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THE RABBIT LAKE OPEN PIT TAILING DISPOSAL SYSTEM

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ABSTRACT

The Rabbit Lake open pit tailing depository is a below-ground tailing disposal system which takes advantage of existing low groundwater hydraulic gradients and low tailing permeabilities in preventing the ex-migration of contaminants. Establishing a highly-permeable surround around the tailing connected to a pumped underdrainage system ensures maximum consolidation of tailing during placement. When pumping ceases at abandonment it provides a preferential path for groundwater flow around the fully consolidated tailing.

INTRODUCTION

Location

In October 1982, Eldorado Resources Limited purchased the Rabbit Lake uranium mine from Gulf Minerals Canada Limited and is now its sole owner.

With the 1983 closure of Eldorado's Beaverlodge operation in Uranium City, Rabbit Lake is the longest-operating uranium mine in Saskatchewan. The operation is located in north-eastern Saskatchewan, 3 km west of Wollaston Lake at approximate latitude 58°15' north and longitude 103°4' west. (Figure 1). From Rabbit Lake, it is 97 km to the Manitoba border and 200 km to the Northwest Territories.

The permanent populaton in the Wollaston Lake area is small. The village of Wollaston Lake, 34 km from Rabbit Lake on the eastern shore of Wollaston Lake, has a population of approximately 640 people. The next village is 130 km away on the northeast end of Reindeer Lake and northward, at even greater distances, are the communities of Black Lake (150 km), Stony Rapids (172 km), Fond du Lac (227 km), Uranium City (304 km) and Camsell Portage (340 km).

History Of The Rabbit Lake Operation

The project began in 1968, when an airborne survey of more than 1.5 million hectares of the Wollaston Lake region detected several radioactive anomalies. Diamond drilling in and around a small lake called Rabbit Lake eventually identified a uranium orebody containing approximately 4.5 million tonnes of orebearing material and 18 million kilograms of uranium oxide. In 1970 a detailed engineering study established the viability of the proposed operation and in 1972 construction of the mill and camp site began. Construction materials were initially hauled to the site over a winter road until November 1973 when the Government of Saskatchewan completed an all-weather road to within 10 km of the operation.

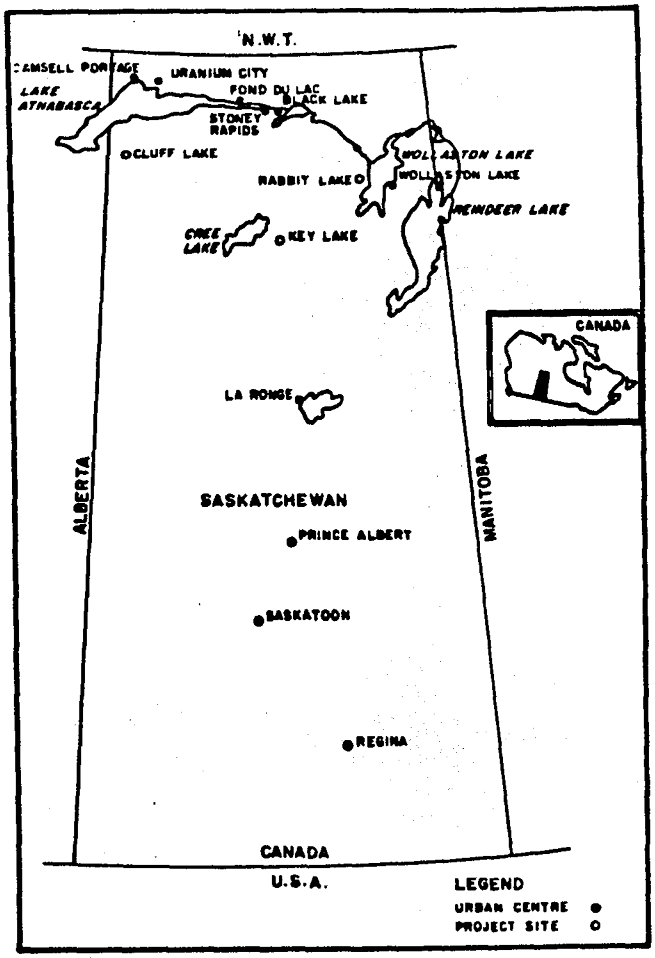

FIGURE 1: LOCATION OF THE RABBIT LAKE PROJECT

In October 1974, stripping of the Rabbit Lake open pit began with the removal of overburden and lake bottom sediments from the previously drained Rabbit Lake. The first ore was processed by the mill in June 1975 and by October 1975 the mill was producing 1.4 million kilograms of uranium oxide per year. Design capacity of 2.2 million kilograms per year was first achieved in 1977 and maintained until the early 1980's when lower ore grades resulted in lower production rates.

It was clear when mining at Rabbit Lake began that, without additional reserves, the Rabbit Lake operation had a life of only 10 years. Exploration therefore continued in the immediate area in an attempt to discover additional uranium mineralization.

Identification of a belt of anomalously radioactive occurrences on the Harrison Peninsula approximately 11 kilometres north of Rabbit Lake led to a closer examination throughout the period 1971 to the present. (Figure 2). Initially a small orebody, the Collins Bay A-zone was identified, followed by the Collins Bay B-zone, D-zone and the Eagle Point deposit. Although recent information has confirmed that Eagle Point is the largest orebody, an assessment in 1979 of the information available at that time identified the Collins Bay B-zone as the largest and, because of its location, the most logical successor to Rabbit Lake.

