TAILINGS MANAGEMENT FOR THE 21ST CENTURY

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Abstract

The evolution of tailings management at Saskatchewan uranium mines is traced from the 1950s to the 1990s. Some of the problems with past systems are discussed. The new tailings systems now being proposed for the new operations currently undergoing environmental assessment in Saskatchewan are examined in detail. These new systems represent a change in tailings management philosophy, from keeping tailings high and dry on the surface, to placement of tailings in a low-energy regime within the water table. There they are removed from the active surface environment, avoiding future erosion problems, with a reduced likelihood of suffering intrusion from future human or animal activities.

1. Introduction

Although the Port Radium mine in the Northwest Territories started up in 1932, until 1954 production was from a gravity mill which produced a physical concentrate and resulted in low-grade rock chips as tailings. (These were later processed through a conventional acid leach mill.) Hence, it is reasonable to consider the start-up of the mills in the Uranium City area in the early to mid 1950s as the start of tailings management systems in the Canadian uranium industry. Since Eldorado's Beaverlodge mill went into production near Uranium City in 1953, the management of tailings, the wastes from uranium extraction, has undergone a major evolution. All of the operations being discussed here are in northern Saskatchewan, between 57° and 59.5° north latitude and between 103° and 109.5° west longitude (Figure 1).

2. The Dark Ages

The three mills in the Uranium City area used conventional mining -industry technology for the day. The Gunnar acid-leach mill(1) produced 5.5 million tonnes of unneutralized tailings between 1955 and 1964. One-fourth of this was placed underground, while the rest was discharged into a small lake, which was filled and then overflowed into Langley Bay on Lake Athabasca. About 22 hectares of tailings remain on surface at a neutral or slightly alkaline pH. The area is rather unsightly and continues to seep into the bay, but the impact of the Gunnar tailings cannot be detected outside Langley Bay.

The Lorado acid-leach mill[1] operated from 1957 to 1960, producing 360,000 tonnes of unneutralized tailings, which were deposited in Nero Lake. Today there are ten hectares of dry, unconfined tailings. Pyrite in the tailings continues to generate acid and leach radium into the lake. The radium concentration in Nero Lake is currently about equal to the Canadian drinking water objective (1 Bq/L) but the pH of the lake water remains low (3 to 4).

The Eldorado Beaverlodge operation (1953 to 1982) used a carbonate leach, producing alkaline tailings which are not acid-generating. The management was somewhat more enlightened in that part of the tailings was disposed of underground. The tailings were wet cycloned, separating the coarser, or sands, fraction (40 to 45% of the tailings) which was used underground for back-fill. However, about 6 million tonnes of the finer, or slimes, fraction were piped to Fookes and Marie Lakes. The two lakes form part of a low-flow watershed, and the full flow of the system was treated for radium-226 removal in later years, but this discharge, flow from Nero Lake and seepage from some other uranium properties did raise the radionuclide content of Beaverlodge Lake, the source of drinking water for the mining camp. Even now, 14 years after shut-down, the uranium concentration in the lake remains elevated (about 190 μg/L average).

3. A Little Enlightenment

Clearly, these were not desirable situations and better methods for tailings management had to be developed. The next operation to come into production was the acid-leach Rabbit Lake mill in 1975. The approach here was to dam both ends of a valley between two till-bedrock ridges and place the neutralized tailings in the basin so formed. Seepage through the south (downstream) dam is collected and treated with the mill effluent before discharge. This system now occupies 54 hectares and contains 6 million tonnes of tailings. The difficulty with the system is that the long beach over which the tailings flowed resulted in particle-size segregation, with the sands deposited around the sides of the basin and the slimes collected in the middle. Because of the fine particle size, the slimes are not free-draining and today, 12 years after the last deposition, still contain 65% water. In addition, because of the winter deposition, there is a large volume of frozen tailings in the north end of the basin.

The decommissioning objective was to produce a drained, consolidated tailings mass, profiled and capped so as to reduce infiltration of precipitation and, hence, reduce contaminated seepage and eliminate the need for continued water treatment. The problems are that the frozen tailings will eventually thaw and subside, changing the cover profile, and the slimes will not readily support a cover. A decommissioning plan[2] has been developed, but this involves dewatering the slimes area by loading it with waste rock and placing sufficient material on the frozen area to off-set future subsidence enough to maintain the integrity of the cover. When the slimes are sufficiently dewatered, a glacial till cover will be placed over the entire area to reduce permeability. The dams need to be armoured against erosion and the agencies are still debating whether or not the cover needs to be armoured to reduce the potential for problems caused by burrowing animals. All of this work will involve moving 615,000 m^3 of waste rock and

310,000 m^3 of till, over a period of several years and costing several millions of dollars. No long-term problem will be left, but the solution is expensive.

