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The Decommissioning of the Denison Uranium Facilities in Elliot Lake

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ABSTRACT

The Denison uranium facilities consisted of the Denison, Stanrock and Can-Met mines. The Denison mine operated continuously from 1957 through to 1992, while the Stanrock and Can-met mines had discontinuous operations. Several other mines in the Elliot Lake area were also developed in the mid 1950's to supply uranium primarily to the United States Atomic Energy Commission. From the 1970s to the 1990s, the Denison mine supplied uranium to electrical power generating facilities; however, the cancellation of the Ontario Hydro contracts resulted in the closure of the Denison mine in 1992. All of the Denison uranium facilities were decommissioned between 1992 and 1998 and have been in a state of monitoring, care and maintenance since that time. The purpose of this paper is to describe the decommissioning activities for each site, the monitoring programs in place and water quality improvements that have occurred since decommissioning was completed.

1. INTRODUCTION

The discovery of uranium in the region of Elliot Lake, Ontario during the post World War II era led to the development of 12 mines and 11 associated mills between the years 1955 and 1958. Most of the uranium was produced for contracts with the United States Atomic Energy Commission during the late 1950s and early 1960s; however, following the cancellation of these contracts, most mines in the area closed. Denison mines continued to operate, supplying uranium to electrical power generating utilities in Japan and Ontario from the early 1970s to the early 1990s. Unfortunately, the demand for uranium as a fuel decreased in the late 1980s and the overall world supply of uranium was in excess of requirements. As a result of diminishing ore grades and high production costs, all of the Elliot Lake mines were forced to cease operations by the end of 1996 and undertake progressive decommissioning and rehabilitation plans.

There are a total of 11 decommissioned mines located within the Serpent River Watershed (Quirke, Panel, Denison, Spanish American, Can-Met, Stanrock, Stanleigh, Milliken, Lacnor, Nordic and Buckles) and two others (Pronto and Pater) are located near the north shore of Lake Huron) (Figure 1). There are also nine decommissioned tailings management areas associated with the mine sites (Quirke, Panel, Stanleigh, Denison, Spanish American, Stanrock, Lacnor, Nordic and Pronto). This paper focuses on the decommissioning, and long-term care and maintenance of the facilities that are the responsibility of Denison Mines Inc. (formerly Denison Mines Limited and Denison Energy Inc.), which are the Denison, Stanrock and Can-Met sites.

Figure 1: Locations of Former Mine Sites in the Serpent River Watershed

2. HISTORY

The Denison property, located 16 km north of the City of Elliot Lake, was developed in the 1950s and consisted of a mine, mill and two tailings management areas (Figure 2). Over its operational period between May 1957 and April 1992, Denison milled a total of 63 million tonnes of uranium ore. Tailings were deposited into two bedrock lined basins, TMA-1 (formerly Bear Cub Lake and Long Lake) and TMA-2 (formerly Upper Williams Lake). TMA-2 was used from the commencement of operations until it was filled in the early 1960s. After TMA-2 was filled, tailings were discharged into the Bear Cub Lake basin, which eventually merged with the Long Lake basin to form TMA-1. The rehabilitation and decommissioning of the surface facilities and TMAs began in 1992 and was completed late in the fall of 1996.

Figure 2: Denison Property in 1992 Prior to Decommissioning

The Stanrock property, located 21 km northeast of the City of Elliot Lake, was also developed in the 1950s and consisted of a mine, mill and TMA (Figure 3). The underground mine was operational from March 1958 until October 1964. During this period, the mill had a capacity of 2995 tonnes per day. From 1964 to 1970, uranium was recovered in the mill from mine water enriched underground by bacterial leaching. Mine water pumping and lime treatment on the surface resumed in late 1970s and continued until 1983. During this period, the mine was rehabilitated and a small amount of ore was hoisted to surface and hauled to the Denison mill for processing. The Can-Met mine and mill operated from October 1957 until March 1960 with a design capacity of 2700 tonnes per day. During mine operations, tailings from both the Stanrock and Can-Met facilities were discharged into the natural basin of a small lake located immediately south of the mines. This became the Stanrock tailings basin (TMA-3) and it contains approximately 5.7 million tonnes of tailings.