As a first step towards obtaining regulatory approval for development of the Collins Bay B-zone, conceptual engineering began in 1979 and 1980. An electrical generating plant, a mobile equipment maintenance shop and a miners' change house and kitchen were planned to serve the immediate need of the Collins Bay B-zone and the long-term needs of the three other orebodies in the area. A haul road, stockpile area, contaminated water handling system and an electrical distribution system were also planned. Dyking methods had to be considered since part of the Collins Bay B-zone was submerged beneath Collins Bay. The adaptability of those methods to the wholly-submerged Collins Bay A-zone and D-zone was also important. Mineralogical differences between the Collins Bay A-zone, B-zone and D-zone ores and Rabbit Lake ore and changing regulations designed to reduce ammonia emissions resulted in mill process design changes. It was also necessary to identify and establish the suitability of a new tailing depository since the depository in use at that time was adequate only for the tailing produced from Rabbit Lake ore. Environmental baseline data were collected and, with the results of a northern community impact study and a study of the company-developed northern employment participation programme, all the information was assembled in an environmental impact statement. (1)

An environmental assessment and public review process led to regulatory approvals in late 1982 so that the detailed engineering and preliminary development work necessary to begin mining and milling the Collins Bay B-zone ore could proceed. The dyke was complete by mid-1984 and stripping of overburden and lake bottom sediments began. Ore was first produced and fed to the newly-modified mill in November 1985.

Mining of the Rabbit Lake orebody was completed in May 1984, although stockpiled ore ensured continuity of mill operations until Collins Bay B-zone ore became available.

Tailing Depositories

A critical part of the regulatory approval process for any uranium mine is of course the proposed tailing depository. When the Rabbit Lake project began the approved tailing depository which was constructed was a relatively conservative

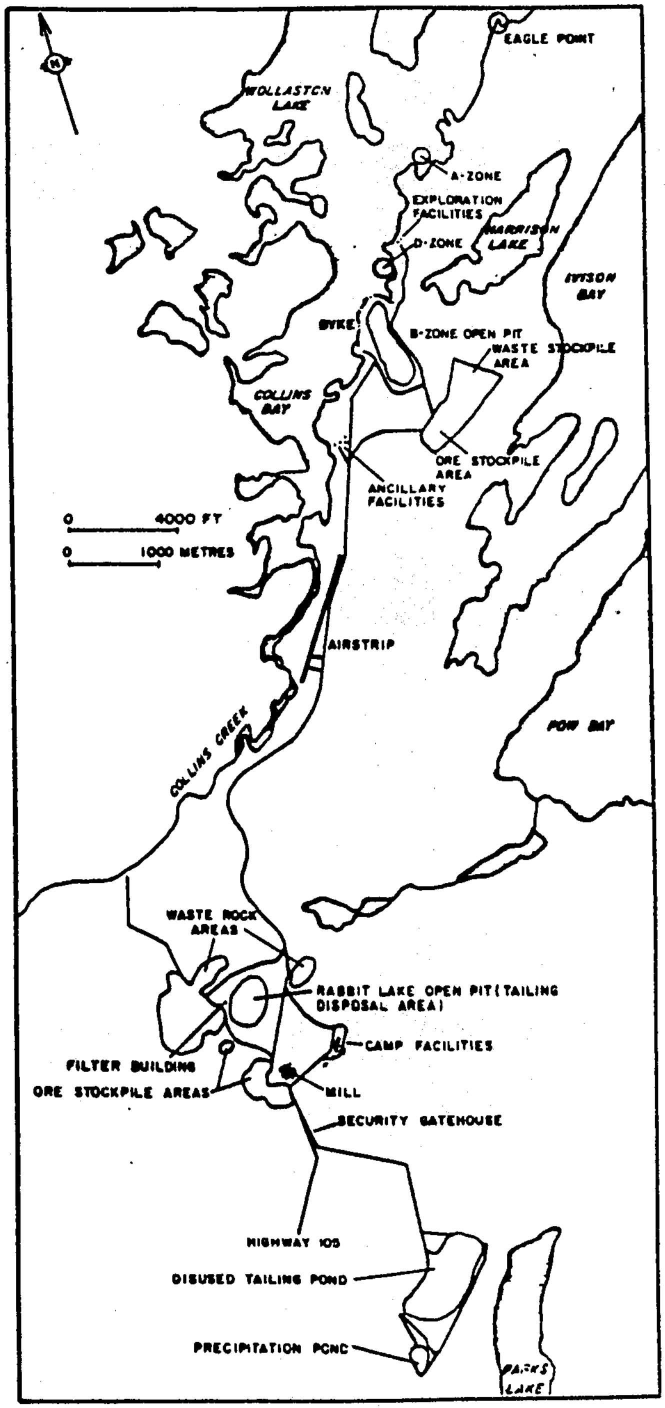

FIGURE 2: RABBIT LAKE PROJECT PLAN

above-ground design. Located approximately 3 km south of the Rabbit Lake mill (Figure 3), it consists of a north and south earth-filled dam, constructed across an elongated valley between two north-south trending ridges. When in use, tailing slurry was discharged at the perimeter of the impoundment area, the point of discharge being moved as required to ensure an even distribution of tailing over the area. The solids were retained in the pond and the clarified water was removed by a floating pump station for final treatment before release. The existing impoundment area had however only been designed to accommodate the 4.5 million tonnes of tailing produced from milling the Rabbit

FIGURE 3: THE ORIGINAL RABBIT LAKE TAILING DEPOSITORY

Lake orebody. The environmental impact statement (1) submitted in the early 1980's therefore presented two alternatives for containing the tailing produced from the milling of the new Collins Bay B-zone orebody.

The first alternative involved the construction of an additional tailing retention dam downstream of the existing south dam. It followed a detailed geotechnical and hydrological study of the proposed site and incorporated geotechnical designs developed since the existing dams were engineered. Seepage through the dam was controlled by a soil-bentonite zone extending through the tills to the bedrock contact and a grout curtain extending into any fractured bedrock zones.

The second alternative was innovative and involved using the exhausted Rabbit Lake open pit as a depository. Following two years of geotechnical development work it became clear that this alternative was superior for three major reasons:

. It avoids the use of any kind of low permeability liner. No liner is absolutely impermeable and the volume of seepage through them although small, is predictable and real. It is also important to realize that construction difficulties and resulting liner weak spots can produce local leakage, the repair of which even if detected, involves severe practical problems.

. It avoids the relatively high hydraulic gradients existing across the low permeability liners of conventional, perched, above-ground systems and the enhanced leakage rates which they produce, especially at weak spots.