The acid-leach Cluff Lake mill[1] started up in 1981 and for the first two years the tailings were stored in concrete canisters. They were later reprocessed to extract gold and additional uranium and were then placed in the current tailings system. Neutralized tailings are discharged behind a bentonite-core, till dam in a natural basin. Again, decant from the tailings is collected and treated before discharge. Last year a new thickener was installed in the mill to produce tailings at a higher solids content (65% objective, although still under development). The intention in producing higher density tailings is to reduce slimes segregation and produce material which will sustain a modest slope.[3] The decommissioning plan calls for capping the tailings with glacial till to promote run-off rather than infiltration of precipitation, thus reducing seepage from the tailings in the long term. The final tailings management area will be about 60 hectares.

Two years later, in 1983, Key Lake started an acid-leach operation.[4] The Key Lake surface tailings facility was constructed on higher ground, with a full bentonite liner, enclosed in a square dyke 600 m on the side. On top of the bentonite liner there is a sand filter blanket and a drainage system to collect tailings seepage. The whole area is graded to slope to the east and the east dyke has a sand filter blanket and drainage system to collect supernatant tailings water. Neutralized tailings are placed subaerially and all water from the two collection systems is recycled back to the mill.

The objective of the Key Lake tailings system was to produce a drained, consolidated mass of tailings above the water table. This would be decommissioned by capping with till to shed water, reducing seepage from the tailings area to a level that could be accommodated in the groundwater flow without causing environmental problems. The system would probably have worked very well in a milder climate, but the winters at Key Lake have compounded another problem. The long beach over which the tailings flowed resulted in particle-size segregation, with the sands depositing close to the discharge points and the slimes flowing to the east (down-slope) side of the facility. The sands drained and consolidated reasonably well, but the slimes retained the water. During the winter there was considerable ice build-up in the poorly drained tailings and, because this ice was being partly covered by new deposits during the summer, it did not completely melt. The result was that the facility filled up faster than planned, because of the poorer consolidation and the ice formation, and also because the average grade of material processed was lower than planned due to dilution by waste rock during mining.

This resulted in two problems: a shortage of space and difficulties for decommissioning. At this point all the tailings from processing the Gaertner pit ore and part of the tailings from the Deilmann pit ore were in the surface facility, but a new tailings area was needed for the last five years of Key Lake production. This was essential regardless of other potential uses of the Key Lake mill, such as the proposed milling of McArthur River ore.

As for decommissioning, the plan called for a consolidated and drained mass of tailings before final closure. A large part of the tailings area did not meet these criteria. A paper study followed by a large field programme identified warm-water injection as the most effective way of thawing the tailings. However, to minimize capital costs, the project would have to operate every summer for eight to ten years.

4. The Dawn of the New Age

4.1 General Considerations

The last 15 years have seen an evolution in tailings management thinking. Tailings management efforts in the 1970s were directed at complete isolation of the tailings, preferably above the water table, using impervious barriers, which are difficult to achieve, lock water in, and could lead to long-term high pore-water pressures. Pore-water pressure is a driving force for expelling contaminants from tailings. An obvious objective in tailings management then must be the elimination of excess pore-water pressure by the time of decommissioning.

For surface disposal, weathering is clearly a factor. If weathering can be eliminated, then water becomes the only carrier of contaminants. A second objective then is to reduce water flow through the tailings; if there is no water flow, there can be no water transport of contaminants. Elimination of water movement leaves molecular diffusion as the only remaining driving force to disperse contaminants. To reduce flow through the tailings, the principle design requirements are low tailings permeability and a low hydraulic gradient, i.e. a small groundwater driving force, across the tailings. The means of achieving this is dependent upon the local conditions.

Clearly, it is desirable to get tailings out of the surface environment, which avoids erosion, and avoids human intrusion. Returning the tailings to the mine means returning them to the same environment as the original ore. Disposal under water greatly reduces oxidation of the tailings, reducing the potential for acid generation, and gives further insurance against weathering and intrusion. These considerations led to placement of tailings below the water table in mined-out pits.

The question of loss of contaminants from the tailings still had to be addressed. Flowing water tends to take the path of least resistance. The task then becomes to place the tailings in such a manner that moving groundwater tends to flow around, rather than through, the tailings. However, as tailings are placed in a pit, the mass of tailings at the top loads the system so as to increase the pore-water pressure above the normal hydrostatic head. This excess pore-water pressure must be relieved before decommissioning, to prevent the expulsion of contaminated pore water. Two similar systems are being implemented at three sites in northern Saskatchewan to accomplish these objectives.

4.2 Rabbit Lake

At Rabbit Lake a new facility was started in 1984, placing the tailings in the mined-out Rabbit Lake pit, using the pervious surround system (Figure 2).(5) A drift, or tunnel, with a 2.2% negative slope was mined from the bottom of the pit to beyond the pit rim, where it connected with a bored raise to surface. The drift was back-filled with crushed rock and a system was installed to pump water from the pit and return it to the mill for use in the process. A crushed rock drain was installed in the pit bottom and continued up the sides of the pit, with an additional liner of sand. Neutralized tailings are placed in the pit and the pore water is drained off through the pumping system, promoting consolidation of the tailings. Complete containment is achieved during operation, because the groundwater is drawn into the pit and collected through the pervious surround and pumping system.

