CANADIAN EXPERIENCE WITH URANIUM TAILINGS DISPOSAL

INIS-mf--9589

BY: K. B. CULVER - RIO ALGOM LIMITED

INTRODUCTION:

No matter what we produce or manufacture in this world, be it food, clothing, metals, petroleum products or energy, waste is produced as a by-product. The disposal of the waste product may be as technically simple as garbage collection from your household and burial in a land-fill site or as politically complex as irradiated fuel bundles from a nuclear power generation station. In the mining industry this waste product is called tailings, which in simple terms represents finely ground rock from which a large percentage of the economic mineral product has been removed. Unfortunately, the mineral content of a ton of rock is generally low, so that large quantities of rock must be treated to meet society's requirements.

TRANSPARENCY 1

For instance, the Lornex mine, a large open pit copper producer in B.C. recovers 7.5 pounds of copper from each ton of rock. Thus, for each 2,000 pounds milled they must dispose of 1992.5 pounds of rock, or tailings. Since they only recover 90% of the copper, the tailings contain 0.83 pounds of copper. Lornex is currently milling in excess of 80,000 tons/day. A typical gold mine will recover 0.29 ounces of gold per ton of rock treated and disposes 1999.93 pounds of tailings. At the uranium operations in Elliot Lake, approximately 1.6 pounds of uranium are recovered per ton of rock treated and 1998.4 pounds of tailings are disposed. Since only 94% of the uranium is recovered, the tailings contain 0.11 pounds of uranium -238. They also contain approximately 4.8×10^{-5} lb/ton thorium -230, 9.4×10^{-7} lb/ton radium -226, 11.4×10^{-9} lb/ton lead -210 and 0.6 lb/ton of thorium -232. Radon daughter measurements taken 3 feet above ground at the Nordic tailings ranged from 0.003 to 0.011 Working Levels. Gamma readings averaged 0.13m R/h. Radon measurements averaged 18pCi/l.

Today, the Canadian uranium industry is milling approximately 32,000 tons per day giving rise to the production of some 11.5 million tons per year of tailings.

Throughout Canada, today, approximately 145 million tons of uranium tailings have been deposited. About 120 million tons are contained in surface deposits in Ontario primarily in the Elliot Lake area, while the remaining 25 million tons are in Saskatchewan. While these quantities may appear quite large, it is interesting to note that in the Province of Ontario, over 1.2 billion tons of tailings have been produced from other mining operations.

In reality, Canadian experience with uranium tailings is probably no different than that with tailings produced by other mining operations. A number of problems are common including method of containment, stabilization to prevent wind and water erosion, control of net acid generation and leaching of various chemical constituents, treatment of tailing effluents, etc. It is only the higher content of radioactivity that distinguishes uranium tailings from other mine tailings. Canadian experience with uranium tailings disposal is probably best illustrated by reviewing the historical development of tailings disposal in Elliot Lake and the parallel development of the regulatory and environmental aspects over the period 1955 - 1982.

TRANSPARENCY 2

HISTORICAL DEVELOPMENT

TRANSPARENCY 3

During the period 1955 to 1958, eleven uranium mines were brought into production in the Elliot Lake area and some nine tailing sites were developed. Stanleigh and Milliken shared a common site as well as Stanrock and Can-Met. In general, the tailings were deposited in the nearest valley, swamp or lake. At the time, this was the standard method for disposal of tailings within the mining industry. Lakes and valleys were natural receptors which required little if any capital expense to build dams for containment of the tailings, or plants for treatment of the tailing effluents. Containment dams, when built, were constructed of local sand and gravel or waste rock derived from the underground operations. They were seldom built to an engineered design and no geotechnical data was collected to assess foundation conditions and potential seepage and groundwater pathways. There were virtually no federal or provincial regulatory requirements for site selection studies, for design of dams or for the quality of effluent discharged from the tailings area.

Since sulphuric acid was being used to dissolve the uranium bearing minerals and nitric acid was being used to strip the uranium from the ion exchange columns, the tailings were neutralized with lime to a pH of approximately 8 prior to discharge to the tailings basin. Effluent discharged to the surrounding waters from the tailings basin was not treated.