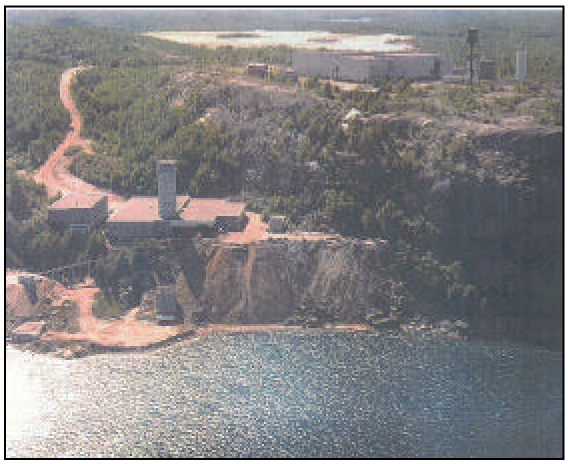


Figure 3: Stanrock Property in 1980

3. SITE INFRASTRUCTURE DECOMMISSIONING

Denison followed seven key steps during the implementation of the demolition and site restoration plans at each mine site. First, the final objective of demolition and restoration was defined, taking into account regulations and company objectives. Next, an environmental and safety audit of the site was conducted that focused on:

- hazardous material,
- hydrocarbons,
- designated substances,
- radiological contamination, and
- potential physical hazards to contractors unfamiliar with the property.

Steps three and four involved determining the regulatory requirements for disposal and permits required, and determining disposal sites for hazardous material, recyclable material and non-recyclable material. Step five involved the development of a comprehensive list of tasks to be completed that consisted of the following:

- Establishing a sales team to catalogue and sell assets. In some cases assets were removed to a central location to facilitate demolition.

- Removing and disposing of hazardous materials, hydrocarbons, and radionuclides.
- Disconnecting services and providing for ongoing services to effluent plant.
- Demolishing buildings.
- Capping or backfilling openings to underground.
- Sorting and disposing of recyclable and non-recyclable debris.
- Breaking foundations.
- Grading site and providing drainage.
- Applying topsoil or suitable equivalent.
- Conducting a post remediation radiation survey.
- Seeding and fertilizing.

Next, a timetable and budget was developed to accomplish each of these tasks and finally, a project management team was established.

3.1 Denison Mine and Surface Facilities

The decommissioning of the Denison Mine was completed in 1996 (SENES 1998) (Figure 4). This involved removal of underground equipment, explosives, fuels, lubricants and other hazardous materials, as well as sealing all openings to surface in accordance with the requirements of Ontario's proposed Mine Rehabilitation Guidelines.

Figure 4: Denison Property in 1997 After Decommissioning

During April and May of 1992, salvageable equipment and materials were removed from the mine. Most of the equipment was later sold for reuse or recycling. Fuels, lubricants and explosives were reused or disposed of. PCB-containing equipment was removed and sent to the storage facility located at the Can-Met Mine for temporary storage before eventually being sent to the Swan Hills facility for destruction. At the end of May 1992, the mine dewatering and ventilation systems were shut off. The underground workings are expected to take 50 to 100 years to flood to the water table. At that time, the near-surface water is expected to be clean and is not expected to overflow from the mine openings.

There were 15 mine openings at the site, consisting of two shafts, six raises, two adits, one ramp, and four small-diameter boreholes. The northwest and 15 Panel raises were filled with demolition debris and the southwest raise was partially filled with demolition debris then capped along with the remaining raises using the concrete saddle and beam method. The adits and surface ramp were backfilled with clean rock fill, the shafts were capped using the saddle and beam method, and the boreholes were plugged with concrete or demolition rubble and rock. The areas around the openings were graded and revegetated after the capping and backfilling were completed.

All surface facilities were demolished and the site was revegetated, with the exception of the Executive Lodge, the two effluent treatment plants, and roadways required for long-term access. Prior to demolition, equipment was removed for sale when possible, and scrap steel was removed for recycling. Asbestos was removed and placed into the Denison Landfill located at the northeast end of TMA-2, which was subsequently graded, capped with a till cover and revegetated. All other hazardous materials, such as laboratory chemicals, were disposed of by a firm licensed to undertake that work.

3.2 Stanrock and Can-Met Mine Sites

The demolition of the Stanrock surface facilities was carried out in 1992 and 1993 (SENES 1997) (Figure 5). Facilities that were demolished included: the mill complex, the head frames, the mine offices, the work shops, the warehouse, the mine hoist rooms, the pumphouses and the sewage plant. The demolition excluded some power lines, an electrical substation, the Moose Lake Treatment Plant and the Dam G pumps, trestle and pipeline, as these services are required for ongoing treatment of acid water. Prior to demolition, equipment and material were sold for reuse or recycling when possible and all hazardous materials were removed and disposed of appropriately. The underground crushing and grinding plant, located 200 ft below the surface, was used as a disposal site for solid waste and was completely filled with demolition material.

