +35° and -48° C were reported during that period. The mean total precipitation of about 460 mm of which 320 mm fell as rain. The mean annual temperature was -2.8° C. The mean annual freezing index is approximately 3100 C degree days and the mean annual thawing index is approximately 2000 C degree days.

GEOLOGY

All of the uranium mines are within the Canadian Shield, a glacially scoured complex of geologically ancient rocks. The oldest rocks are ancient Archean granites which comprise the basement complex. These are more than 2 billion years old. They are overlain and interfolded by a series of Aphebian aged (1.7 to 2.0 billion years old) metamorphosed, deformed and recrystallized sediments which were derived from the basement rocks. The Athabasca Sandstone Formation of Helikian age was laid down on the older rocks approximately 1 billion years ago. Uranium mineralization is usually near the contact between the Athabasca Sandstone and the older rocks, or within highly altered Aphebian rocks. Uranium mineralization is commonly associated with significant structures and with arsenic, iron, nickel, cobalt, copper, zinc, molybdenum, lead, vanadium, and sometimes thorium and selenium. A host of other minor minerals plus clay and graphite are commonly present.

The surface of the Precambrian rocks has been extensively scoured by glacial erosion and covered with a thin veneer of glacial and preglacial sediments. The elevation of the ground surface varies from approximately 213 m ASL at Lake Athabasca to a maximum of about 600 m ASL on local uplands. Local relief is generally less than 100 m. Glacial sediments are generally thin (less than 50 m) and comprised of coarse textured glacial till and outwash sand derived from the Athabasca Sandstone. Silt may be present locally, but clay is virtually absent. Topographic depressions are often infilled with peat. The entire area is within the zone of discontinuous permafrost, and the peat filled depressions often contain ice-rich, permanently frozen ground.

SURFACE WATER

Drainage patterns within the Canadian Shield are poorly integrated with numerous small landlocked lakes, many at elevated positions. Surface water has a very low mineral content, generally with a total dissolved solid content of less than 200 mg/L, and very often less than 100 mg/L. The pH of the water varies from about 5.5 to 8, but may be as low as 3 in stagnant muskeg areas.

HISTORY OF THE SASKATCHEWAN URANIUM INDUSTRY

Interest in Uranium began in Saskatchewan after F.J. Alcock of the Geologic Survey of Canada discovered pitchblende on the north shore of Lake Athabaska in 1934 (1). Based on this discovery further exploration was responsible for the development of a valuable resource based industry, however, the change in environmental protection

philosophy in uranium mining is evident when the evolution of tailings handling and treatment technologies utilized in Saskatchewan is reviewed.

The only consideration given to tailings containment by the early operations was that afforded by the natural topography. The only environmental protection available was that provided by the natural assimilative capacity of the environment. Deposition in existing lakes was selected as the most economic and convenient waste management system. No controls on effluents were incorporated.

The **Gunnar Mill** (52° 22' N. Lat., 108° 54' W. Long) operated from 1955 to 1964 using a conventional acid leaching circuit with ion exchange for uranium recovery. It produced about 5.5 million tonnes of unneutralized tailings which were deposited into Mudford Lake. Some tailings were placed underground but an estimated 4.1 million tonnes remain on the surface (14). The tailings were discharged at approximately thirty-two percent solids. Following the eventual filling of Mudford Lake to capacity, the tailings flowed from the point of discharge downslope into Langley Bay of Lake Athabasca. Due to the topography, three surface tailings deposits are exposed. The total area of the three exposed tailings surfaces cover an estimated twenty two hectares. The areas are referred to as Gunnar Main, Gunnar Central and Langley Bay.(10) The tailings are unreclaimed at a pH which is neutral or slightly alkaline.

The **Lorado Mill** (59° 33[N. Lat., 108° 30[W. Long.) was a custom operation which received ore from six major suppliers and some twenty five small-scale mining operations. The facility operated from 1957 to 1960 using an acid leach circuit, ion exchange with NaCl elution and magnesium diuranate precipitation. Approximately 360,000 tonnes of tailings were produced and discharged at pH 2 directly to Nero Lake. The Lorado site has an exposed dry tailings surface area of approximately ten hectares. No reclamation has been undertaken and the pyritic tailings have considerable acid generating potential.

The **Beaverlodge Mill** (59° 33' N. Lat., 108 30' W. Long.) operated from 1953 to 1982 using a carbonate leaching circuit and caustic precipitation. It produced 10 million tonnes of alkaline non-acid generating tailings. Approximately 4.3 million tonnes were backfilled into underground mines, leaving approximately 6 million tonnes deposited on surface, mostly in Fookes and Marie Lakes.

The waste management systems were upgraded in 1977 when Eldorado Nuclear Limited responded to environmental concerns raised by the Province by installing control structures and chemical treatment facilities on a three lake tailings effluent handling system. Radium removal was incorporated by treatment with barium chloride and ferric sulphate. Effluent quality monitoring was also undertaken.

The first appearance of a specially constructed uranium tailings containment structure occurred in conjunction with the start-up of the **Rabbit Lake Mill** in 1975. This impoundment consists of two engineered dams situated between till/bedrock ridges at the headwaters of a small drainage basin. The Rabbit Lake Mine (58° 15' N. Lat. 103° 40' Long) began operation in 1975 using an acid leach circuit, CCD thickeners and solvent extraction followed by ammonia precipitation. The mill feed averaged 0.37 percent U_3O_8, and the mill processed an average of 640,000 tonnes of ore per year.