INITIAL SURVEILLANCE:

Chemical and physical examination of tailings effluents and of receiving waters was begun in 1957 on a routine basis by the Ontario Water Resources Commission (OWRC). During the summer of 1958 the Industrial Hygiene Branch of the Ontario Department of Health undertook a program of surveillance of radioactivity in the public water supplies of Elliot Lake and Bancroft areas. In the fall of 1961 general sampling surveys were conducted on a number of lakes and streams not associated with flows from the tailing areas. A special reconnaissance survey of the Serpent River watershed was carried out in 1963. During the period 1957 to 1964 a total of 1,588 samples from the Elliot Lake area were examined for radium -226 and/or uranium -238. Uranium -238 concentrations in receiving waters were well below maximum permissible levels. However, radium -226 levels, which were considered border-line or below recommended permissible concentrations in 1958-59, were considered excessive in certain lakes and streams in 1965. This was due, in part, to an increase of approximately two times in the actual concentrations in these lakes between 1959 and 1965, and in part to a lowering of the recommended maximum permissible concentrations for radium -226 by a factor of four. The surveillance programs also indicated significant pH depression occurring in these same lakes.

TRANSPARENCY 4

This transparency shows representative radium -226 concentrations in a number of lakes during 1959 and 1964. Mine water being discharged to Quirke Lake, Pecors and North Nordic Lake were the primary sources of radium, with seepages and effluent discharges from the tailings being the secondary sources.

THE DEPUTY MINISTERS' REPORT:

As a result of a Reconnaissance Survey Report being released by the OWRC in November, 1964, a Committee of Deputy Ministers was established to seek a full assessment of the radiologic problem, its implications and means of solution. The Deputy Ministers' Report was issued in November, 1965. This report conclude that certain public waters in the Elliot Lake and Bancroft areas had been contaminated by low level radioactivity as a result of waste disposal practices which were standard within the mining indust There was no danger to persons drinking the waters in question over the short-term. However, improved waste control measures were needed to reduce the levels for the long-term. Further, it appeared that provincial statutes were in-operative in view of the authority assigned to federal agencies under the Atomic Energy Control Act. The report recommended that:

TRANSPARENCY 5

- the jurisdictional issue be resolved;
- concentrations of 3-10pCi/l of radium -226 be adopted as initial objectives to be attained in public drinking waters in the Elliot Lake and Bancroft areas;
- the Province work with the uranium mining industry to seek practical means for control of radioactivity and to establish sound design criteria for impoundment and effluent treatment works;
- a detailed investigation of the effects of uranium waste disposal on surface water quality be initiated and the monitoring program be expanded and extended on long-term basis.

RESEARCH AND REGULATORY DEVELOPMENT:

six twelve

By 1960, ~~five~~ of the eleven uranium mines were shutdown. By the end of 1964 only two uranium mines were operating (Denison and Nordic) as the uranium market collapsed. In 1963, the discharge of mine waters to surface waters was either discontinued or the mine water was neutralized prior to discharge. During 1963 and 1964 research was initiated into the use of barium chloride as a precipitating agent for the control of radium. In 1965, a barium chloride treatment plant was installed at the Nordic tailings area and successfully operated until the mine closed in 1968.

From the mid sixties to the mid seventies, a number of water quality studies were undertaken in the Elliot Lake area by the OWRC. These studies indicated that effluent discharges and seepages from the uranium tailings areas were causing further degradation to the upper reaches of the Serpent River water system. Radium -226, pH depression, total dissolved solids (TDS), ammonia and nitrate were the primary concerns.

In 1968, the Quirke Mine was re-opened and an application was made to the OWRC to expand the Budd Lake tailings area. Approval was granted in 1969 and the main dam and the west dam, were the first engineered dams to be constructed in the Elliot Lake

.... 6

area. The completed facility included barium chloride treatment and

SLIDE 1

precipitation ponds for radium removal, and a lime treatment plant for pH control. Similar effluent treatment facilities were

SLIDE 2

established at the inoperable tailings areas and Denison shortly thereafter. Since the installation of these controls, radium -226 levels in Quirke Lake have dropped to the 4-5pCi/l range and pH has increased to 5.5 .

TRANSPARENCY 6 - This transparency illustrates the efficiency of the radium -226 removal.

