Denison Mines- 10 Years After Closure

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Abstract

Denison Mines was closed in 1992 after 37 years of operation. The buildings have been dismantled, the mine openings sealed and the disturbed lands reclaimed. The remaining legacy is the tailings stored within two engineered basins called TMA-1 and TMA-2. These basins contain about 63 million tonnes of acid generating uranium tailings. In the late 1980's and early 1990's, Denison undertook an evaluation of the options for closure of the tailings basins and concluded the application of a shallow water cover (0.9 m) was the preferred option. The water cover would control acid generation, eliminate dusting, reduce radiation exposure (lower gamma fields and radon releases) and would restore the lands to a condition similar to that which existed prior to mining (lakes and wetlands).

Tailings relocation was required to fully implement the plan. This included the flattening of the main tailings beach in TMA-1 by dredging about 1.8 million m^3 of tailings from the exposed beach to below water. In TMA-2, about 1.7 million m^3 of highly acidic stacked and beached tailings were relocated to TMA-1 and the underground mine. During relocation, lime and lime rejects were added to control acidity levels in the basins. This work was completed in 1996 and the basins have now been flooded for about 7 years.

As projected, acid generation has been controlled and the shallow water covered basins are becoming productive wetland areas with the invasion of many plants and animals. Water quality has been good and only a minor degree of final effluent polishing has been required to meet discharge standards.

During 1999, a major environmental effects monitoring program was completed to assess the performance of the facility and the cumulative impacts of all mining operations on the Serpent River watershed. The results are positive and indicate the closed mines are having no material effect on the ecology of the region.

This paper will present an update of the performance of the shallow water covered basin and an overview of the results of the environmental effects monitoring programs completed to date.

INTRODUCTION

The Denison Mine was the largest uranium mine in the Elliot Lake region that operated between 1956 and 1992 and produced 63 million tonnes of low-level radioactive and acid generating tailings. The tailings were placed into adjacent lake basins and valleys contained by several engineered structures. The tailings basins were named TMA-1 and TMA-2. Denison also operated the Stanrock Mine located about 5 km. to the east. The Stanrock tailings basin named TMA-3 contains an additional 5.7 million tonnes. The mines are regulated through the issuance of a Uranium Mine Decommissioning Licence issued by the Canadian Nuclear Safety Commission (CNSC).

During the early 1990's, the mines and mill were demolished and the mine sites along with the tailings basins were reclaimed. The reclamation plans for the tailings basins were developed after a thorough review of potential options including direct vegetation, soil covers, water covers and tailings relocation. The preferred plans for each basin were presented before a series of public hearings under the auspices of the Federal Environmental Assessment Review Office (FEARO). The key issues that arose during hearings were control of acid generation, long term management and risk of catastrophic

failure, mitigation measures, cumulative impacts on the valued ecosystem components, long term responsibility, ownership (surrender of title) and land use.

Denison Mill 1990- Pre-Closure

The control of acid generation was deemed to be the most important issue. In the 1960's, the primary impact from uranium mining was not associated with radiation but rather acidification of the local lakes and river systems. Flooding of tailings areas was accepted as a positive control strategy for several of the sites, but this increased the concern over the long-term stability of engineered containment structures. The FEARO Panel accepted the reclamation plans.

At TMA-1, 1.8 million m^3 of tailings in the 240 ha basin were dredged to create a flat surface and subsequently water covered. At TMA-2, half of the tailings in the 40 ha basin were relocated to TMA-1 and the other half were relocated to the underground workings via an open raise. At Stanrock, the old dykes constructed with tailings were replaced with engineered dams. The tailings surface was graded, covered with soil and paper mill sludge where necessary and vegetated. The overflow from TMA-1 and TMA-2 has excellent quality and only polishing of the effluent is required from time to time to meet discharge standards. At TMA-3, the lime treatment plant was upgraded and is operated on a batch basis as required to maintain effluent quality.

Denison Mill 2002- Post-Closure

MONITORING, CARE AND MAINTENANCE REQUIREMENTS

All three tailings management areas (TMA's) have all been upgraded to ensure they meet current standards for the protection of health, safety and environment. General programs to ensure the continued safe operation, care and maintenance of these decommissioned properties include: Site Security; Radiation Protection Programs; Health and Safety Programs; Inspection Programs; Tailings Management Operating Programs; Monitoring Programs; Reporting Programs; and Emergency and Contingency Response Programs. Some selected programs are discussed below.

ANNUAL INSPECTION BY A GEOTECHNICAL ENGINEER

The focus of the annual inspection by a professional engineer is to: Verify that the facility is performing as designed; Confirm that routine care and maintenance activities are being completed as required; and Identify any potential areas of concern that may require remedial action.