4.3 Key Lake

Five options were considered for the needed new tailings system at Key Lake(6):

1) increase the embankment height of the existing surface facility
2) a new surface facility beside the existing surface facility
3) in the ground near the existing surface facility
4) the Gaertner pit
5) the Deilmann pit

After initial assessment, the 3rd and 5th options were considered technically viable, but the Deilmann pit was preferred, because the pit already existed and far less construction was required, resulting in far less environmental disturbance.

At Rabbit Lake, the pit was largely in the Precambrian basement rock; the Deilmann pit is partly in the basement and partly in the Athabasca sandstone. The Rabbit Lake basement rock is fairly tight but with a high hydraulic gradient due to the adjacent high mill hill; hence, relatively high groundwater flows were expected in the basement rock. At Key Lake, there is a much lower hydraulic gradient in all geological units, higher permeability in the sandstone and very high permeability in the sand overburden, with the result that more than 99% of the flow is in the upper sands. Prudence suggested the use of the pervious surround at Rabbit Lake to ensure a low hydraulic gradient by creating a free-flowing path around the tailings. Deilmann was ideally suited to the tailings plug concept, whereby a high-density, low-permeability tailings deposit is developed, which combined with the natural benefits of a low hydraulic gradient and high by-pass flow, results in very low flow through the tailings, without the need for a pervious envelope.

Two other considerations influenced the design of the Deilmann system. First, the Deilmann pit was much larger than the Rabbit Lake pit. As the tailings level in the pit rises, successive layers of tailings will become very thin and prone to freezing during winter operation. The ice lenses will impede consolidation and cause continuing seepage as they eventually melt. Second, the sandstone walls of the Deilmann pit are much more prone to weathering than is the basement rock of the Rabbit Lake pit. Over an extended period of time this could result in hazardous conditions for workers in the pit. A solution to these potential problems was to flood the pit so that the water (and ice) cover would prevent freezing of the tailings and also protect the pit walls from weathering.

The optimum system for the Deilmann pit in terms of release of contaminants proved to be a two-stage system, with initial, subaerial deposition, essentially the same as the Rabbit Lake system. This system is now in operation and will be used for the remaining Key Lake tailings. Phase 2 will be implemented for the McArthur River tailings (Figure 3). The top of the pervious surround will be sealed with a layer of tailings and the pumps will be throttled back to allow partial flooding of the pit. Subaqueous deposition of thickened slurry tailings will be done by tremie-pipe injection into the material already in the pit. A deep-well thickener has been installed at Key Lake to produce higher density tailings for the subaqueous injection. The tremie pipe is a standard civil engineering technique for underwater concrete placement and its use has been demonstrated at Key Lake in tests conducted in one of the effluent ponds.

The advantages of the Deilmann system are:

- More efficient use of the pit volume with no envelope
- Preservation of pit volume for potential future expansion of reserves at McArthur River
- Avoidance of ice formation as deposition rises into the upper, wider sections of the pit.
- Optimization of design with local hydrogeology.
- Reduced dewatering volume when compared with a full pervious surround.
- Better protection of pit walls from weathering.
- Protection against gamma radiation from the pit.
- Elimination of dust and radon emissions from the pit, reducing potential environmental impact.
- Continuing to pump from the pit bottom during the subaqueous phase maintains the cone of depression of groundwater around the pit and gives complete hydrodynamic containment during operation.
- This also allows collection of leachate from surrounding waste rock piles, giving an effective "pump-and-treat" system to control leachate and reduce the impact of waste rock.

4.4 Decommissioning

The closure procedures for both the Rabbit Lake system and the Deilmann system are similar in intent, if not in execution. After all the tailings have been deposited in the pit, a cover of sand or till will be placed on top of the tailings and the pumps will be shut off allowing original water tables to re-establish. (For the already flooded Deilmann pit, cover placement will require the use of a submerged diffuser.) The cover serves two purposes: initially it adds weight to consolidate the final layers of tailings, squeezing out pore water, and in the longer term it provides a diffusion barrier between the tailings and the Deilmann pond. The cover material and optimum thickness will be determined late in the operation of the tailings system, because it will depend upon local conditions at the time. (For example, our past experience has shown that a clay fraction in the cover material would tie up radium, if this were a problem in the pond water at the time of decommissioning.)

It is expected that some short-term flushing of contaminants from the waste rock piles around the Deilmann pit will occur, leading to higher nickel concentrations in the pit water late in the operating period and early in the decommissioning period. Contaminated water will be pumped from the pit and treated in the mill or in the dedicated water treatment plant. The pumping will maintain the groundwater gradient toward the pit, continuing the collection of all contaminants. Water treatment is expected to be necessary for only a few years after shut-down. Biological methods of improving water quality are also being investigated as a possible passive approach for decommissioning with less human involvement.