In 1969 Rio Algom started a research program to assess the use of vegetation as a means of stabilizing the tailings. The primary objective was to control dust and water infiltration. Initial field trials were very disappointing because of low pH conditions and lack of nutrients. Ongoing research was aimed at finding ways of neutralizing the acidity of the tailings surface, fertilizer application rates and determining suitable varieties of grasses and legumes. Field test programs were carried out in 1971, 1973 and 1977. In 1978 an extensive program was carried out to revegetate Nordic, Pronto and Lacnor, a total of 310 acres. By 1980 a self-sustaining, vegetative growth was well established. Suspended particulate and dustfall in the immediate vicinity of the tailing areas were reduced to approximately 1/5 of the MOE criteria which are $60 ug/m^3$ and $55 g/m^2$ respectively. We were not as successful in controlling water infiltration.

SLIDES 3, 4 & 5 & 6

Typical reagent requirements per acre of tailings are:

-	limestone	10 to	30 tons
-	fertilizer	700 lb.	10-20-20
		250 lb.	0-44-0
-	grass	40 lb.	creeping red fescue
		20 lb.	birdsfoot trefoil

In 1974 and 1975 Rio Algom and Denison announced the signing of a number of long-term contracts and that major expansions of mine and mill capacity would be undertaken from 1976 to 1983.

In 1976, the Province of Ontario, through an order-in-council, caused the Ontario Environmental Assessment Board (EAB) to conduct hearings into the environmental impact of the proposed expansion of the uranium industry in Elliot Lake. The containment and shutdown of uranium tailings was a major issue of discussion at these hearings. Again, radioactivity, pH control, TDS, ammonia and nitrate coming from the tailing areas were primary concerns. The jurisdictional issue was also discussed.

Up to this time, the role of the prime regulatory authority, the Atomic Energy Control Board (AECB) was passive. Rio Algom, under the terms of a mining permit issued in May, 1968 was authorized to carry on development, mining, milling and concentrating operations at Lacnor, Milliken, Nordic, Quirke, Panel and Spanish-American. It is my understanding that prior to 1968, the only permit required from the AECB was for sale of uranium. During the initial constructic phase 1955-1958, tailing areas were regulated through licences of occupation issued by the Department of Lands and Forests if the lands were not held as patented mining claims, or by application to the Mining Commissioner for an order under Section 195(i) of the Mining Act. If a dam had to be constructed on a river or lake outlet (inlet) construction drawings and specifications had to be approved under the Lakes and Rivers Improvement Act. However, there were no regulations in effect covering the release of chemical constituents from uranium tailings areas to the surrounding environment. The first regulation that affected the uranium industry was The Metal Mining Liquid Effluent Regulations issued in February, 1977 by the Department of Fisheries and Environment under the Fisheries Act. This covered radium -226 and pH. The OWRC (and later the Ministry of the Environment) had surface water criteria, and drinking water criteria, but no criteria for effluent discharges.

Just prior to the start of the EAB hearings the MOE issued control orders to the uranium mines in Elliot Lake relating to the control of uranium tailings for acid production, dust, radioactivity, ammonia and nitrate releases. At the same time the AECB issued a similar set of control requirements and limited the mining permit to the Quirke mine, with the proviso that a separate application would be required for the expansion of the Quirke mine and the Panel and Stanleigh mine rehabilitation programs. They also issued guidelines covering the application for an operating licence, and selection criteria for a uranium tailings waste containment area.

The philosophy of containment versus disposal, which I believe was originally developed for the high level wastes, was also applied for the first time to uranium tailings. You may have noticed that I used the word "disposal" in the title of this speech. It is not a Freudian slip. I think that I can speak for the uranium industry as a whole when I say that tailings deposited up to 1976 have been disposed. The enunciation of a philosophy to the uranium industry in 1976 by the AECB regarding "containment versus disposal" does not in our view make the philosophy retroactive. However, the application of this philosophy to uranium tailings deposited after 1976 is a matter which I am sure industry and the AECB will eventuall resolve to the satisfaction of all concerned.

URANIUM TAILINGS MANAGEMENT TODAY:

As a result of increased federal and provincial regulatory controls and increased public concern fo. the environment, the development of a uranium tailings area today, is considerably more complex in terms of technology, politics and economics, than it was in the fifties. To illustrate this, I will take you quickly through the engineering and regulatory process as it applied to the recent expansion of the Quirke Mine Tailings area.

TRANSPARENCY 8

This transparency summarizes the various reports and applications made over the past 2½ years. Twenty-eight (28) regulatory applications were made. This compares with one made in the fifties.