The Rabbit Lake Waste Management Process involved pumping the tailing slurry into a main pond where at the end of its operational life contained approximately six million tonnes of neutralized tailings. The contaminated decant was initially treated with barium chloride and allowed to settle in a precipitation pond prior to discharge. In 1977-78, this system was improved by installation of an additional precipitation pond and the use of a flocculent to aid in settling. In addition, a mine water collection and handling system was installed to route mine water to the mill for use as process water. This was the first project to attempt separation of contaminated and fresh drainage, and to undertake some monitoring of groundwater.

The **Cluff Lake Operation** (58° 22' N. Lat., 109° 39' W. Long) consists of two separate phases. The environmental protection measures incorporated at this operation received detailed review by the **Cluff Lake Board of Inquiry.** Phase I of the Cluff Mining operation involved complex and special waste handling problems due to the high grade of the ore and the absence of a conventional mill effluent stream. This phase started in 1981 and mined approximately 54,000 tonnes of high grade ore from the "D" ore body, yielding approximately 3,600 tonnes of uranium. The milling process consisted of gravity concentration, acid leaching, and direct precipitation of the leach liquor with magnesia.

The mill process resulted in three waste streams. Gravimetric tailings were separated and stockpiled in lined ponds for subsequent reprocessing. Leach residues were placed in concrete vaults and were held in storage pending the outcome of a technical investigation into the identification of an appropriate disposal option. Neutralized waste solutions containing a minimal amount of precipitates were discharged to the Tailings Management Area. Mine water is collected and either used as process water or transported to the tailings pond. The engineered tailings pond is constructed in a muskeg filled depression containing sporadic permafrost. Containment is provided by a dyke constructed of local glacial till and incorporating a soil bentonite cutoff.

The decant from the tailings area is treated with barium chloride and a coagulant to precipitate radium from solution. Following further settling in a series of ponds, the effluent is polished by being passed through a dual media (sand and anthracite) filtration unit before discharge.

In addition, fresh water is diverted around contaminated areas and water usage is reduced by recirculating contaminated water in the mill. The complete waste management facility is a carefully planned and monitored system.

The **Key Lake Project** (57° 12' N. Lat., 105° 36' W. Long.) began milling operations in October, 1983. The Key Lake operation was subjected to public scrutiny by the **Key Lake Board of Inquiry** in 1980-81 (11). The objectives put forward during the design

of the waste management system were to provide permanent confinement of all solid waste materials with adequate factors of safety to ensure long-term stability; to eliminate all potential seepage pathways; to ensure that contaminated liquid will be intercepted and contained until such time as it can be recycled or treated to remove contaminants and render it acceptable for discharge; to provide an integrated layout of the mill, water reservoirs and tailings storage facility which would ensure that all accidental spillage of contaminated materials were contained; and to provide a safe and efficient decommissioning system. This was the first time these objectives had been clearly spelled out during conceptual design of a waste management system.

In response to these objectives an extensive waste management system has been installed. All potential contaminant sources such as ore stockpiles are contained in specially constructed structures to ensure all contaminated water, including mine water is collected and directed to two large, lined contaminated water storage reservoirs from which the water is used in the mill, or treated and discharged. The tailings storage facility was designed to achieve a partially saturated, drained, and consolidated deposit of tailings contained by embankments. The tailings storage facility incorporated a filter blanket over the entire area beneath the stored tailings to allow for continuous release of all free draining liquid in the tailings; a bentonite seal over the entire area beneath the filter blanket to confine seepage and direct it to the seepage collector system; and deposition of the tailings using a sub-aerial technique intended to achieve the maximum possible loss of retained liquid and minimum separation of fines to yield tailings with the highest possible density and lowest possible permeability. The bulk tailings are pumped to the tailings containment area at a bulk density of 26 to 32 percent solids. Uniform incorporation of the radium precipitates, heavy metals and other radionuclides into the tailings pile reduces their mobility and alleviates the problem of dealing with highly contaminated sludges when decommissioning. The liquid effluent is retained in monitoring ponds and checked for quality and compliance with license requirements prior to discharge, giving one final control measure. A concerted effort has been made to provide an integrated, secure waste management system.

The ore body is very high grade, containing approximately 2.5 percent U_3O_8 with high levels of heavy metals, arsenic and radium as contaminants, but with low thorium levels. The milling circuit, with a capacity of approximately 700 tonnes per day, consists of two-stage acid leaching and CCD thickeners and solvent extraction for uranium recovery and purification. Uranium is precipitated with ammonia and an ammonium sulphate crystallization plant removes ammonia from process streams to ensure acceptable ammonia levels in the final effluent. The ammonium sulphate crystallization step of the circuit reduces the ammonia levels in the effluent from 4000-10,000 ppm to an average level of 20 ppm. The waste solution treatment circuit includes bulk neutralization with lime followed by thickening and filtration of the waste precipitates. The filtrate from this first stage treatment is further neutralized and barium chloride is added for radium precipitation. Final dewatering is accomplished in a clarifying thickener. Clarified effluent is collected in monitoring ponds for check analysis prior to release to the environment. The waste products containing calcium sulphates and arsenates, are combined with the neutralized leach residue for disposal in the tailings area. Since the start-up of the facility in October, 1983 and until the end of 1987, this operation discharged approximately 6,500,000 cubic metres of treated effluent to the environment, with an average total Radium 226 content of 0.11 Bq/L. Operational and regulatory compliance monitoring demonstrated that habitually, all parameters were well below the water quality concentration limits specified in their operating license. Initially, treatment problems were encountered due to equipment sealing with gypsum. The company has remedied the situation by installing different or modified equipment and by increasing their maintenance program.