Each tailings management area associated with the operation of a CNSC licenced facility is

inspected annually by a qualified Engineer. No major issues at any structure have developed and the basins are operating as designed.

TAILINGS MANAGEMENT AREA INSPECTION PROGRAM

Each tailings management area associated with the operation of a CNSC licenced facility is monitored routinely and in response to unusual events. Site-specific inspection forms are maintained for each TMA and elements monitored include: Dams, dykes, berms, other water retaining structures; Spillways and other flow-control structures; Culverts, channels, collection ditches and other flow directing structures; Staff gauges, flow meters and other flow and elevation monitoring devices; Dam instrumentation; Access roads and gates; Electrical lines, transformers and substations; and, Pipelines (water, reagents, gas/propane). Ongoing monitoring has demonstrated the facilities are operating as projected.

MONITORING PROGRAMS

The monitoring program is intended to track on-going facility performance and to serve as a basis for future program modifications as required. The program is comprised of the following components: Serpent River Watershed Monitoring Program (SRWMP); In-Basin Monitoring Program (IBMP); Source Area Monitoring Program (SAMP); Tailings Operational Monitoring Program (TOMP); Quality Management Program; Standard Operating Procedure Program; and Database Management Program. Selected programs are reviewed.

SERPENT RIVER WATERSHED MONITORING PROGRAM

The Serpent River Watershed Monitoring Program (SRWMP) was initiated in September of 1999. This ecosystem-based aquatic monitoring program is designed as a basis for: Evaluation of cumulative effects of mine discharges on the Serpent River Watershed; Evaluation of the effectiveness of mine decommissioning plans relative to conditions predicted in environmental assessment and screening documents; and Assessment of long term trends in environmental quality in the watershed.

IN-BASIN MONITORING PROGRAM

The In-Basin Monitoring Program was initiated in September of 1999. The objective of the program is to provide quality assured chemical and biological data for each of the decommissioned TMAs to allow for: Assessment of chemical and ecological conditions in the basins, which permit definition of realistic food-chain pathways (data complimentary to the SRWMP); Tracking ecological changes through time within these areas, in terms of species composition and organism abundance, as ecological succession proceeds; and Assessment of potential food-chain effects on biota that may access the TMAs.

SOURCE AREA MONITORING PROGRAM

The objective of the Source Area Monitoring Program (SAMP) is to provide quality assured chemical data for each of the decommissioned TMAs to allow for: Characterization of the nature and quantity of contaminants being discharged from the TMAs consistent with SRWMP and In-Basin programs; and Evaluation of the effectiveness of mine decommissioning plans relative to conditions predicted in environmental assessment and screening documents.

TAILINGS OPERATIONAL MONITORING PROGRAM (TOMP)

The objective of the Tailings Operational Monitoring Program is to provide quality assured chemical data for facility operation and control. The program is designed to provide relevant, site-specific operational data to: Demonstrate compliance with discharge criteria; Confirm proper function of key process control

instrumentation (pH probes, flow monitors); Evaluate effluent treatment plant performance and make required operational adjustments; Evaluate TMA performance and make required operational adjustments; Evaluate site-specific mitigation measures to identify any potential residual areas of concern that may require remedial action; Evaluate containment dam performance; and Evaluate operating strategies and contingencies plans.

STATUS OF TMA-1, TMA-2, TMA-3 AND MINE SITES

REGULATORY COMPLIANCE

Uranium mines in Canada are regulated by the federal Nuclear Safety and Control Act and a number of regulations administered by the Canadian Nuclear Safety Commission (CNSC). The CNSC is a publicly appointed body which administers the Act and Regulations. The CNSC relies on a comprehensive licensing system to regulate the uranium mining industry, and currently issues Mining Facility Operating Licenses and Mining Facility Decommissioning Licenses. The system of CNSC licensing is administered with the cooperation of other federal and provincial government agencies such as Ministry of Labour, Ministry of Natural Resources, Environment Canada, Ontario Ministry of the Environment and Ministry of Northern Development and Mines. Since closure in 1992, the facilities have remained in compliance.

WATER QUALITY

An environmental assessment report was completed in 1995 which projected the cumulative impact that would result if all of the tailings management areas in the upper Serpent River watershed were to discharge to the watershed without treatment. The report concluded that at the loads projected, receptor doses would be extremely low and water in the major receiver, Quirke Lake, would not be impaired. In fact, the long-term projections for Radium^{226} concentrations in Quirke Lake would be less than 10% of the provincial water quality objective. The current water quality data has confirmed that Radium^{226} is well below 10% of provincial water quality objective and that metal discharge from the decommissioned mines is negligible (Table 1).