The investigative phase incorporated aerial photo interpretation, and topographic and surface geological mapping to identify the major geological structures for more detailed evaluation. This phase finished with cored and non-cored borehole drilling, in-situ hydraulic testing and installation of multi-level piezometers and groundwater geochemistry sampling points.

The results of the investigations were used to construct a series of two - and quasi three - dimensional computer models of present groundwater flows which were adjusted until they satisfactoril simulated known surface water occurrences and groundwater conditions monitored in the boreholes. Subsequently, model boundaries were adjusted to reflect changed conditions resulting from tailings deposition in order to enable projections to be made of groundwater flows over the life of the facility. This data was in turn used to examine the impact of seepages on water quality in the surrounding lakes and streams.

SLIDES 6, 7, 8 & 9

FURTHER RESEARCH:

As I mentioned earlier ammonia and nitrate were raised as concerns. The sources were from the mill process (nitric acid for stripping the IX columns and ammonia for precipitating the uranium as ammonium diuranate, more commonly known as yellowcake) and underground where ANFO (ammonium nitrate - fuel oil) is used as a blasting agent. A two year program of research was successful in developing a new process whereby sulphuric acid was used to strip the IX columns and magnesia used to precipitate uranium. The process was installed in the Panel and Stanleigh mills.

We also launched a joint program of research with Environment Canada to develop a more efficient radium removal system.

SLIDES 10 & 11

One program looked at flow rates, retention times, pH control, addition rates and various flocculants for the straight forward gravity settling system.

The second program examined the use of sand filters for the removal of the barium-radium precipitate. Data developed in the gravity system were used for the design of the Panel effluent treatment system, while the sand filters are being installed at Stanleigh. Both systems will produce effluents containing less than 4pCi/l dissolved radium -226 and under 25pCi/l total radium -226.

SLIDE 13

We are also supporting research with CANMET on groundwater monitoring and geochemistry at an abandoned tailings area. This research shows that if acid generation can be controlled in the upper 3 feet of the tailings, leaching of heavy metals and the radioactive elements will be minimal.

To assess the applicability of the underwater tailings disposal concept, a multi-stage study was developed in conjunction with the regulatory agencies. The most important facet identified for investigation during the first stage investigations was an assessment of the effects of underwater disposal on water quality in the Serpent River Basin watershed. To simulate the effects of underwater disposal, a computer simulation routine was developed and integrated with a water quality model previously developed for the Basin which predicts levels of total dissolved solids, ammonia, dissolved radium -226 and pH. The underwater disposal model component reflects the effects of direct input of tailings into the hypolimnion, the chemical/biological transformation of dissolved constituents in the water column, the reactions of pyritic tailings deposited on the bottom, and the flux of dissolved constituents from the tailings into the water column.

CLOSE-OUT:

As in other areas of the nuclear industry, waste disposal, in this case uranium tailings, is an issue. In Canada today, there is no legislation specific to the close-out of uranium mine tailing areas. A position paper was formulated by the AECB early in 1981 and issued for comment. In summary, the AECB's position was that numerical limits should be set for radioactive emissions, specific methods of achieving these requirements were given and performance guarantees were requested to ensure that requirements would be met in the long-term. The government's position was that institutional control was required but it could not be considered as a control measure by itself.

Upon reviewing the position paper and criteria established elsewhere, the mining companies in Elliot Lake developed a set of objectives from which to assess their research and development works related to close-out of their facilities. The following close-out objectives were proposed:

- institutional control is required to restrict land use and site access at a closed-out facility and within a reasonable buffer zone around such a facility;

- the close-out of a tailings area is site specific and must be assessed on the characteristics and requirements of a particular location;

- the design of close-out systems should maximize the use of passive or natural systems;

- the annual loadings of any substance to the environment after close-out, allowing for a transition period, should not be greater than the loading of such a substance during the operating phase of the facility unless it can be reasonably demonstrated by a pathways analysis that a greater annual loading of such a substance would not cause significant harm;