. It encourages seepage and depletion of tailing pore water during placement, ensures a maximum degree of dehydration at abandonment and during deposition allows precise monitoring of the flow rates and concentrations of all contaminants leaving the placed tailing.

This alternative was eventually approved and began operation when the original tailing depository was abandoned, in November 1985. It is the subject of this presentation and is described in detail in the following paragraphs.

SYSTEM DESCRIPTION

Geological And Hydrological Setting Of The Rabbit Lake Open Pit

The now-depleted Rabbit Lake deposit lay entirely within the Wollaston domain which is locally composed of amphibolite to granulite facies supracrustal gneisses of the Aphebian age Wollaston Group.

The major structural feature of the Rabbit Lake open pit is the Rabbit Lake Thrust Fault, (Figure 4) a predominantly northeasterly trending fault which dips to the southeast at generally less than 60°. The Rabbit Lake Fault Zone is a complex zone of sub-parallel faults that trends roughly southwesterly from Wollaston Lake's Pow Bay, through First and Second Link Lakes, through Rabbit Lake, and southwesterly for several kilometres. It formed the footwall of the orebody itself which occupied highly brecciated and altered rocks within the complexly-fractured hangingwall. The footwall rocks are not highly fractured or altered.

Within the Rabbit Lake pit area, the fault zone consists of a wide (100 to 150 m) zone of strongly sheared and brecciated rock that shows progressively more severe shearing as the main thrust sole is approached. The fault zone and the thrust sole dip about 45° to the southeast. Within the sheared and brecciated rocks of the hangingwall, innumerable subsidiary shears are evident. These subsidiary shears show attitudes from horizontal to vertical, but on a gross scale they tend to parallel the main thrust sole. Within a few metres from the thrust sole are blocks of all sizes that have been rotated between anastomosing subsidiary shears and often show well developed, complexly-disposed slickensided surfaces. It should be noted that within the pit area, the Rabbit Lake thrust faults are superimposed upon a northeasterly-trending vertical fracture zone. Near the main thrust sole, those earlier fractures are not recognizable, but to the east, away from intense shearing, they are readily apparent. (1)

Piezometric investigation programmes carried out around the open pit and local lake and swamp level measurements all confirm that the ground water flow pattern is influenced by the dewatering of the open pit. Seepage into the pit creates an identifiable cone of depression near the excavation. Elsewhere in the immediate vicinity, topographic features influence shallow flow systems. Deep ground water movement below the zone of influence of the open pit is essentially horizontal, trending in an easterly direction towards Wollaston Lake. Of special interest was the transmissivity of the Rabbit Lake Fault since it could possibly have provided a direct groundwater link between the proposed tailing depository and Wollaston Lake. Water levels measured in piezometers installed above and below the Rabbit Lake Fault Zone however indicated that the fault does not have a significant influence on the groundwater system and the bedrock units above and below the fault zone behave essentially as a single hydrostratigraphic unit. This evidence is supported by the computed coefficients of secondary permeability which are generally in the range of 10^{-6} to 10^{-7} cm/s.

are there greater than a five percent gradient found in the high ground to the south of Rabbit Lake.

The Rabbit Lake open pit is located partly within the area originally occupied by Rabbit Lake, with the high wall on the south side standing some 30 m above the original lake level. (Figure 6).

Typical design slopes of the open pit vary from 45° overall for the greater part of its perimeter on the south, east and north sides, to 30° overall in the area of the Rabbit Lake Fault on the west side. Bench heights are typically 12 m and the final depth of the open pit is about 135 m.