Figure 5: Stanrock Property in 1999 After Decommissioning

There were seven openings on the Stanrock property that were sealed in 1995. The shafts were sealed by constructing a "seat support" at the collar, and placing precast reinforced concrete strips across the openings. The raises were plugged with monolithic reinforced concrete slabs doweled at the collar and the adits were closed off with plugs of crushed rock.

Various spills had occurred on the Stanrock mine site during operation (SENES 1997). Historical spills at the site were remediated between 1997 and 2000. All areas having a gamma radiation level greater than 150 μR/h were remediated either by removing the material and depositing it within the TMA or covering the area with a layer of till. Additional till was applied as necessary to the spill sites, followed by grading and revegetation. The final gamma level was less than 100 μR/h.

The Can-Met mill site was demolished in the summer of 1995. Structures that were demolished included the remnants of the mill, which had burned in 1964, and the crushing and grinding facilities (Figure 6). Two shafts and one raise were sealed and the surface was rehabilitated by grading, placement of till cover and hydroseeding (SENES 1997) (Figure 7)

Figure 6: Demolishing Can-Met Mill Site 1995

Figure 7: Rehabilitating Can-Met Mill Site 1995

4. TAILINGS MANAGEMENT AREA DECOMMISSIONING

The Elliot Lake uranium deposits are classified as low grade (< 0.1% U_3O_8). Although the radioactive characteristics of the tailings are a concern, detailed radiological modeling conducted as part of the National Uranium Tailings Program has confirmed that exposures and risks to the public from the Denison facilities are very low (Denison Mines Limited 1995). However, in addition to radioactive elements, the tailings contain an average pyrite content of 6%. When pyrite is exposed to air it reacts with oxygen to produce sulphuric acid, which in turn mobilizes metals and radioactive isotopes having a detrimental effect on receiving waters if not treated. Acid generation was deemed to be the most significant issue for consideration during the development of decommissioning options (Denison Mines Limited 1995).

Prior to decommissioning the tailings management areas, Denison undertook a thorough review of potential options that would address the problems associated with acid mine drainage (Table 1).

Table 1: Options Considered for Decommissioning of TMAs (SENES 1995)

Option	Description
Base Case	• long-term collection and treatment of contaminated seepage and run-off water
Water Cover	• use of natural precipitation and run-off water to flood the exposed tailings • water retaining perimeter dams required
Soil Cover	• use of non-acid generating soil material to cover the exposed tailings and encourage a raise in the water table elevation
Complete Removal	• hydraulic relocation of tailings • underground disposal • deep lake (Quirke Lake) disposal
In Situ (Stanrock only)	• a modification to the base case • construct new, low permeability dams to establish and maintain an elevated water table near the tailings surface • similar advantages to a water cover

The ability of each option to meet the specified design objectives and criteria for each TMA was assessed on the basis of the option's potential environmental, economic, and social impacts. The evaluation also took into account the guidelines for environmental assessment laid out by the Federal Environmental Assessment Review Organization (FEARO) Panel and the recommendations made at public hearings. The key conclusions regarding the options that were not selected included:

- Complete removal to Quirke Lake was inappropriate because it would reverse the dramatic improvements that have been made to the lake over the past 10 years and eliminate the potential development of the lake for over 100 years. This option would also involve excessive capital and operating costs and increased doses to downstream residents.
- Underground disposal was rejected due to the associated high costs and the impossibility of returning all tailings to the underground due to the concept of volume expansion.
- The long-term treatment and sludge production associated with the base case was undesirable.

The decommissioning plans that were selected for the Denison and Stanrock TMAs are described in the following sections.

4.1 Denison TMA-1 and TMA-2

A water cover was selected as the most suitable option for decommissioning of TMA-1 and TMA-2 based on the following reasons:

- elimination or near elimination of acid generation,
- elimination of airborne releases (i.e., dusting),
- geography of the area is well-suited to flooding,
- risk of structural failure is very remote,
- flooded tailings would result in no requirement for new lands,
- limited burden on future generations,
- basins are returned to a use very similar to what they were like pre-mine development,
- radiation dose to receptors will be much less than anticipated limits, and
- water cover is an effective barrier to intrusion by man.