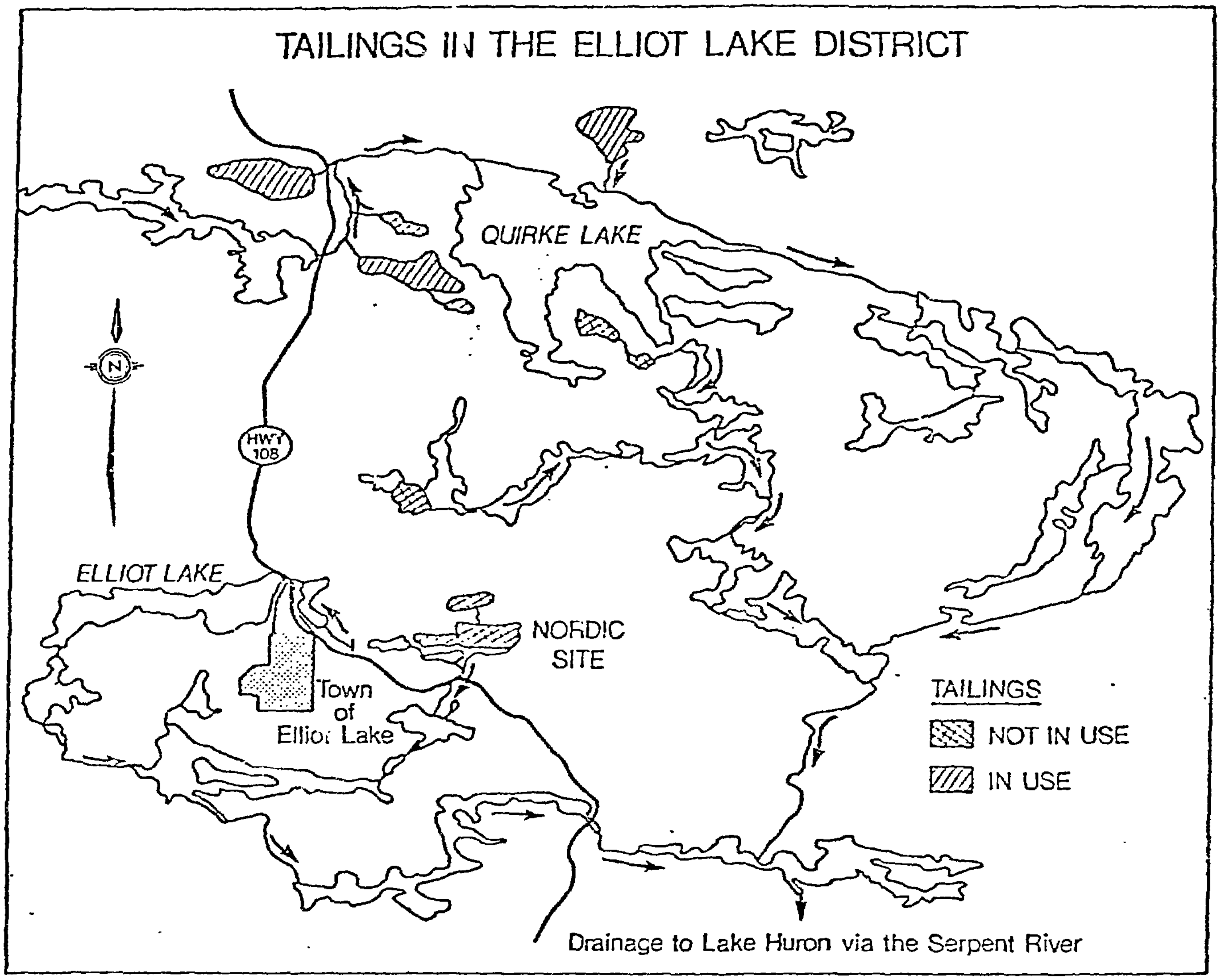
- the ALARA principle should be applied to total radiation exposure to an individual with the recognition that there exists a level below which no further action to reduce exposure is warranted; it is assumed that such a level will be reached when the total radiation exposure is within the normal range of fluctuation of natural background radiation in a given area;

- no practice be adopted unless its introduction produces a net positive benefit.

The primary differences between these criteria and those proposed by the AECB, is first that criteria should allow for site specific solutions and not be restricted to government set emission standards and second that institutional control is a valid means of controlling the use of the property in the long-term. A major concern of industry was the objective of 2-10pCi/m^2-S for radon emanation. At Elliot Lake, this would require approximately 10 feet of cover at a total cost of $660 million (1981 $).