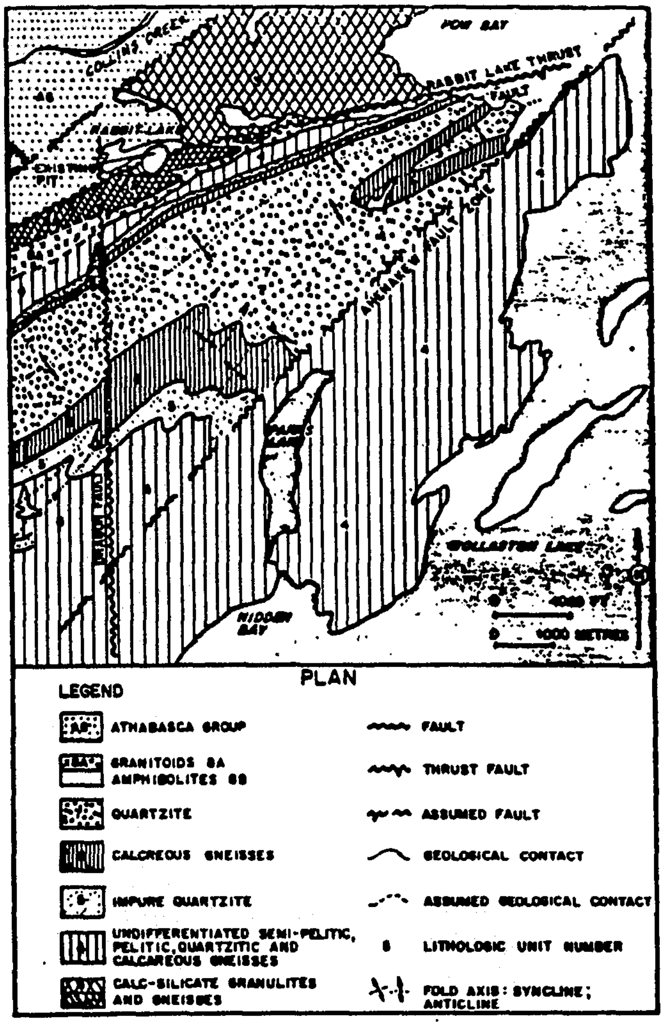

FIGURE 4: REGIONAL GEOLOGY OF THE RABBIT LAKE OPEN PIT

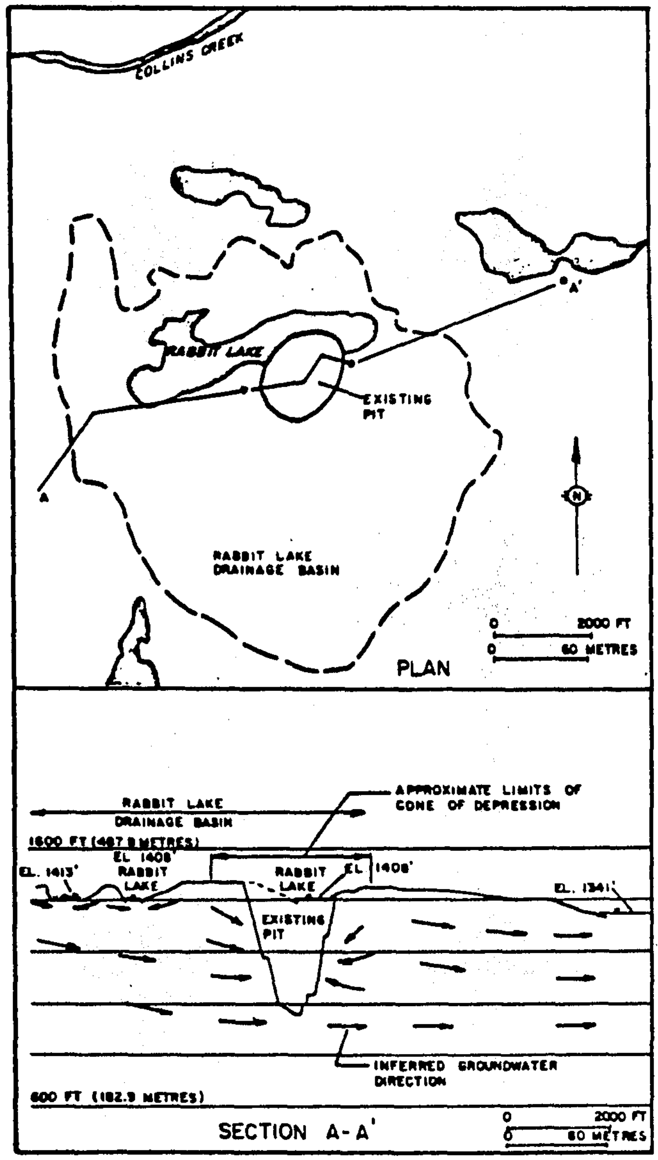

FIGURE 5: INFERRED GROUNDWATER FLOW PATTERNS, RABBIT LAKE OPEN PIT

The original groundwater pattern prior to drawdown by dewatering in the open pit is inferred from both the original Rabbit Lake water level and the groundwater table configuration beyond the cone of depression. (Figure 5).

It has been shown that hydraulic gradients are generally low throughout the area and that nowhere

A field inspection of the open pit produced the following observations:

- The wall surfaces showed numerous open fractures and joints. Joint orientations are highly variable, although in one local area at least, a well defined prominent joint set dipping into the open pit was observed.

- Although spring thaw conditions prevailing at the time of the inspection resulted in a higher than normal amount of surface run-off, most of the water flowed for short distances only on the surface of individual benches and then disappeared into rock fractures and joints.
- Talus slopes occurred in many places on benches at the foot of local cut slopes, sometimes completely covering the bench surface.

FIGURE 6: AERIAL PHOTOGRAPH OF THE RABBIT LAKE OPEN PIT

It was apparent from that inspection that a highly pervious zone of bedrock fractured by blasting and stress release effects, existed around the periphery. Since this feature was important to the proposed scheme of tailing deposition, a drilling programme was completed and confirmed the expected presence of fracturing and loosening of joints resulting from blasting and stress relief. The rock was in fact so highly fractured and pervious that it was found impossible to advance the boreholes without casing. From the total loss of drill water and the core recovered it was evident that a zone of very high secondary permeability existed for the full height of the bench slope.

General Arrangement Of The System

The in pit tailing disposal system eventually developed (Figure 7), takes advantage of the low prevailing hydraulic gradients in the below-ground environment of the Rabbit Lake open pit and, with special measures to enhance it, the extremely high permeability of the walls. These features, together with the established low permeability of consolidated tailing enabled the design of a system which:

- encourages tailing consolidation during placement by promoting drainage of pore water
- provides total containment and collection of the pore water for monitoring and treatment
- incorporates a high-permeability layer around the low permeability tailing to promote consolidation during placement and to ensure that after abandonment, when the normal flow pattern establishes itself, the groundwater will flow around the tailing rather than through it
- ensures that the integrity of the depository is maintained even if occasional departures occur from specified construction material properties and methods.

Following completion of mining and to prepare the open pit for receiving tailing, construction of a pore water seepage collection system began in June