In early 1984 the Key Lake Mining Corporation experienced difficulties with the volumes of contaminated water available on site that required treatment prior to discharge. Consequently, the Company researched the feasibility of installing an ion-exchange treatment plant. Initial results were favorable and a radium selective process was commissioned in October, 1984.

The ion-exchange water treatment plant is a simple system utilizing a sand filter and two absorption columns. The initially proposed ion exchange material was Dow Chemicals Radium Selective Complexer resin (XFS-43230) in one column and Union Carbide's Synthetic Zeolite resin (IE-95) in the other. Based on performance and economics KLMC eventually charged both columns with the Dow Chemical Product. Provision is made in the piping and valve arrangement to operate the two columns in series if removal of heavy metals is required. The absorption columns are of the fixed bed down-flow type, although provisions are included in the vessel design to convert them to a moving bed continuous ion-exchange plant (CIX) with the minimum of modifications if conditions warrant CIX operations in the future (12). Operational effluent quality monitoring results indicates a 94% to 96% radium recovery with discharge values achieving a range of 0.09 to 0.17 Bq/L Ra-226.

In 1985 the **Cluff Lake Phase II** began operation. This operation is expected to recover approximately 12,500 tonnes of uranium from ore averaging about 0.5 percent U_3O_8 using conventional acid leach, CCD and solvent extraction circuits, followed by magnesia precipitation. (5) Mill capacity is approximately 230,000 tonnes of ore per year. The tailings and waste solutions are bulk neutralized with lime and pumped to the waste management area.

In order to maintain good effluent control, Amok Ltd. enhanced their tailings management area during Phase II modifications by the installation of a primary treatment system. This facility is situated on a newly installed "divider" dyke that effectively divides the tailings pond into "liquid" and "solid" areas. The solid area refers to the section of the tailings pond that receives liquid and solid waste streams and provides for initial settling. The Primary Treatment System has been designed to allow the addition of barium chloride and aluminum sulphate to the water pumped from the "solid"

section. Treated flows are settled in a small pond prior to entering the liquid side where the waters are stored prior to processing in the secondary treatment system and subsequent discharge to the environment. The primary treatment system has pH adjustment works available. The overall system has been designed to handle 1200 usgpm. Since the start-up of the facility in late 1981 and until the end of 1987, this operation discharged approximately 7,200,000 cubic metres of treated effluent to the environment with an average Total Radium 226 content of 0.18 Bq/L. Operational and compliance monitoring demonstrated that all parameters were well below the water quality concentration limits specified in the operating license.

During the construction season of 1986 the Amok tailings management area underwent modifications in order to allow the incorporation of the reprocessed Phase 1 leach tailings. During the Phase I milling a total of 6475 dry tonnes of leach tailings were generated. At that time the Company proposed to bury these concentrated tailings in concrete vaults as a form of disposal. This proposal was rejected by the regulatory agencies for various environmental reasons and the company was asked to develop an environmentally sound disposal plan. In the interim, Amok Ltd. stored this waste in 2916 specially constructed circular concrete vaults, each containing approximately one cubic metre. The vaults were stacked on a pad constructed specifically for this purpose as runoff collection and containment for chemical treatment is required. Typically the unblended leach tailings contained 6,000 Bq/g - Pb-210; 5,000 Bq/g - Th-230; 6700 Bq/g - Ra-226. After assessing several options ranging from burial in a mined out open pit to solidification Amok Ltd. elected to pursue a reprocessing option that would allow them to recover uranium and gold.

The Company reprocessed the leach tails through the existing Phase II mill over a period of 12 months commencing February 1987. The vaults were relocated to the mill and the contents dumped and reslurried for feed into a small CIP gold recovery circuit. From this the leach tails slurry was advanced to the Phase II uranium leach circuit where it was mixed with the regular mill feed and the uranium extracted with eventual tailings discharge to the Tailings Management Area. The reprocessed leach tails constituted 0.3% of the Phase II tailings discharged and upon completion of reprocessing the enriched leach/phase II tailings made up approximately 2% of the overall tailings mass that will be generated during phase II operations. Extensive environmental work was conducted by the Company to demonstrate that the dilution and eventual burial of the blended leach tails within the complete tails mass would provide the most reasonable approach for the disposal of a non-conventional uranium mill waste. This proposal was reviewed in detail by Saskatchewan Environment & Public Safety and a conditional approval was issued. Preliminary company reports indicate that 245,000 grams of gold, 38,811 kg of uranium, and 99,881 grams of silver was recovered from the reprocessed leach tails. (7)

In 1985 the Rabbit Lake Mill was modified by **Eldor Mines Limited** to process ore from the **Collins Bay B-Zone** ore body. The ore body was estimated at approximately 3,100,000 tonnes of ore with an average grade of 0.45% U_3O_8.(9) Circuit modifications were made to accommodate the varying mineralogy of the ore, particularly its arsenic content and other minor constituents. Changes to the circuit include use of strong acid stripping for solvent extraction, hydrogen peroxide for uranium precipitation, and modification to the waste treatment circuit for efficient removal of contaminants from mine water and mill effluents. The level of ammonia in the effluent had been identified as an environmental concern; consequently, ammonia was eliminated from the process.