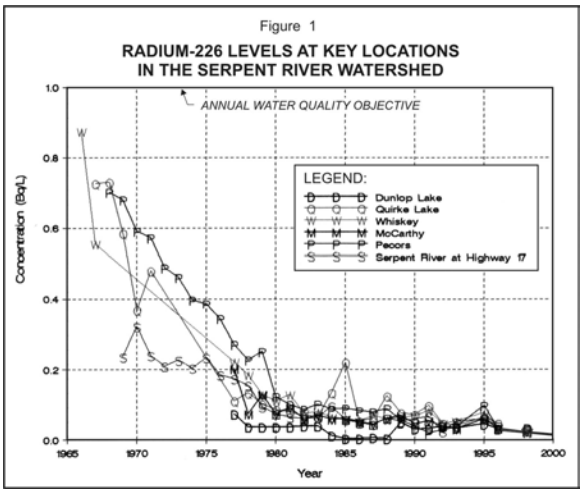
TABLE 1 -RECEIVING WATER QUALITY KEY PARAMETERS

Parameter	2000-2002 Water Quality Quirke Lake	Water Quality Objective
Copper mg/L	0.001	0.005
Nickel mg/L	0.0019	0.025
Lead mg/L	0.0005	0.003
Zinc mg/L	0.006	0.020
Ra^{226} Bq/L	0.051	1.00

Water quality was predicted to continue improving throughout the Serpent River system and meeting all drinking water standards and surface water quality objectives for the protection of aquatic species. A historical review of radium levels at 4 locations in the Serpent River system is provided in Figure 1.

CONTAMINANT LOADINGS

The discharge loadings from TMA-3 Stanrock were calculated as the average of the last three years (2000-2002). This period is representative of the most conservative level (lowest level of discharge) from this property, which has been closed since the sixties. Construction of a new effluent treatment plant and the revegetation and remedial work of the tailings management area completed during the decommissioning period has contributed to reducing acidity, radium and metal effluent loadings and are therefore very conservative compared to historical discharges from these properties to the receiving waters.



Additionally, loadings for the period 2000 to 2002 have been calculated for the untreated flooded tailings effluent for comparison with releases of treated water during the operating years. This comparison is a measure of the potential impact on the watershed from shutting down effluent treatment plants once the transitional phase is complete, For the purpose of this discussion, the transitional phase is taken to be the period from completion of decommissioning activities until the effluent from the TMA's is relatively stable and is only treated for radium removal.

Metals content in the effluents from the Elliot Lake tailings management areas which could impact on the discharge to the receiving waters of May Lake and Quirke Lake (the first major downstream receptors of effluents) are well below levels of concern. Table 2.0 lists total combined annual loadings for copper, nickel, lead, and zinc for the treated effluent during the last operating years, and for the untreated effluent during the transition/long term care and maintenance phase. It is apparent that metal releases have decreased dramatically below levels during the operating years. Average annual loadings in the untreated effluent are now so low that there is no measurable impact on the receiving waters.

TABLE 2.0 TOTAL ANNUAL METALS LOADING (kg/y)

Metal	Quirke Lake	May Lake	Quirke Lake	May Lake
	Pre-Closure (1989)		Post-Closure (2000-2002)	
Copper	399.15	2.11	26.31	2.11
Nickel	1047.39	5.10	43.54	5.10
Lead	909.65	3.84	24.61	3.84
Zinc	1109.08	11.57	45.00	11.57
Total Metals	**3465.27**	**22.62**	**139.46**	**22.62**

At the Denison TMAs, the treated effluent Radium^{226} loading for the last full year of operation (1990) was 8.238 bBq while the untreated effluent loading from 2000 to 2002 (representative of the long term care and maintenance phase) for Radium^{226} averaged 0.382 bBq/yr.

The treated effluent Radium^{226} loading for the period 2000 - 2002 averaged 0.086 bBq/yr. This period is considered to be representative of recent discharges and is not anticipated to materially change for an extended period. Effluent treatment for pH adjustment is anticipated to be required for the long term.

ECOLOGICAL CONDITIONS

One of the final but very important stages of the decommissioning process at the Denison TMA is the successful revegetation of the area. Since 1997, efforts to establish a self-sustaining vegetation community have been underway. As the Denison site contains flooded tailings, it is anticipated that a productive wetland ecosystem will dominate the area over time. At the time of the initial survey in 1997, the Denison TMA was essentially limited to scattered pockets of cattails, common reed and pondweeds. Since that time, through natural invasion and efforts of the Elliot Lake Research Field Station of Laurentian University there is a much greater diversity of plant species as well as the surface area in which they occupy. Other plant species which can be observed in the area include pickerel weed, white and yellow water lilies,

bladderwort, horsetail, burreed and muskgrass along with a greater abundance of the originally observed species.