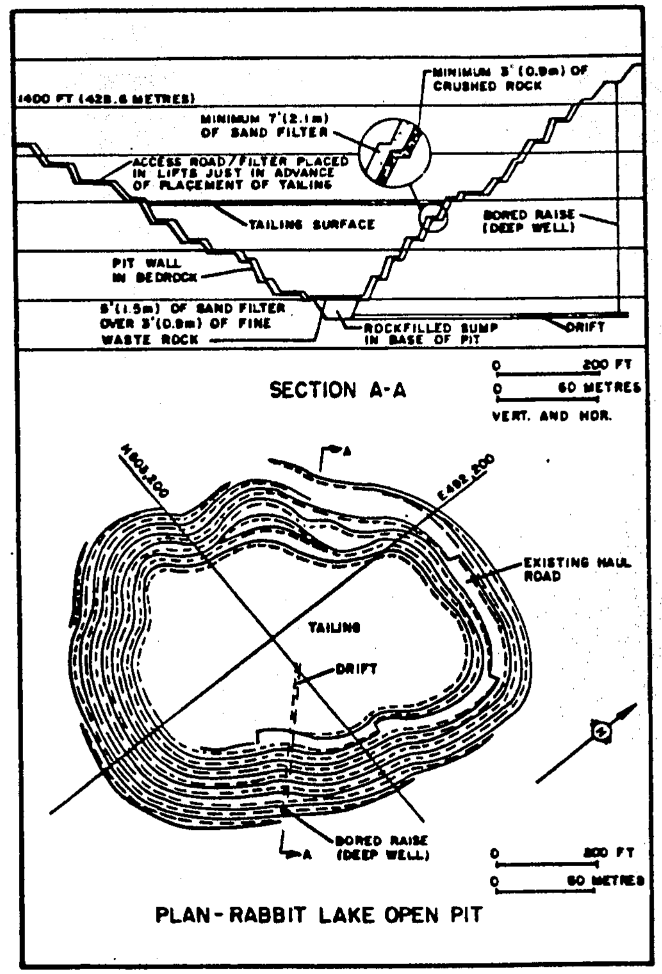

FIGURE 7: THE IN-PIT TAILING DISPOSAL SYSTEM

1984. After the heavy inflow of runoff from spring thaw into the open-pit had subsided, a drift of 2.5 m square section and about 425 m in length was driven from the pit wall at a level about 6 m above the pit bottom, dipping at five percent towards the pit brow. A raise was bored to surface from the end of the drift to house three 450 mm diameter concrete-encased well casings. Two of these wells were for active pumping and a 75 L/s capacity, level-controlled electrical submersible pump was installed in each. The third was reserved for standby purposes. The bottom part of the pit below the invert of the drift was filled with random mine run waste rock. The drift and an area around the entrance was filled with clean, screened mine waste rock fill grading between 25 to 300 mm. to a level just above the crown of the drift. The remaining space of the pit bottom around and over the clean rock fill was filled by several layers of progressively-finer rock fill, finishing with minus 230 mm crusher-run mine waste rock at a level about eight feet above the crown of the drift to complete the rock-filled bottom sump. The backfilled sump was finally covered with a 1.5 m thick sand layer which would prevent the migration of solids during tailing placement. Diversion of seepage water to the submerged pump and immobilization of placed tailing solids during placement would be achieved by ensuring that both the sand and fine waste rock layers were continuous around the walls of the open pit from the rockfilled sump at the bottom to an elevation above the rising surface of the tailing. Thus during placement, consolidation is encouraged by continuous removal of all seepage water enhancing the expression of pore water from tailing surcharged by the vertical loading of continuous placement.

When placement is finally complete and the seepage monitored at the pump discharge is satisfactory, the pumps will be de-energized and the contrasting permeabilities of tailing and permeable envelope will establish the groundwater flow pattern required to achieve total bypass of all groundwater around the tailing.

PREDICTED SYSTEM PERFORMANCE

Short-Term Performance

During active tailing deposition and over a short transition period between the end of that operation and final decommissioning of the facility, total containment of water-borne contaminants is achieved by operating the dewatering system. The cone of depression created in the natural groundwater table as a result of this dewatering operation, imposes a flow pattern which converges towards the open pit from all directions, thus positively preventing any outward migration of contaminants from the immediate vicinity of the open pit.

Seepage of pore water from the deposited tailing into the unsaturated zone of natural bedrock above the groundwater table within the cone of depression, is of course to be anticipated at this stage. However, this contaminated water will eventually be recaptured when it migrates downwards and enters the saturated zone where the above-mentioned flow pattern will return it to the dewatering system for routing to water treatment facilities. If necessary, the contaminated zone of bedrock immediately surrounding the open pit can be flushed clean in the process of decommissioning by pumping from the dewatering system at a suitably reduced rate to maintain a shallow cone of depression over the top of the deposited tailing for a short period of time.

As discussed later, long-term performance of the system relies on mitigation of mass transport potentials to negligibly-low levels on close out of the facility. One of the major mass transport mechanisms of concern is the release of pore water from the deposited tailing due to consolidation under self weight and superimposed loading from the top cover. Lowering of the groundwater level surrounding the tailing deposit by operating the dewatering system, enables the tailing to be consolidated under its full weight which would be more than twice its buoyant weight under the submerged condition in the post-decommissioning state. Using the non-linear, large strain consolidation theory applicable to this situation (2), it can be shown that the surcharging effect due to lowering of the groundwater table during active tailing deposition would be sufficient to ensure an over-consolidated condition at the end of the deposition operation. Consequently, it is anticipated that decommissioning of the facility can proceed almost immediately following the completion of tailing deposition. An illustration of the results of consolidation modelling of the Rabbit Lake open pit operation is shown in Figure 8.

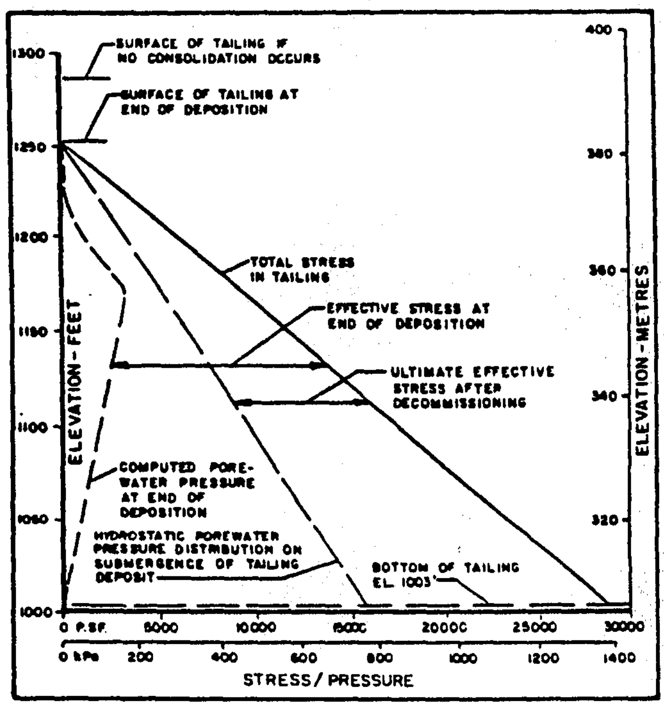

FIGURE 8: TYPICAL RESULTS OF CONSOLIDATION ANALYSIS

In the cold climate prevailing in the Canadian North, freezing of the tailing deposited in winter will interfere with the normal consolidation process. Although the upper part of the frozen tailing deposited in each winter will thaw during the following spring, the lower part will undoubtedly remain permanently frozen. The interaction of freeze, thaw and consolidation processes is complex and involves thermodynamic and osmotic effects which are not fully understood at present. It is known however, that the freezing front tends to induce pore water movement from the unfrozen material towards it and thus tends to promote consolidation of the unfrozen material. This effect is of relatively minor significance in comparison with the interruption of the consolidation process for the material which free and the resulting loss of storage volume.