An innovative tailings disposal scheme has been implemented for this expansion. The scheme consists of depositing partially filtered tailings in the Rabbit Lake Pit. The tailings are surrounded by a highly pervious zone that contains the tailings, while allowing the drainage of leachate radially and towards the base of the pit from where it is removed for treatment during operations. Underdrainage is maintained during operations to achieve consolidation, and to minimize the amount of leachate produced in the post-operational phase. The differential in permeability between the consolidated tailings and surrounding pervious zone should minimize the amount of water moving through the tailings, and the mass flux of contaminants from the decommissioned tailings pile. The need for engineered seepage barriers is avoided, and the mass flux of contaminants to the environment should be reduced to acceptable levels.

Since the implementation of this tailings disposal strategy began, extensive geotechnical and environmental monitoring has been required. Monitoring information available to date demonstrates that this facility is operating in accordance with the concepts put forward by the company during the Environmental Impact Assessment Review.

The Collins Bay ore body contained nickel and arsenic in sufficient levels to require additional treatment of effluent waters prior to discharge to the environment. Following the identification of this characteristic, Eldor Mines Limited responded by designing a water treatment system that could handle Collins Bay pit water, Rabbit Lake pit tailings consolidation water and mill process bleed solutions. Significant start-up problems were encountered with this system, however, the Company identified a pH control problem which has been satisfactorily remedied.

The Collins Bay mine water is transported to the mill via a heat traced and bermed pipeline. The mine water is utilized to a practical maximum in the process with the remainder being pumped to the Fe addition tank where the Fe/As ratio is balanced. The solution pH is adjusted to 8-9 normal in the lime addition tanks to enhance precipitation of Nickel and Arsenic. The mine water treatment circuit discharge is pumped to a metal hydroxide settling pond where the precipitates are allowed to settle with the aid of a settling agent. The water from this pond is pumped to the effluent holding tank where the pH can be adjusted to 8 with sulphuric acid. Barium Chloride and Flocculent is added and the water is allowed to overflow to the radium precipitate settling pond. From here the pond effluent is pumped to a sand filtration unit for polishing prior to discharge to the

environment (6). In the period from 1981 to the end of 1987, this operation discharged approximately 18,000,000 cubic metres of treated effluent to the environment with an average total radium 226 content of 0.14 Bq/L. Operational and regulatory compliance monitoring demonstrated that all parameters were well below the water quality concentration limits specified in their operating license.

POTENTIAL FOR THE FUTURE

Eldor Mines has indicated that with the present rate of production their Collins Bay B-Zone ore body will be exhausted by 1991. In June, 1987 the Company submitted an Environmental Impact Statement for review by Saskatchewan Environment & Public Safety that identified three new ore bodies that would extend the life of this operation into the 21st century. The Collins Bay A-Zone and D-Zone are small ore bodies which can be surface mined in two winters. The Eagle Point ore body located on Harrison Peninsula, is much larger and is expected to become a major underground mine for many years. On January 4, 1988 Saskatchewan Environment & Public Safety issued an Environmental Assessment Approval authorizing Eldorado Resources Ltd. to initiate implementation of their proposal. It is anticipated that these three ore bodies will yield 155.5 million pounds of U_3O_8 with average grades ranging from 1.8% (Eagle), 2.19% (D) and 5.6% (A). The tailings produced from processing the A-Zone, D-Zone and Eagle Point ore bodies will be disposed of in the Rabbit Lake in-pit tailings disposal facility. (8).

In May 1985 the **Cigar Lake Mining Corporation** was established. This joint operating company was assigned the responsibility of bringing into production the Cigar Lake uranium deposit, which is located at the south end of Waterbury Lake approximately one hundred and fifteen kilometers northeast of Key Lake. At the present time, it is the largest high grade uranium deposit in the world. Total reserves are estimated at 385 million pounds of U_3O_8 contained in ore that averages approximately 8% uranium. The orebody lies at a depth of 430 metres below surface and appears as a flat crescent shaped deposit 2 kilometers in length, 25 to 125 metres wide and has a thickness ranging from 1 to 20 meters.

On October 21, 1987 the Cigar Lake Mining Corporation received Environmental Assessment Approval from the Department of Environment & Public Safety to implement a test mine proposal. This is the first step in their plan to develop and operate a uranium mining complex at Cigar Lake. The test mine project will involve sinking a vertical shaft to 480 metres depth; lateral development of two horizontal drifts to provide access to the orebody; stoping tests of three alternative mining methods within the orebody; and development of surface facilities to support the test mine. Stoping tests will be performed on the raise boring, blind drilling and undercut/fill mining methods. The project is scheduled to take 2 1/2 years. (15)

Due to the rich ore grade and anticipated poor ground conditions it is expected that the Cigar Lake Mining Corporation will have to develop well planned and innovative methods to satisfy the various occupational health/safety and environmental requirements.

In March 1988 **Dennison Mines Limited** as operator of the Midwest Joint Venture, submitted a preliminary Environmental Impact Statement to the Environmental Assessment Branch for the purpose of conducting a test mine at the Midwest orebody. This resource is located beneath the southern end of McMahon Lake 700 kilometers north of Saskatoon and 30 km west of the Rabbit Lake Mine. Midwest Joint Venture ore reserves are estimated at 50 million ponds with an average grade of 1.25% (16). The orebody is approximately 180-200 metres deep with an approximate length of 900 metres, 135 metres wide and 36 metres thick. A test mine has been proposed in order to confirm geological and hydrogeological information while allowing the performance of a blind hole boring test such that a determination can be made as to the appropriate production mine strategy and design. A shaft and upper cross-cut will be developed. It is estimated that the test mine will take two years with the intent of having a production decision available by the end of 1990.