4.5 McClean Lake

The pervious surround system was initially proposed for the McClean Lake project[7], using the JEB pit, which is the first of the McClean Lake ore bodies to be mined. However, when the decision was taken to process Cigar Lake ore at McClean Lake rather than build a new mill at Cigar Lake, some modifications were required. The use of a pervious surround system requires regular work in the pit to raise the surround, as the tailings level rises. With the initial ore grades expected to be 25%, the radiation fields in the pit would be high enough that workers would reach the annual dose limit in only a few months. Hence, the flooded pit concept with no surround is preferred.[8] No work in the pit is required and the water gives good shielding against the potential high gamma radiation fields. The JEB pit is also blessed with favourable hydrogeology to permit the use of this system without the surround. One variance is planned in the closure of the JEB pit. Unlike the Rabbit Lake and Deilmann ore bodies, the JEB ore body was not under a lake. Hence, when tailings deposition is completed, the tailings will be covered, the pit will be completely back-filled and the surface will be revegetated. However, the restored water table will cover the tailings, providing an additional radon barrier.

5. Modelling

There has been extensive theoretical modelling of all three in-pit tailings disposal systems. However, only the work on the Deilmann system will be described in detail.

Samples of Key Lake tailings were characterized by scanning electron microscopy, x-ray diffraction, grain size determination, mineralogy, and tailings and pore-water chemistry.

Geotechnical testing was performed to determine specific gravity, sedimentation characteristics, consolidation properties, and permeabilities. ACCUMV[9], a finite difference computer program for analysing one-dimensional, self-weight consolidation of accreting layers of compressible materials, was used to model the consolidation of the tailings. The model was validated by using it to predict the settlement of tailings in the Rabbit Lake pit. After it was shown that the program was conservative, i.e. actual consolidation exceeds the predicted consolidation, it was used to predict the consolidation of Key Lake tailings in the Deilmann pit under both subaerial and subaqueous deposition. As a further check on the modelling, three column tests of the Key Lake tailings were done, two using a 200 mm diameter by 1.5 m high column and one using a 1.0 m diameter by 11.0 m high column. These tests also demonstrated that the computer modelling was conservative.[10]

Geochemical testing[11] was done to characterize the tailings pore water, the materials to be used in construction of the facility, the effects of residual mineralization of the pit wall rock, and the effects of any materials which could be co-disposed with the tailings (various types of mineralized waste rock). Prior work had been done on the geochemical characteristics of the waste rock piles around the Deilmann pit.[12]

Both local and regional hydrogeological modelling[13] was done using MODFLOW[14], a three-dimensional, finite difference code developed by the US Geological Survey. The accumulated knowledge of 15 years of hydrogeological monitoring and operation of dewatering systems at Key Lake supplied the input parameters for the model. Contaminant transport from the tailings is primarily by diffusion, which is dependent upon the concentration gradient between the tailings and the surrounding materials. Other contaminant sources considered were the small residual groundwater flow through the tailings, the expulsion of pore water during the relief of the excess pore-water pressure above the hydrostatic head, leaching of residual mineralization in the pit walls, and changes in groundwater chemistry due to the oxidation of the various geological units around the pit during the time when the cone of depression of the groundwater was maintained by the dewatering system. In addition to the tailings cases, leachate from the waste rock piles around the pit was also considered.

The analyses were carried out for three cases, full side drain (pervious surround), partial side drain and no side drain. Although the full side drain case resulted in the least flow through the tailings, it did not result in the lowest impact. The full side drain provides a pathway by which groundwater sweeps the diffusive loading from the tailings out of the envelope and into the pond above the tailings, resulting in a higher mass loading on the environment. The no side drain case resulted in greater flow through the tailings with a corresponding higher mass loading. The partial side drain case proved to be the optimum for overall environmental impact.

The data from the regional groundwater model were used in the Environmental Transfer Pathways Model (ETP) to predict impacts to local and regional human communities and ecological receptors.[15] Because there are no communities in the Key Lake area, two hypothetical communities were developed: a seasonal hunting and fishing camp on the shore of

Lower Key Lake and a permanent community living on country food on the shore of Russell Lake, a larger lake downstream of the project. Calculations were carried out for natural uranium, ^{226}Ra, ^{230}Th, nickel and arsenic over a 10,000-year period, using both the realistic best estimate and the hypothetical worst case for environmental loadings. In all cases, the predicted radiation doses to the receptors are far below any criteria which could be applied (worst-case dose <30 μSv/a, realistic case <5 μSv/a). The water quality in the Deilmann pond is predicted to meet the Saskatchewan Surface Water Quality Objectives for all contaminants except ^{226}Ra which in the worst case was predicted to marginally exceed this objective (0.12 vs 0.11 Bq/L).