Long-Term Performance

Having eliminated the transport potential of consolidating tailing, the only controlling mechanism for release of contaminants in the long term is hydrodynamic dispersion resulting from natural groundwater flowing past the tailing deposit. The disposal system takes advantage of the initially low hydraulic gradient of a body of natural groundwater and further modifies it by introducing a highly conductive envelope around the tailing deposit. It is clear that by increasing the transmissivity of the pervious envelope relative to the surrounding bedrock and the tailing deposit, the rate of groundwater seepage through the tailing deposit can be reduced to any desired degree.

The systems's complex three-dimensional flow pattern and extreme contrast in dimensions and permeability values between different material zones, makes precise mathematical modelling of the whole system impossible. However, two-dimensional finite element models have been used (1) (3) to illustrate that it is practically feasible to use commonly available natural, inert materials such as rock fill or pit-run sand and gravel for constructing a pervious envelope with the necessary transmissivity to virtually nullify the hydraulic head differential across the tailing deposit, thereby eliminating the long term potential for seepage through it.

A typical finite element mesh and prescribed boundary hydraulic head distribution used in such an analysis of the Rabbit Lake case is shown in Figure 9. The model represents a horizontal section through the open pit, incorporating a two-layer pervious envelope made up of a 1 m thick layer of crusher-run mine waste rock and a 3 m thick layer of sand filter. The Rabbit Lake Fault known to intersect the open pit is represented by a 15 m wide zone in the bedrock formation.

Using the input parameters given in Table 1, the analysis (Table 2) demonstrates that the pervious envelope is sufficiently effective to eliminate the advective component of the hydrodynamic transport mechanism thereby reducing the system to a diffusion controlled condition in the long term.

Considering steady-state diffusion through the sand filter zone governed by Fick's first law (4) and conservatively assuming a constant source boundary at the sand/tailing interface and perfect flushing at the sand/rock fill interface, the maximum rate of solute release when the open pit is filled to capacity, is estimated to be 2258 Co, where Co is the source concentration. Taking a simplistic but highly conservative approach in which the entire release is assumed to enter directly into the reinstated Rabbit Lake, the increase in concentration of any particular parameter in the Rabbit Lake water is approximately defined by the expression 4.44×10^{-4} Co. As an example, in the case of ^{226}Ra, the system is predicted to be able to tolerate a maximum source concentration in the tailing pore water of 250 Bq/L without exceeding current Saskatchewan surface water quality objectives of 0.11 Bq/L.

Recent test work on the Collins Bay B-zone tailing being deposited in the open-pit indicates

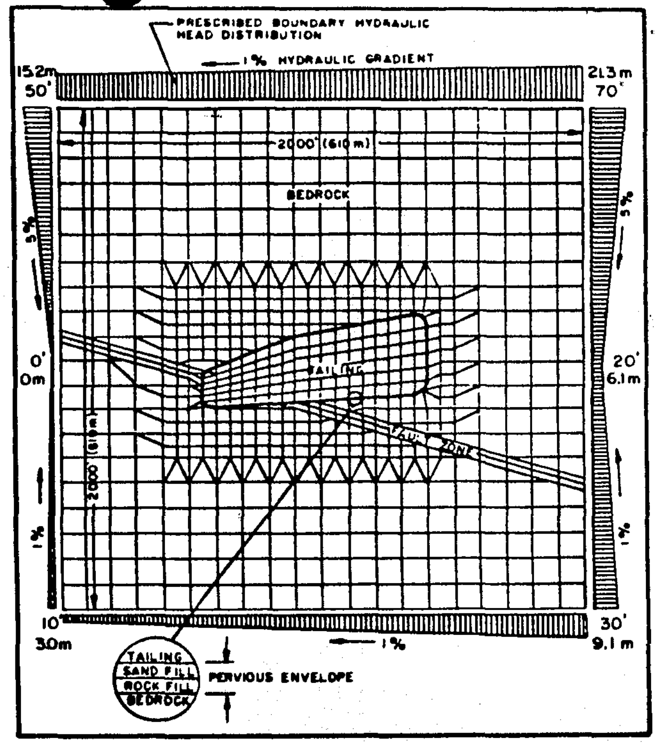

FIGURE 9: TYPICAL FINITE ELEMENT MESH AND PRESCRIBED BOUNDARY CONDITIONS

TABLE 1: INPUT PERMEABILITIES (cm/s)

Material	Permeability
Rock fill	3
Sand fill	0.1
Tailing	5×10^{-7}
Bedrock	5×10^{-6}
Fault	1×10^{-3}

TABLE 2: COMPUTED VALUES

Parameter	Tailing	Rock Fill	Sand Fill
Total flow* (L/d)	9.3×10^{-4}	70.8	
Max. hydraulic gradient	4.5×10^{-5}	3.0×10^{-5}	3.1×10^{-5}
Max. Darcy velocity (m/d)	1.9×10^{-8}	7.9×10^{-2}	2.7×10^{-3}

* for 30 cm thick model

that its pore water contains ^{226}Ra concentrations of approximately 150 pCi/L which are substantially lower than the maximum indicated source concentration.

Comparison With Conventional Above-Ground Storage

The most significant difference between the below-grade disposal at Rabbit Lake and conventional above-ground storage is the underlying philosophical approach in achieving long term control on contaminant migration. The former seeks to mitigate the causes of contaminant migration whereas the latter relies on barriers to resist it.