As of June 1988 **Minatco Ltd.** is considering the feasibility of developing the McClean Lake deposit. As they are in the early stages of planning, minimal information is available, however, Canadian Occidental Petroleum Ltd. has published drill estimated reserves for the McClean North and South Deposits as being 14 million pounds of U_3O_8 at an average grade of 1.8% (17).

ENVIRONMENTAL IMPACT ASSESSMENT

In the event that a new mining operation is proposed or a significant expansion is identified at an existing operation, the proponent must first gain approval from the Minister of Environment & Public Safety under the provisions outlined in the Environmental Assessment Act (1980). Proponents normally file an Environmental Impact Statement with the **Environmental Assessment Branch of Saskatchewan Environment and Public Safety.** This group, in consultation with an inter-departmental review panel, assesses the proposal at a conceptual level to ensure that all potential environmental impacts have been identified and mitigative measures developed such that the detrimental effects of the proposed operation are kept to a minimum. Under this review, Environment includes both the bio-physical environment and social, economic, and cultural conditions. With regard to a mining operation, occupational health and safety is closely scrutinized under advice from the Saskatchewan Department of Human Resources, Labor and Employment.

Proponents are required to undertake a public participation program as early as possible in the preparation of an EIA so that the public's comments and recommendations may be considered during the final preparation of the EIA (4). When the Environmental Assessment Branch considers the EIS acceptable, public notice of receipt of the EIS is given with a list of places where the EIS and the department's technical review comments may be inspected by the public. A minimum 30-day public review period is required, although the Minister may extend this to 60 days. Within the time specified, any person may make a written submission to the Minister about the development or the EIS. At any time, the Minister may establish a Board of Inquiry

or require local information meetings to be conducted. If the Minister establishes a Board, it holds public hearings to review those issues contained in its terms of reference, it receives public comment on those issues, and submits to the Minister a report containing its recommendations. When the Minister is satisfied that the proponent has met with all the requirements of the Environmental Assessment Act he will either give Ministerial Approval to proceed, with or without conditions, or refuse to approve the development. After receiving an approval for a mining development the proponent then proceeds to obtain approvals required under legislation administered by the Mines Pollution Control Branch.

With regard to a mine/mill proposal, should the proponent be successful in receiving approval to proceed, the proponent is required to negotiate and sign a surface lease with the Province of Saskatchewan. This lease contains, but is not limited to, specific requirements related to environmental protection, decommissioning, occupational health/safety, and land use.

SASKATCHEWAN ENVIRONMENTAL REGULATORY PROGRAM

The **Mines Pollution Control Branch of Saskatchewan Environment & Public Safety** is responsible for ensuring that satisfactory environmental protection measures are in place at all Saskatchewan mine sites. The Uranium Section of this organization has been assigned the task of administering the licensing and inspectorial aspects related to Saskatchewan's uranium and gold industry.

Within the Uranium Section, each Uranium Operation under environmental scrutiny is assigned a Project Officer who in turn reports to the section Manager. At present the section is responsible for eleven uranium properties that are in various stages of exploration, construction, production, or decommissioning. A primary responsibility of the project officer is to ensure that they are intimately familiar with the operational and environmental status of their assigned property. This is achieved through the licensing process, regular site inspections, in-depth knowledge of site activities and Company generated reports. Most essential is a clear understanding of the trends that are available within the environmental data base for that site. A thorough compilation, review and interpretation of the environmental data base must be performed which includes but is not limited to the baseline data and environmental assessment predictions; trends within the operational monitoring data mass balance calculations; seasonal trends within the data base; and trends within the monitoring information for effluent discharge sites and receiving waters. It is very important that an ongoing evaluation of the environmental data be conducted.

Regular site inspections are the primary mechanism utilized to fulfill our mandate. Every operating site is inspected at least once per month and more often should circumstances dictate. Co-operation from on site operational personnel is generally good, consequently we are better able to assess the site on an environmental basis while at the same time, keeping our observations in perspective.

While on site, the project officer's primary responsibility is to ensure that all environmental conditions relevant to that site are being adhered to. These conditions range from those specified in the operating license to those having arisen from the Environmental Assessment and Surface Lease activities. The operational status of all waste collection handling, treatment and disposal facilities are inspected. These areas are mainly related to tailings management, contaminated water control, ore storage, waste rock disposal, site specific problem areas and on occasion, spill investigation. Also included in the inspection schedule, is a review of the companies environmental monitoring programs. This involves discussion with on site environmental personnel and the inspection of the monitoring equipment being utilized. Once a project officer has assured himself that he has addressed all areas of environmental consequence at an operation, he conducts compliance water quality sampling. We primarily sample the final point of control or discharge of liquid effluents to the environment, however, we do sample anywhere on the property or receiving waters should it be deemed necessary to improve our understanding of the environmental status of an operation or verify the Company's monitoring information.

Upon completion of an inspection the inspector usually discusses his findings with the company's Manager of Operations, prior to his leaving the site. Once back in the office an inspection report is prepared. The Company is notified of our site evaluation and any problem areas or infractions are highlighted for remedial action. For future reference, an extensive time logged photographic library is maintained.

It must be realized that a large volume of environmental data is generated by each operation. Although mainly effluent and surface water quality oriented, extensive data is collected by the Company for radiological, hydrogeological, air, sediment and biological aspects . The specifics for these monitoring programs are laid out in detail within the operating licenses, however in addition to this required monitoring, every Company conducts varying forms of monitoring to assist in their operational planning. Also the environmental data base is bolstered by the compliance monitoring conducted by the Mines Pollution Control Branch. During the 1987 license term, the Uranium Section conducted 50 inspections at the licensed uranium sites. During these visits 108 compliance surface water quality samples were collected from 21 locations with 3685 analyses being performed.