However, there were several very conservative assumptions made in these calculations. No credit was taken for source depletion as contaminants are leached from the tailings over the long term. For purposes of the analysis, it was assumed that the pit was filled with tailings from the processing of Key Lake ore. In fact McArthur River ore, which would be the mill feed for the last 15 to 20 years of operation, is very clean, containing only tiny traces of nickel and arsenic. Arsenic and ^{226}Ra are the limiting contaminants from the Key Lake ore. The result is that the pore water in the blended tailings will have a lower concentration of arsenic than the pore water in straight Key Lake tailings, and the environmental impact will be proportionately lower. In addition, the Key Lake area is not very productive and it is doubtful that there is enough game to permit a community to exist on country food, meaning that the radiation doses would be even lower than predicted.

6. Field Evaluation

Because Phase 1 tailings placement in the Deilmann pit only commenced in 1996, it is too soon to assess the actual performance; however, the Rabbit Lake pit has been used for tailings for almost 12 years. Instrumentation to measure settlement and pore-water pressure was installed in the Rabbit Lake pit several years ago, allowing comparisons to be made between predicted and measured performance.[16] The tailings are settling somewhat faster (Figure 4) and the excess pore-water pressure is dissipating somewhat faster (Figure 5) than predicted in the modelling used in the original Rabbit Lake assessment. This means that the system should be ready for decommissioning with a shorter delay after the end of tailings deposition.

The Rabbit Lake impact assessment was based on pore-water chemistry for fresh tailings. From sampling of pore water in the pit, we have found that, as the pore water ages, more radium precipitates out of solution, reducing the concentration in the pore water and reducing the flux of radium from the decommissioned pit. In modelling the Deilmann project, the realistic case used this fact, while the worst case assumed that the pore water concentrations would remain at the original high levels. Our expectation is that the Deilmann system will work as well as the Rabbit Lake system, meaning that there is another layer of conservatism in the performance predictions.

7. Conclusions

The use of mined-out open pits for tailings disposal is a new concept which has a number of advantages over past practices. Tailings are removed from the active surface environment, eliminating problems associated with weathering and erosion. The likelihood of intrusion by future human activity and burrowing animals is greatly reduced, particularly if the pit is flooded after closure. From an oxidation/acid generation point of view, submerged tailings are an advantage. Placement of tailings within the water table can be safely done, if steps are taken to create a low-energy regime, with minimal water flow through the tailings. The method of creating this tailings environment is dependent upon local conditions; the primary need is the flexibility to take advantage of local hydrogeological conditions. The primary mechanism remaining for release of contaminants is molecular diffusion, which is a very slow process. The environmental pathways analyses show that concentrations of contaminants in the environment as a result of this type of disposal will always be at acceptably low levels and the resultant radiation doses to future residents of the area will be far below both current and proposed criteria and natural background doses.

8. Acknowledgements

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9. References

(1) BARSI, R.G. "An Overview of Saskatchewan's Program for the Environmental Regulation of Uranium Mining", Proceedings International Symposium on Uranium and Electricity, September 18-21, 1988, Canadian Nuclear Society, pp 7-22 to 7-31.

(2) RUHRMANN, G., ADRIAN, L. AND HOLL, N. "Decommissioning of the Rabbit Lake Tailings Management Facility", Cameco Corporation, Saskatoon, 1992.

(3) BARSI, R.G. Personal communication with author, May, 1996.

(4) KEY LAKE MINING CORPORATION "Key Lake Project, Volume 1, Environmental Impact Statement", September, 1979.

(5) GULF MINERALS CANADA LIMITED "Environmental Impact Statement, Collins Bay B-zone Development, Rabbit Lake Operation, Third Addendum", November, 1981.

(6) CAMECO CORPORATION "Deilmann In-Pit Tailings Management Facility, Environmental Impact Statement", February, 1994.

(7) MINATCO LIMITED "McClean Lake Project Environmental Impact Statement", Volume 1, August, 1991.

(8) COGEMA RESOURCES INC. "The Midwest Project Environmental Impact Statement", August, 1995.

(9) SCHIFFMAN, R.L., SZAVITS-NOSSAN, V. AND MCARTHUR, J.M. "ACCUMV - Nonlinear Large Strain Consolidation", ©1992, Department of Civil Engineering, University of Colorado.

(10) H.K. MITTAL AND ASSOCIATES "Laboratory Test Results and Geotechnical Design, Deilmann Pit TMF", November, 1993, Environmental Impact Statement, Deilmann In-Pit Tailings Management Facility, Appendix C, February, 1994.

(11) STEFFEN, ROBERTSON AND KIRSTEN (CANADA) INC. "Key Lake Tailings Management Facility Water Chemistry", November, 1993, Environmental Impact Statement, Deilmann In-Pit Tailings Management Facility, Appendix D, February, 1994.

(12) ADRIAN, L.W. "Key Lake Operation Interim Waste Rock Study Report", March, 1994.

(13) GOLDER ASSOCIATES LTD. "Hydrogeological Studies, Proposed Deilmann TMF, Key Lake Operation", November, 1993, Environmental Impact Statement, Deilmann In-Pit Tailings Management Facility, Appendix A, February, 1994.