By locating the waste in a low-energy environment below the permanent groundwater table, the driving forces causing long term migration of waterborne contaminants can be easily reduced as described earlier to achieve a high level of immobilization. In contrast, above-ground waste deposits are permanently subjected to high seepage potentials which have to be resisted by long-lasting barriers.

Common experience has revealed the difficulties associated with selecting suitable materials for, and constructing such barriers to live up to, design expectations. The use of natural, inert materials in constructing the pervious envelope in the present system, particularly in the cool groundwater environment of the Canadian North, will provide a substantially higher level of confidence in long-term performance of the system compared to those requiring low-permeability seepage barriers.

The performance of the present system is not only insensitive to major natural bedrock fracture zones but is more tolerant to minor imperfections in construction than are seepage barrier systems. The pervious envelope also has the advantage of being insensitive to settlement and able to tolerate minor disturbances due to natural phenomena or human activities.

Final close out of the below-grade facility is simply achieved by placement of a top cover and termination of the dewatering operation to allow recovery of the groundwater table to its natural position above the waste deposit. The top cover in this case acts only as a barrier to diffusion and long term radon and particulate emissions and is not settlement sensitive. By contrast, close out of an above-ground facility is costly and requires special efforts to avoid settlement of the waste deposit in the long term.

In addition to the above long-term advantages, the positive control of contaminant migration during active deposition in the present system also gives greater assurance of adequate short-term performance than is achieved by above-ground systems. Although operation of the dewatering system is not required after abandonment, it can be reactivated if required thus providing a safeguard against unforeseen events. Its reactivation not only provides immediate total containment of contaminants, but also generates a flushing action by reversing the direction of groundwater flow particularly along the more prominent pathways.

Finally, its performance is easily confirmed by monitoring the head differentials across the tailing deposit usng piezometer installations thereby increasing the level of confidence in the system.

CONSTRUCTION AND MONITORING

Demonstration Programme

Immediately following the completion of the bottom sump described earlier, a demonstration programme began to prove the methods of construction of the pervious envelope against the walls of the open pit and the methods of placement of tailing. Mining and milling of the Collins Bay B-zone ore had not yet begun and tailing from milling of stockpiled Rabbit Lake ore was therefore used for the demonstration programme.

Extensive testing prior to and during the programme established the suitability of the minus 230 mm crusher-run mine waste rock for constructing the pervious envelope. Although the non-Darcian behaviour of flow through rock fill (5) is well documented, virtually no information was available on the flow characteristics of the rock fill under the extremely low hydraulic gradients of the existing system. It was necessary therefore, to fabricate a special large-scale constant-head permeameter measuring about 1 m in diameter and 2.4 m in height to test the rock fill. The permeameter covered a range of hydraulic gradients over 2-1/2 orders of magnitude between 5×10^{-4} and 1×10^{-1}. Test results substantiated the anticipated non-Darcian flow behaviour over the full range of applied hydraulic gradients and establised a clear and consistent trend of increasing permeability with decreasing hydraulic gradients for all samples tested.

It was clear that the labour-intensive and time-consuming large permeameter tests were not suitable as a routine quality assurance test. A correlation between permeability and grain size characteristics was therefore established. A plot of measured permeability values (k_3) at an applied hydraulic gradient of 1×10^{-3} near the low end of the test range, versus the 15 percent passing size (D_{15}) of the test samples is shown in Figure 10. From this plot, a simple criterion was established for subsequent quality control by specifying a minimum D_{15} size of 0.1 mm which ensured a minimum mean permeability of 3 cm/s at a hydraulic gradient of 1×10^{-3}. Because the hydraulic gradients in the rock fill under long-term field conditions are anticipated to be approximately two orders of magnitude lower than that used in establishing the above criterion, and because the actual rock fill used in construction was considerably coarser than the minimum gradation as specified, the actual average permeability of the rock fill zone was anticipated to be in the 10 to 100 cm/s range.

As a result of the well-graded characteristics and relatively-high fines content of the rock fill, an esker deposit near the open pit was suitable for providing sand which is filter graded with the rock fill. Although some local migration of sand into the rock fill did occur in practice, surface evidence indicated only limited migration into localized areas of segregated rock fill which were coarser then normal.

Some difficulties were initially experienced in placing the narrow zones of rock fill and sand filter against the irregular open pit walls. This was overcome, however, by using scrapers to place a wider zone of sand filter than necessary in the form of a low berm around the perimeter of the open pit bottom. The berm was raised in about 0.5 m lifts, the toe limits of which were flagged by survey stakes to provide the required minimum clearance of 1 m from the pit wall for subsequent placement of rock fill. The surface of the rock fill was maintained about 30 cm below the surface of the sand fill berm and provided a ditch section to capture any surface runoff flowing down the open pit wall. In areas of concentrated surface flow the rock fill zone was widened to approximately 3 to

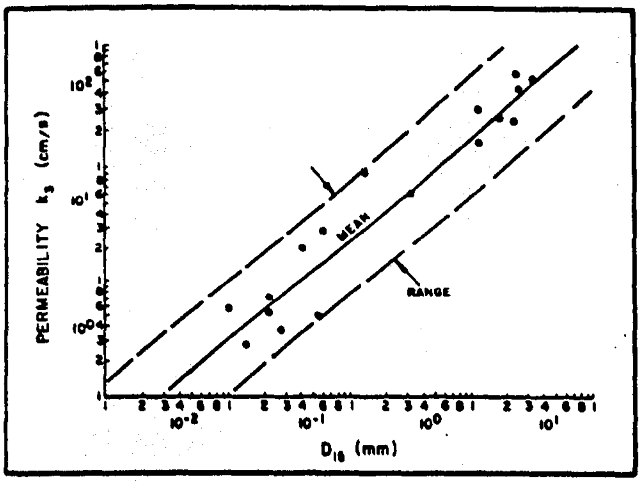

FIGURE 10: PERMEABILITY OF CRUSHER RUN MINE WASTE ROCK

6 m to cope with the large flows experienced during spring thaw and heavy rain.