In addition to the other regulatory responsibilities, the section is encouraged to identify potential environmental concerns or problem areas at the assigned mine/mill sites. These concerns are not immediate in nature as they would be addressed in the license, rather they are potential problems that fall in the "unanswered" category. Where necessary, in order to ensure the integrity of the study, external expertise and assistance is solicited from government or private organizations. The Company is kept fully informed of our intentions, study status and conclusions. it is our desire to involve the operator in these studies where able, by establishing a jointly funded and staffed project. The final conclusions of these

specific studies is expected to improve everyones knowledge and understanding of the operation under environmental surveillance.

Two types of regulatory documentation is utilized by the Mines Pollution Control Branch to enforce environmental affairs at a mine/mill facility, namely Construction and Operating Approvals. Construction Approvals are self explanatory and are issued to a proponent authorizing the construction of waste handling and treatment facilities after the Department has conducted a detailed review of the Company's application. This Approval may or may not contain specific conditions, however, they always require the submission of "As-built" drawings after construction is complete.

Permits to Operate are issued pursuant to the Environmental Management and Protection Act and the Air Pollution Regulations. These documents are set to expire on an annual basis. Prior to expiry, the Mines Pollution Control Branch initiates a thorough and detailed compliance review of the environmental status of the operation. Based on this review a draft license is prepared and subsequently discussed with the Company prior to final authorization by Senior Department staff.

Typically, a license will contain operating conditions common to the industry as a whole, site specific operating requirements, and detailed environmental monitoring programs for effluent control, surface and ground waters, sediments, biological media, and where applicable, gamma radiation and radon monitoring. The licenses also require report submissions for monthly monitoring results, an Annual Environmental Report and various site specific problem oriented reports.

The licenses are very comprehensive documents and form the basis of our regulatory program. The public has access to the licenses and any monitoring information that is submitted to the Department as a result of license requirements. Our regulatory approach is based on co-operation with the operator. In order to make this philosophy work in a real world situation, the onus is on our Branch to be firm and consistent in our efforts to protect the environment. To date this approach has worked well, largely due to the fact that in Saskatchewan we have a Uranium Industry that is committed to protecting the environment. Besides having the will and the technology to provide these control measures, the Industry is fortunate in having richer ore grades on a world scale that provides the financing for well designed and constructed environmental protection facilities.

During 1988, the Department of Environment and Public Safety will be approaching the Saskatchewan Mining Industry as a whole with a comprehensive set of regulations entitled The Pollution Prevention Regulations For The Mineral Industry 1988. We found it necessary to redraft the previously available legislation due to its inappropriateness for Saskatchewan's updated, modern and expanding mining industry. Our Department is committed to discussing the draft regulations with the industry prior to final document preparation and promulgation.

QUALITY ASSURANCE

Significant sums of money are expended by the Industry and Regulatory agencies to measure and document the environmental impacts associated with a Saskatchewan Uranium mine. Extensive problems can be encountered if insufficient quality control is exercised in the field, in the laboratory or in data handling (13). These problems may be simple in origin, however, the repercussions associated with invalid data are often extreme. These problems can be resolved by implementing environmental monitoring programs that are well planned in conjunction with adequate quality control programs.

For the uranium industry in Saskatchewan, I estimate that a minimum of 700,000 dollars is expended annually by the uranium operators and our Department on surface and ground water analytical costs alone. This estimate does not include the funding for the design, construction and operation of environmental protection facilities or the staff involved. During the 1987 license term, the three operation uranium sites collected 1408 surface and ground water quality samples from 193 specified sites. As a result of this sampling 20,695 analyses were performed and the data submitted to the Department. These values do not include statistics for air, sediment, biological or spill response monitoring or the monitoring conducted by our branch.

One method of enhancing the reliability of the data base is to ensure that a carefully planned Quality Assurance and Control Program is in place for a specific monitoring program. For example, in 1985 significant negative public pressure was placed on the Eldor Mines Rabbit Lake operation and our Department. This activity was largely attributable to inconsistent and unreasonable data that had been generated and allowed to reside in the environmental data base. In order to avoid a similar situation in the future, Eldorado Resources Limited and our Department agreed upon a Quality Assurance and Control Program. A report submitted to our Department by this Company focuses on Quality Assurance sampling methodology, detection limits, reporting procedures and audit of environmental data. Our Department supports this initiative. We have required our contract laboratory to supply our Department with a similar report. Internally we have reemphasized the need for consistent field procedures and data handling within our branch. Also, to ensure an industry wide response, we have inserted a requirement into the operating licenses that instructs all Operators in the province to establish a similar program and review it on an annual basis.

Another area of caution relates to interpretation and how "less than" values are utilized. Many public concerns have been traced to misinterpretation and misuse of "less than" values. Data submitted utilizing a "less than" value but a high detection limit can be interpreted many different ways. Therefore, it is also essential to ensure that appropriate detection limits are being utilized for the purpose identified. Data relating to the Saskatchewan Surface Water Quality Objectives (receiving waters) would require a detection limit of at least equal to 1/2 of the guideline value or preferably one order of magnitude less than the

objective. Ongoing review of detection limits, duplicate and replicate sampling, laboratory and field procedures and data entry accuracy is an important part of an environmental protection program.