(14) MCDONALD, M.G. AND HARBAUGH, A.W. "MODFLOW, A Modular Three-Dimensional Finite-Difference Groundwater Flow Model", United States Department of the Interior, USGS Open File Report 83-875, 1984.

(15) BEAK CONSULTANTS LIMITED "Environmental Pathway Analysis of the Proposed Deilmann Tailings Management Facility", February, 1994, Environmental Impact Statement, Deilmann In-Pit Tailings Management Facility, Appendix E, February, 1994.

(16) CAMECO CORPORATION "Environmental Impact Statement, Collins Bay A-zone, D-zone and Eagle Point Development, Revised 1992".

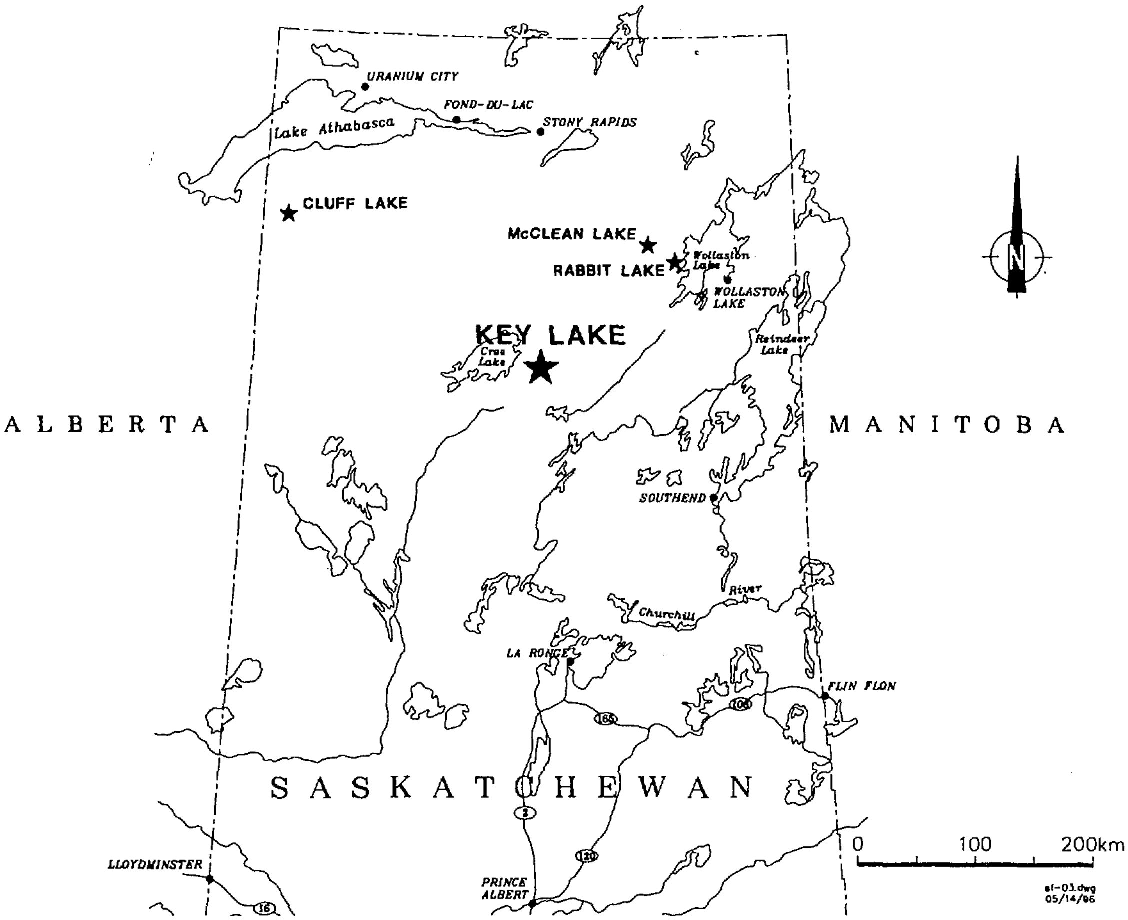

Figure 1: Project Location Map

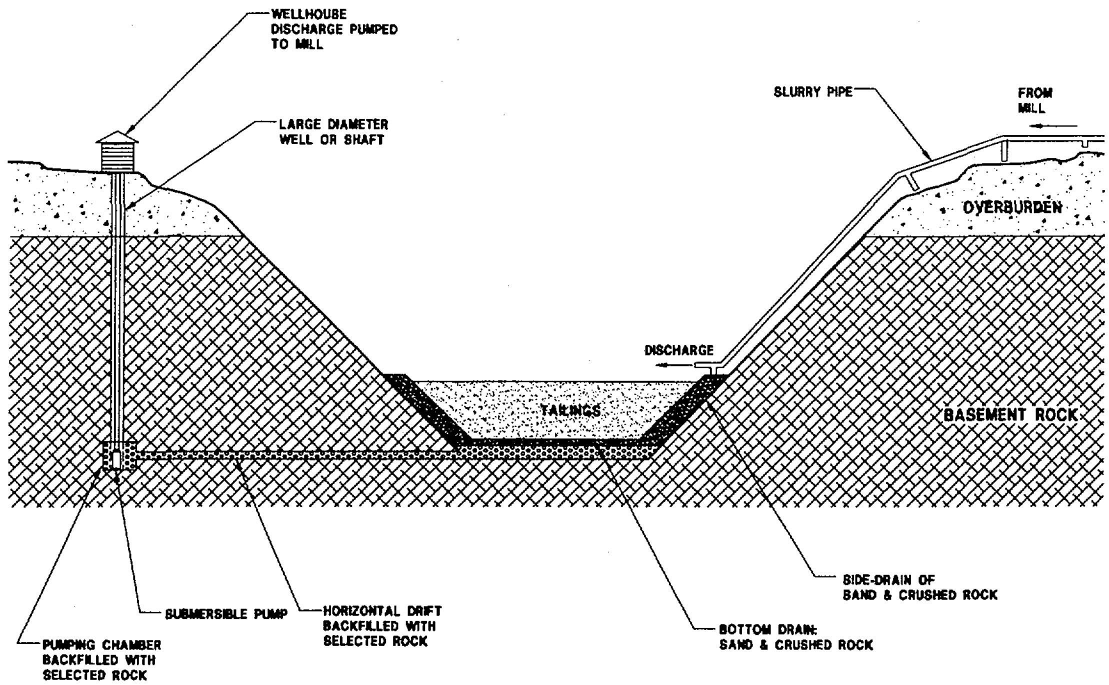

Figure 2: Rabbit Lake Pervious Surround Tailings System

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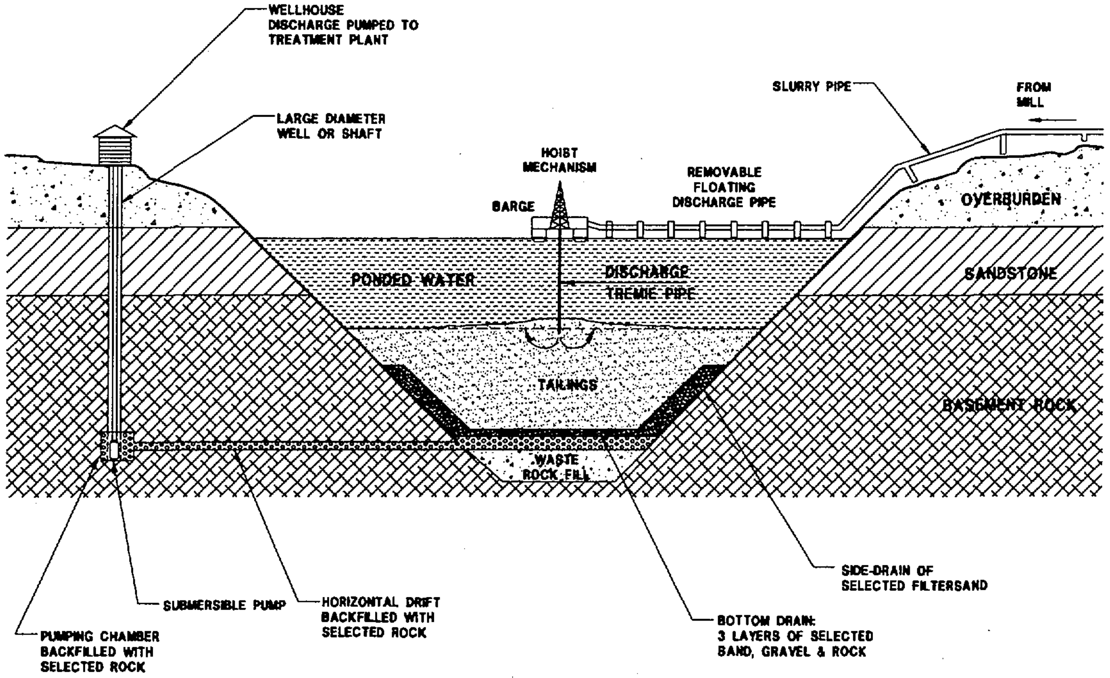