Placement of filter-dewatered tailing began in early October 1984. It was hauled by scrapers to the bottom of the ramp and spread forward by dozer over the prepared part of the open pit bottom. Some difficulties with trafficability over the freshly placed tailing were experienced initially although with the onset of subzero weather, trouble free placement proceeded over the frozen tailing surface. By the end of the demonstration programme in March 1985, the tailing deposited in the open pit was approximately 12 m deep.

Placement of Collins Bay B-zone Tailing

Milling of the Collins Bay B-zone ore began in mid-November 1985 and continued intermittently at rates below the full design capacity. Raising of the pervious envelope and placement of tailing in the open pit up to the spring of 1986 essentially followed procedures established during the demonstration programme. At the onset of warm weather however, trafficability of the tailing deteriorated and placement by hauling and spreading was no longer feasible. A field trial of delivery of the tailing by pipeline was therefore initiated in June, which is still on-going at this time.

Production and placement of the Collins Bay B-zone tailing provided the first opportunity for testing its geotechnical properties in place. Samples of the filter-dewatered tailing freshly deposited in the open pit were therefore taken before it froze. Testing of the samples provided information for the consolidation modelling mentioned earlier. That testing also demonstrated the relationship between void ratio and permeability (Figure 11). Consolidation modelling defined the distribution of void ratios with depth which in turn defined the permeability values of the in-place tailing used for long-term groundwater seepage modelling.

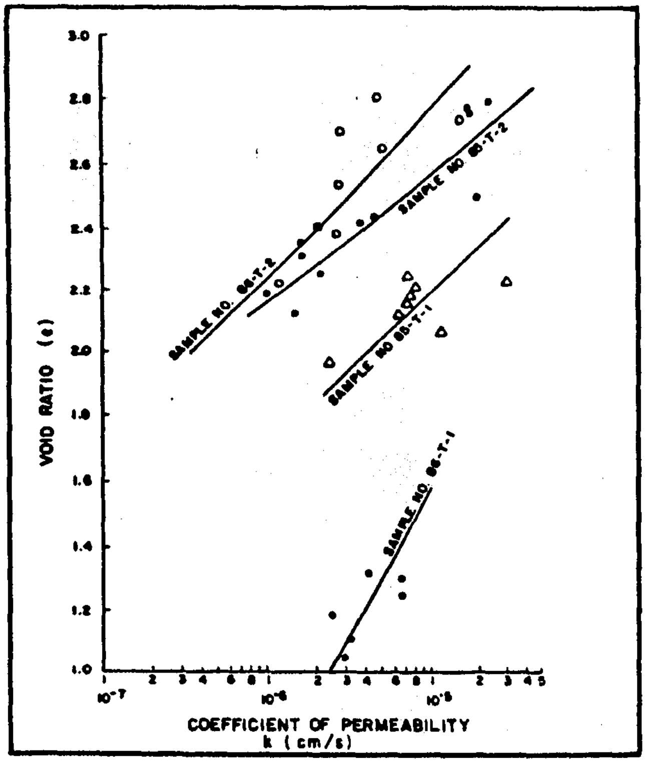

FIGURE 11: PERMEABILITY OF COLLINS BAY B-ZONE TAILING (FROM OEDOMETER TESTS)

Piped discharge of tailing into the open pit resulted in modification to the filter dewatering procedure to provide the right tailing consistency for transport. Instead of filtering all the tailing as practised initially, only part of the tailing is now filtered. Test work is now in progress to assess the changes in material properties and the impact on the consolidation behaviour of this procedure.

Piezometer Installation And Observation

A number of open-well type piezometers were installed in the deposited tailing during the demonstration programme and subsequently when the Collins Bay B-zone tailing was deposited. Both were however winter installations and no useful pore water pressure information was expected unless the frozen tailing around them thawed in the following summer. They would however provide information on the extent of thawing of the tailing by allowing the installation of a thermistor to determine the tip temperature. Observations to date in most of these piezometers have confirmed their permanently frozen status. The few which did show above freezing temperatures at their tips showed practically no pore water pressures or water levels close to the tip. Although this provided preliminary confirmation of the results of consolidation modelling described earlier, more data from future installations in unfrozen tailing is necessary.

Four clusters of pneumatic piezometers were installed in the rock fill and sand fill zones of the pervious envelope. They were approximately evenly distributed around the perimeter of the open pit at a level about 8 to 10 m above the bottom of the tailing deposit. Each cluster consists of three piezometers placed side by side. They will monitor pore water pressures in the pervious envelope and hence the long-term hydraulic gradients across the tailing deposit during and after decommissioning when the groundwater table is restored to its natural position above the top of the tailing deposit. With the operation of the dewatering system during deposition of tailing, these piezometers remain above the water level in the pervious envelope, except during short periods of large surface inflow to the open pit. As a result, no positive pressures have been measured to date, except during the spring thaw of 1986 when high rates of water inflow and periodic shut down of the pumps allowed the water level in the pervious envelope to rise to within 3 m of the top of the rock fill zone. Piezometer measurements during this period showed head differentials of no more than 1 m across the open pit even though the flow through the pervious envelope was several orders of magnitude higher than is anticipated in the post-decommissioning state. Those readings confirmed that the existing pervious envelope is indeed sufficiently pervious for the purpose intended.

Conclusions

The basic principles and predicted performance of the in-pit tailing disposal system used at Rabbit Lake show that the system is capable of a high degree of control of contaminant migration both in the short term during active tailing deposition and in the long term after close out of the facility. The system is insensitive to surrounding hydrogeological features and is tolerant of minor imperfections in construction.

General observations during construction and tailing deposition, results of material testing and instrumental monitoring information have all provided preliminary substantiation of the expected performance of the system. The overall transmissivity of the pervious envelope essential for long-term control of contaminant migration has been established and the progress of consolidation essential to the timely close out of the system on completion of tailing deposition is satisfacatory. Although more definitive monitoring data and further materials handling developments are anticipated as the system matures, a high degree of confidence can therefore be placed on it to perform in accordance with design expectations.

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