In our efforts to ensure that a comprehensive and well designed monitoring program is contained within the operating licenses, we initiated a detailed internal quality assurance review of our monitoring requirements and strategy in early 1987. In order to assist our review, we consulted various technical and research experts such that they could assist us in critically reviewing the monitoring requirements we presently have in place. After extensive deliberations, it was evident that we could improve the quality and usefulness of the environmental information collected via the licensing program by making a few subtle changes. As we are in the middle of this review, all of the details are not yet available, however, our main thrust will focus on proper site, media and parameter selection; sampling frequency; proper sample collection, preparation and preservation; proper analytical technique and detection limits; a re-emphasized focus on quality control and assurance; toxicity testing; electronic data transfer; revised reporting intervals for monitoring information and environmental status reports. Guideline documentation will be prepared and made available to those involved in order to ensure consistency and continuity within a particular operation as well as within the mining industry as a whole. Emphasis will be placed on structuring the reporting such that each mine site conducts a detailed review and prepares a "State of the Environment" report at predetermined intervals such as every third year. This report will compare actual operational environmental monitoring data with predictions made during the Environmental Impact Assessment stage. Besides documenting environmental actualities and trends, this report will assist the operator in updating his Conceptual Decommissioning Plan at the same time.

As this approach to environmental monitoring will require the full co-operation of the mining industry in order to be successful, we will be discussing our draft guidelines and approach with them prior to finalization and implementation.

ENVIRONMENTAL EXPERIENCE

Since the creation of the Mines Pollution Control Branch in 1979, a lot of time and effort has gone into conducting an in depth environmental surveillance program for the Saskatchewan uranium industry. Given the potential for environmental contamination that is available, this scrutiny is warranted, however, the industry has to be credited for the effort they expend in order to ensure that they cause minimum environmental disruption while developing and recovering the valuable uranium resource. Generally, our inspections and compliance monitoring indicate that the industry consistently adheres to the environmental requirements specified in their assessment, construction, operational and decommissioning approvals. When problems are encountered, the situation is usually promptly analyzed and remedial action is implemented. However, given the complexity of some situations, extensive study and engineering is often required prior to the initiation of a response plan.

On occasion, we encounter situations that require analytical expertise other than that available in house. In those circumstances, we will solicit the services of a qualified consultant in order to ensure the best possible solution is made available for the protection of the environment.

One event that received national media attention was the Key Lake spill which occurred on January 5, 1984. On this date, 87,300 m^3 of untreated minewater overtopped number two reservoir causing a containment berm failure. The contaminated waters were contained on site and remedial action involved retrieving the spilled waters and retaining them in storage for re-use in the mill and eventual treatment prior to discharge to the environment. In order to avoid a similar situation occurring in the future, the Company made extensive water management and equipment alterations. From an environmental perspective, follow-up monitoring has demonstrated that there will be no long term impact to the environment due to this incident. This would not have been the case had the company and our department not been in a position to quickly respond to an emergency situation.

As a way of confirming our own environmental projections with regard to a particular operation, we will on occasion retain a recognized expert to independently inspect the property and review the environmental database. In essence, this is another form of internal quality assurance and control.

In 1985 Dr. Don Lush of Beak Consultants Limited was commissioned by the Mines Pollution Control Branch to review the environmental status of the Wollaston Lake receiving waters after ten years of receiving liquid effluents from the Eldor Mines Rabbit Lake Operation. Following his review of all environmental data and reports made available by the Company, Saskatchewan Environment, Saskatchewan Research Council, National Uranium Tailings Program, Environment Canada and several private consulting companies, he prepared a report entitled "An Environmental Evaluation of the Effects of the Eldor Mines Rabbit Lake Operations on Wollaston Lake" (13).

This assessment was thorough and all encompassing. The report includes a review of water quality criteria and provides background information regarding the development and selection of these criterion, particularly for radionuclides and such trace elements as uranium, arsenic, copper, lead, nickel, selenium, vanadium and zinc. A summary of the environmental monitoring data is provided with emphasis being placed on water quality, sediment quality and fish tissue analysis. The significance of monitoring results is discussed with regard to the effects on the aquatic environment and local human populations. Specific areas addressed were dilution in Hidden Bay and Wollaston Lake; radiation effects on the aquatic environment chemical effects on the aquatic environment; and the assessment of chemical effects and radiological risks to humans in the area.

The report also presented technical recommendations with a view to improving the handling and assessment of the environmental

database and monitoring program. All of the recommendations provided in the report have been implemented on an industry wide basis by our Branch.

As an overall conclusion the report states that "on the basis of the available data, the operation of the Rabbit Lake uranium mining and milling operation has had no significant nor discernable effect on the aquatic ecology, fishery or any other use of the waters of Hidden Bay or Wollaston Lake."

DECOMMISSIONING

It has been a practice of Saskatchewan Environment & Public Safety to encourage proponents to design decommissioning into a newly proposed project. It is our firm belief that if the concept of decommissioning can be implemented at the design stage and carried through the life cycle of a facility then subsequent environmental, operational and financial benefits will be realized. In support of this, the Mines Pollution Control Branch stresses the need for two actions on behalf of the operator. First it is essential to have on hand an approved conceptual decommissioning plan for all aspects of the operation. As the mine/mill facility changes, the conceptual plan should be modified and updated as necessary. Secondly, we require the early decommissioning of a facility or disturbed area that will no longer be utilized within an active operational site. Experience shows that quite often a defunct yet serviceable facility can often be rehabilitated to satisfy a different on site need. If this rehabilitation is not feasible, early decommissioning of an unused facility avoids ongoing maintenance costs, and where applicable, allows a period of post-decommissioning monitoring while the operator is still present to conduct remedial work should it be deemed necessary.