Figure 3: Deilmann Subaqueous Tailings Deposition

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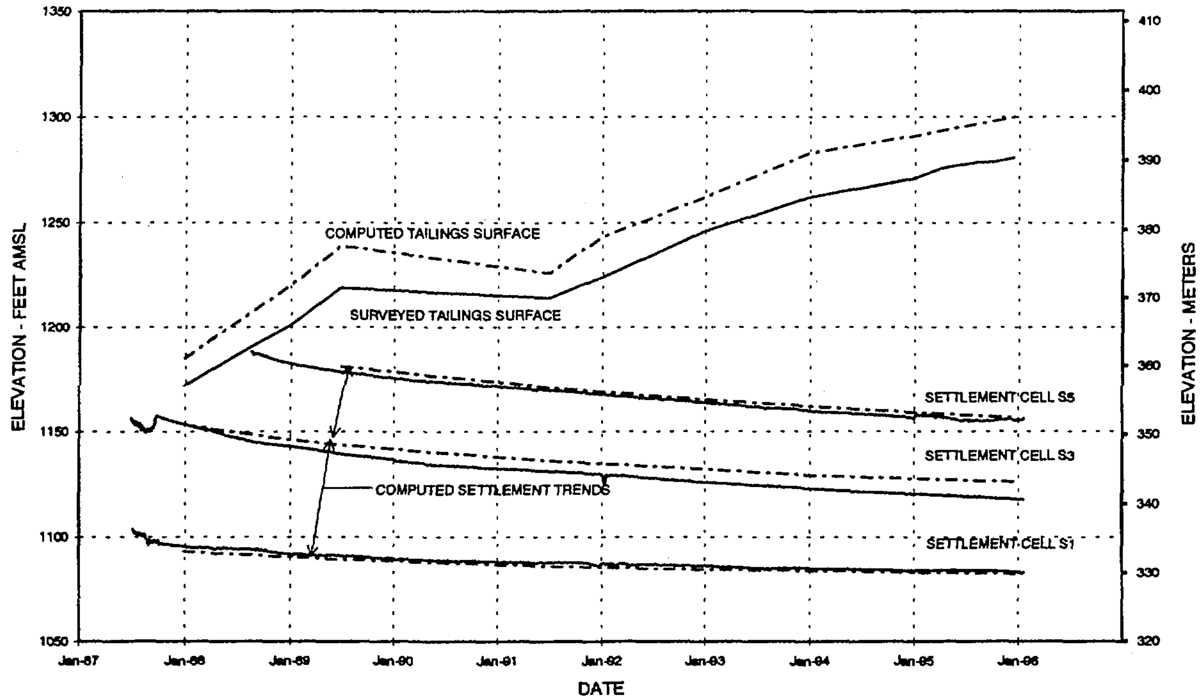

Figure 4 - RABBIT LAKE COMPUTED VS. ACTUAL ELEVATIONS

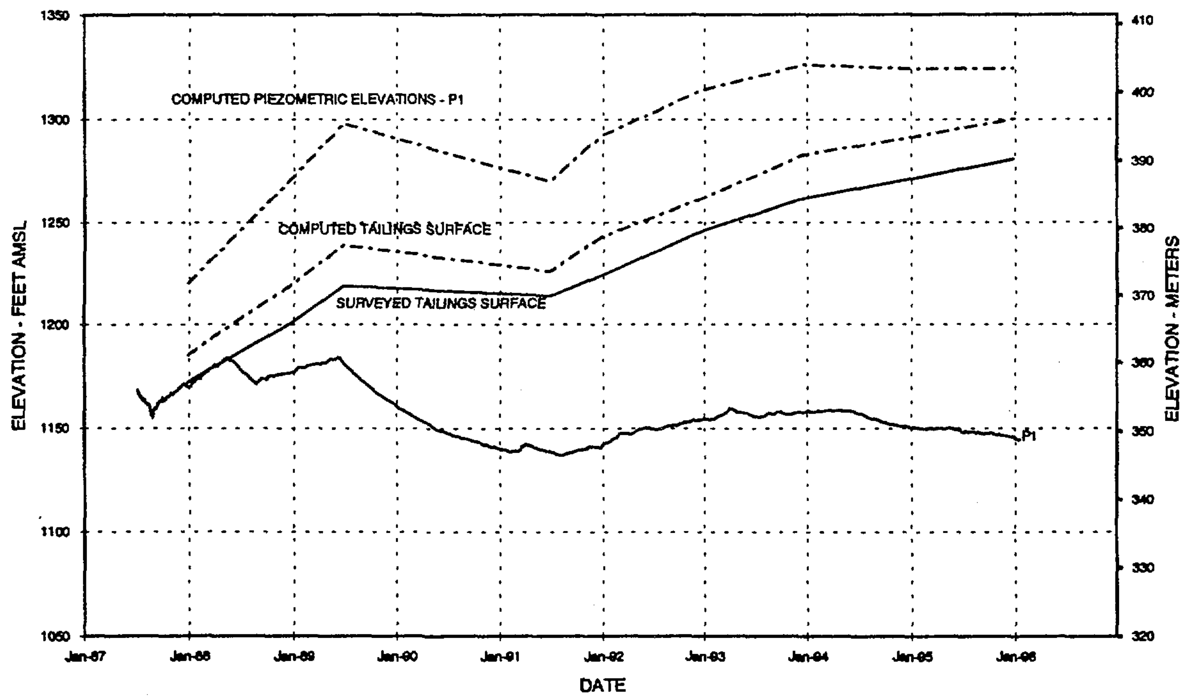

Figure 5 - RABBIT LAKE COMPUTED VS. ACTUAL PIEZOMETRIC ELEVATIONS