In Elliot Lake, we believe that there is adequate evidence available to show that radioactivity is not a long-term problem with uranium tailings. Acid produced from the oxidation of pyrite is the potential long-term problem. Our research effort has, and will be, therefore, oriented towards eliminating oxygen and pyrite from the upper zone of tailings and providing natural alkalinity in this zone to inhibit the acidic conditions produced by the oxidation of pyrite.

In summary, both industry and government have progressed considerably in their understanding of each others position regarding the management of uranium tailings. I am sure this progress will continue over the coming years.


TAILINGS IN THE ELLIOT LAKE DISTRICT
QUIRKE LAKE
N
HWY 108
ELLIOT LAKE
NORDIC SITE
Town of Elliot Lake
TAILINGS
NOT IN USE
IN USE
Drainage to Lake Huron via the Serpent River

URANIUM MINES AND TAILING DISPOSAL SITES, ELLIOT LAKE, ONTARIO 1955-1958

MINE	START OF PRODUCTION	TAILINGS RECEPTOR
Pronto	Sept. '55	Valley and swampland north of mill.
Quirke	Sept. '56	Manfred Lake west of mill.
Nordic	Jan. '57	Swamp & valley north of mill.
Denison	May '57	Williams Lake, Bear Cub & Long Lakes.
Lacnor	Sept. '57	Valley east of mill.
Panel	Feb. '58	Swamp & S.W. corner Strike Lake.
Stanrock	Mar. '58	Natural basin south of mill.
Stanleigh	Mar. '58	Crotch Lake.
CAN-MET	Mar. '58	Natural basin south of mill - (Same as Stanrock).
Milliken	Apr. '58	Crotch Lake.
Spanish American	May '58	Northspan Lake.

TRANSPARENCY 4

RADIUM -226 CONCENTRATIONS

ELLIOT LAKE AREA

(p Ci/l)

	1959	1964
Quirke Lake	17	36
Pecors Lake	-	67
North Nordic Lake	11	28
Dumbell Lake	12	8
Elliot Lake	8	7
Depot Lake	-	2
Serpent River (Highway 17)	2	6
Lake Lauzon	20	4

SOURCE: Report on Radiological Water Pollution in the Elliot Lake and Bancroft Areas, 1965. Deputy Ministers' Committee.

SOME RECOMMENDATIONS OF THE 1965 DEPUTY MINISTERS' REPORT

- The jurisdictional issue be resolved;

- Concentrations of 3-10pCi/l of radium -226 be adopted as initial objectives to be attained in public drinking waters in the Elliot Lake and Bancroft areas;

- The Province work with the uranium mining industry to seek practical means for control of radioactivity and to establish sound design criteria for impoundment and effluent treatment works;

- A detailed investigation of the effects of uranium waste disposal on surface water quality be initiated and the monitoring program be expanded and extended on a long term basis.

TYPICAL CHEMICAL ANALYSIS OF TAILINGS

EFFLUENT FROM QUIRKE TAILINGS AREA

	MILL EFFLUENT*	DECANT	TREATED EFFLUENT
Flow	145 l/s	240 l/s	240 l/s
Diss. Ra-226	4500pCi/l	400-1000pCi/l	3-10pCi/l
pH	10	8-10	6-8
Fe	-	-	0.05-1.5mg/l
TDS	3500mg/l	2000-3000mg/l	850-2700mg/l
SO_4	2000mg/l	1200-1500mg/l	600-1500mg/l
NH_3	120mg/l-N	10-25mg/l-N	10-25mg/l-N
NO_3	650mg/l-N	60-80mg/l-N	30-80mg/l-N
Trace Metals (Cu,Zn,Ni,Pb)	-	-	<0.16mg/l

* Mill capacity 4700 tons per day.

REPORTS, APPROVALS AND PERMITS
EXPANSION QUIRKE TAILINGS AREA

Reports (AECB)

- Site Selection
- Design Brief
- Hydrogeological Assessment
- Design Brief Update
- Monitoring and Response Plan

Site Approvals (MNR 11)

- For each Dam and Channel Diversion

Construction Approvals (MNR 11)

- For each Dam and Channel Diversion

Permit To Take Water (MOE 3)

- Evans Lake
- Gravel Pit
- Lake 'C'

Certificate Of Approval (MOE 2)

- Store and Treat Industrial Waste
- Tailings Effluent Treatment Plant

Cutting Permit (MNR)

Public Information Meetings (2)