Biological conditions within the TMA's are quite variable and appear to be linked in part to the extent of organic substrate available. Several sites at the Denison TMA that were once barren now contain healthy vegetation. This vegetation not only improves the aesthetics to the area but also provides habitat to many forms of wildlife.

Pond A of TMA-2 Post-Closure 1997

Pond A of TMA-2 Post-Closure 2002

Species that have been observed in the area include several forms of waterfowl, small mammals as well as large game. Forage fish were also found to be present in the TMA's. Although many years will be required to fully revegetate the area the process is well underway.

ENVIROMENTAL EFFECTS

Detailed modeling and environmental and radiological pathways analysis were conducted for humans and a broad range of biota for heavy metals and radionuclides. Each source was modeled separately, and cumulative impacts were also assessed and reported in the 1995 EIA report. Cumulative exposures to radiation were projected to be a small fraction of natural background (typically <50 μSv/a). No negative effects were projected to any biota.

The first cycle of the Serpent River Monitoring Program was undertaken in the fall of 1999 (Minnow et al. 2001). Samples were collected in a total of 20 lakes and 28 streams. The program successfully characterized watershed conditions upstream and downstream of all the historical minesites in the Elliot Lake area. In spite of decades of historical mining activity, the biological communities in most areas of the watershed were similar to those in reference areas. Where differences were observed, they were rarely attributable to the mining activities and were instead, more typically associated with natural habitat factors.

The parameters that served as the most consistent tracers of mine influence in water samples were: salts/total dissolved solids (e.g. sulphate, hardness, magnesium, sodium and potassium), manganese, barium, strontium, silicon, selenium and silver since these all exceeded background concentrations in 40% or more of samples across the watershed. These parameters are indicators of mine influence and will allow for future tracking of changes in water quality associated with the minesites.

Certain water quality parameters occasionally exceeded the Provincial Water Quality Objectives including iron, uranium, arsenic, cadmium, cobalt, copper, aluminum, alkalinity, lead, thallium and pH; however, such occurrences were only associated with a few specific locations, minor in magnitude $\leq$ 2 times the PWQO concentration, and/or associated with a low frequency at a given location.

At least one-third of all sediment samples collected downstream of historical minesites showed elevated concentrations of salts, titanium, molybdenum and cobalt relative to the concentrations observed in the background lakes. Ecological effects thresholds have not been established for most of these substances and adverse effects would not necessarily be implied by the observed elevations in concentrations relative to background levels. In fact, effects associated with mine related chemicals were rarely observed. Sequential extraction analyses and toxicity testing suggested that much of the total metal concentrations are present in a form that is not biologically available.

Statistical comparisons showed no significant differences between the benthic invertebrate community characteristics in reference lakes and streams compared to those of communities located downstream of the mine sites.

Fish abundance was not adversely impacted in five lakes downstream of the mine sites. Fish health was also assessed by extensive measurement of characteristics associated with growth, condition and reproduction of white sucker. The fish residing in the lakes downstream of the mine sites showed similar health characteristics to those residing in the upstream reference lakes.

Potential metal and radiation doses to watershed wildlife were estimated using measured concentrations in water, sediment and vegetation and conservative assumptions about such factors as feeding patterns and bioavailability. The data indicated that effects among wildlife populations are unlikely since the estimated doses were conservative and usually either less than benchmark concentrations or comparable to values for reference (background) areas.

Therefore, although water and sediment chemistry in the Serpent River watershed reflect the influent of historical mining activities, the concentrations of mine related substances did not correspond with observed biological effects. The fish, benthic invertebrates and wildlife seem to be relatively unaffected by the mine sites, representing naturally healthy communities.

FUTURE EXPECTATIONS

Denison will continue to care and maintain the sites for the foreseeable future and may at some point in time choose to return the properties to the Crown. Denison has a financial assurance plan with the Province and Canadian Nuclear Safety Commission. With the exception of the treatment facility at Stanrock TMA-3, the facilities require a minimum of care and maintenance with the exception of the ongoing monitoring requirements. It is expected these plans will be streamlined as the continued monitoring of the facilities to date indicate the basins are performing as expected.

Denison expects to decommission the treatment plant for TMA-1 and TMA-2 in the near future as these plants are essentially superfluous. At TMA-3, projections indicate that treatment for acidity control will be required for 50 years or more.

REFERENCES

SENES Consultants Limited, Environmental Impact Statement, Decommissioning of the Denison and Stanrock Tailings Management Areas, Report to Denison Mines Limited, February, 1995.

Minnow Environmental Inc. and Beak International Inc. Serpent River Watershed Monitoring Program-1999 Study, Report to Denison Mines Limited and Rio Algom Limited, April, 2001.