The Mines Pollution Control Branch views the concept of decommissioning as being a progressively phased process that once initiated leads to the satisfactory environmental reclamation of a mine/mill facility with the ultimate abandonment of the property by the operating company. As previously mentioned, the design stage and the conceptual decommissioning plan are the essential building blocks in this process. Once a shutdown decision has been finalized by the operator, it is necessary to perform the final modifications to the conceptual plan such that it can now serve as the final decommissioning plan for the complete mine/mill facility. Once the final plan has been approved by the Regulatory Agencies the operator can proceed to implement the various activities necessary to reclaim the site. Following satisfactory completion of this work the site is allowed to stabilize during a transition monitoring phase which usually lasts for a minimum of five years. During this time the operator continues to be responsible for the site with the primary activity relating to monitoring and inspections. After the transition monitoring has been completed, the Company prepares a final post decommissioning environmental report which outlines the performance of the site as a whole, following reclamation activities. In the event that the site has recovered as predicted, the Minister of Environment & Public Safety will authorize the final abandonment of the property by the operator. At that time, institutional control is put in place for the decommissioned uranium facility.

This form of control is necessary to ensure that unauthorized activity on the decommissioned lands will not jeopardize the environmental or public safety of the site. In the event that future remedial action is required, the Government of Saskatchewan has available the "Environmental Protection Division" of the Heritage Fund. The money for this fund was initially derived from provincial revenues and is available for cleanup of unforeseen problems which may arise at an abandoned uranium mine/mill site.

To date, Saskatchewan has been the site of the most intensive decommissioning project related to a uranium mine/mill shutdown in Canada. The decommissioning process previously described was employed for this site. In June 1981 Eldorado Nuclear Limited submitted a conceptual reclamation plan to the regulatory agencies. Some discussion about the plan had occurred prior to the announcement on December 3, 1981 that the Beaverlodge operation would be shut down. Thereafter, the Company and the regulatory agencies began in earnest to develop an acceptable decommissioning and reclamation plan for the facilities.

After almost 30 years of continuous mining and milling, the facilities in the Beaverlodge area were closed on June 30, 1982 when decommissioning activities were initiated. Over the period of operation, the facility produced 10 million t of ore and some 20 million Kg of uranium, 10.1 million t of mill tailings and 4.8 million t of waste rock from its Fay-Verna and satellite mines. Some 40 percent of the tailings were used as backfill in the mine and 60 percent were deposited using shallow lake disposal, in three natural lake basins (2).

Efforts to decommission this site were complicated by the fact that environmental protection measures were not implemented until late in the operational life of this facility. Provincial criteria for the decommissioning of this facility were stringent and in part required that the Saskatchewan Surface Water Quality Objectives (1983) be met at specified locations in the affected watersheds. Consequently, extensive work was conducted by the Company in order to identify problem areas, assess the environmental status, develop mitigative actions, prepare an all encompassing final decommissioning plan and implementing the required actions. Reclamation activities were completed in June 1985. Subsequently, two water control structures failed. New re-designed structures have been installed. Transition phase monitoring to date indicates that the site is responding as predicted.

Following the experience gained at Beaverlodge, Eldorado Resources Ltd. began in 1983 to plan the eventual decommissioning of the Rabbit Lake Tailings Management Area. A conceptualized plan has been developed and site studies are being done to assist in the development of a final plan scheduled for implementation in the early 1990's. While this work is in progress, the tailings mass is being dewatered as it has been estimated that three years of desiccation will be required before sufficient consolidation has occurred to permit final reclamation of the site.

One of the conditions in the Environmental Impact Statement approval issued on January 5, 1988 for Eldorado to develop the A-Zone, D-Zone and Eagle Point uranium deposits was that the company must develop a decommissioning plan for the open pits that encroach on Collins Bay prior to the initiation of mining. This report is in preparation and will be submitted to our Department in late 1988.

In October 1986 Amok Limited submitted a conceptual decommissioning plan for their Tailings Management Area. The Company has based their planning on the premise that retardation and radioactive decay mechanisms are available to attenuate the concentration of Radium-226 released from the tailings impoundment (18). Ongoing research is being conducted by the Company and the Conceptual Decommissioning Plan will be updated as new information becomes available. To date, Amok Limited has rehabilitated ore storage facilities into mine water handling works and are also monitoring the decommissioning of the mined out D-Pit area.

In 1987 the Key Lake Mining Corporation's Gaertner pit was mined out. While preparing an adjacent ore zone the Company partially backfilled the Gaertner Pit with the available overburden. In conjunction with this, the dewatering system has been modified to allow partial flooding of the pit while protecting the nearby Deilmann dewatering capability. The Company is presently investigating and assessing the various close-out options available for the Gaertner Pit and should be submitting a final decommissioning plan to our Department in the near future.

CONCLUSION

Since milling of uranium ores began in Saskatchewan in 1953, in excess of 20 million tonnes of tailings have been produced, and in excess of 16 million tonnes of these remain on surface. The technology and operating methods for the waste management systems has improved greatly in the intervening period and a high level of performance is expected from both existing and proposed operations. Regulatory experience indicates that existing operations are consistently meeting environmental objectives. Technological and operational improvements for the purpose of environmental protection are expected as additional experience is obtained. While the production potential for the future looks very promising, the higher grade prospects will pose their own unique problems. In order to ensure that a high level of environmental protection is maintained within the uranium industry, it is essential that a firm and co-operative regulatory approach be conducted in conjunction with industry initiative and innovation.

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