The Denison TMAs lie south of the former mill complex area between Quirke and Dunlop Lakes (Figure 8). TMA-1 has an area of 235 ha and contains 60 million tonnes of tailings. Prior to decommissioning, TMA-2 had an area of 36.3 ha, containing 3.3 million tonnes of tailings. The tailings of TMA-1 are contained within valleys surrounded by east-west trending ridges and five engineered structures (Dam 16, Dam 10, Dam 18, Dam 9, and Dam 17). Water flows from TMA-2 into TMA-1, then into the Stollery Lake polishing pond before entering the Upper Serpent River. TMA-2 was originally contained by Dam 1 to the west and Dams 11 and 12 to the south and southeast, respectively. Two internal dams (Dams 2 and 4) contained tailings and controlled drainage. Dam 5 contained a spill and directed drainage into TMA-1. Prior to decommissioning of TMA-2, the area west of Dam 2 drained through a spillway to Dam 1. The effluent was treated at a treatment plant downstream of Dam 1.

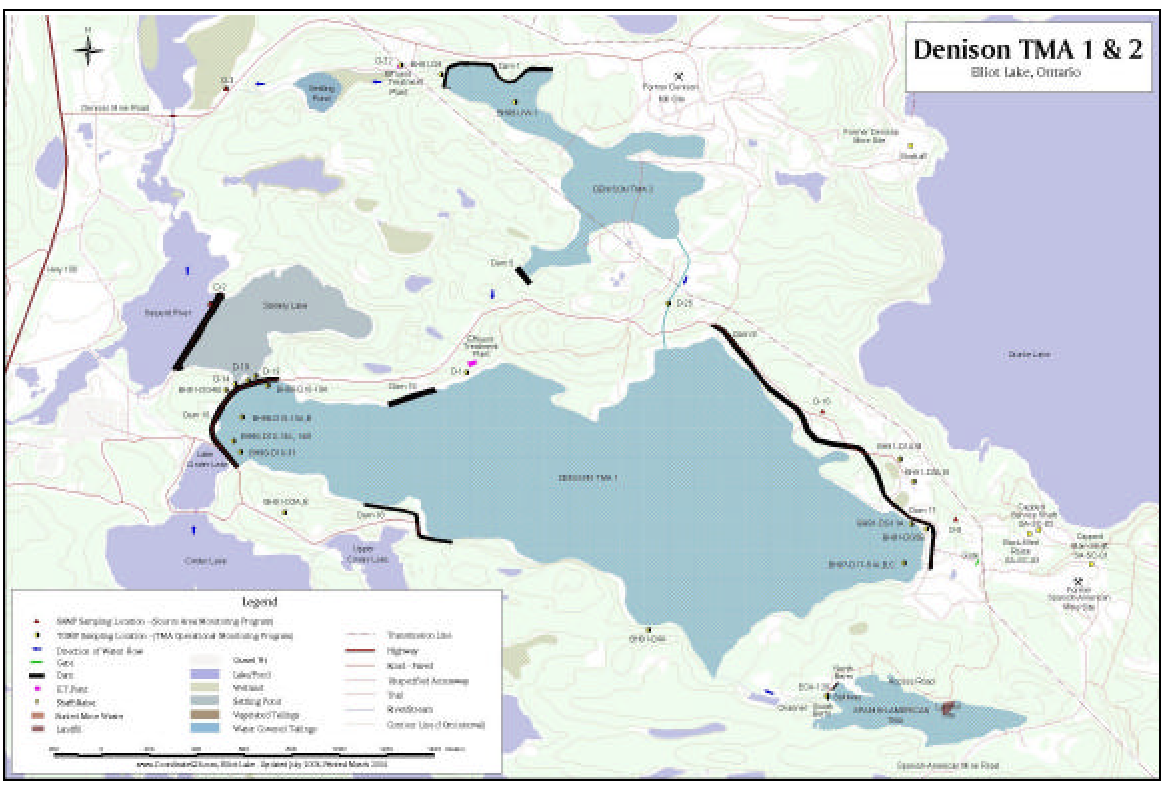


Figure 8: Denison Site Map (TMA-1 and TMA-2)

In accordance with the decommissioning plan, the following major activities were completed to decommission the two TMAs:

- Sealing the TMA-1 decant tower in Dam 10 with concrete.
- Redistributing and leveling the tailings in TMA-1 with dredges.
- Hydraulic monitoring and pumping of tailings from TMA-2 to underground and TMA-1.
- Constructing new spillways on the north side of TMA-1 and from TMA-2 to TMA-1 designed to pass the probable maximum flood.
- Lowering the crests of Dams 9 and 17 to improve long-term stability and raising Dam 10 to provide more freeboard.
- Reinforcing the base of Dam 10 to ensure long-term stability.
- Increasing the height and reinforcing Dam 1 to redirect all the flow from TMA-2 to TMA-1.
- Installing new monitoring piezometers in the dams.
- Installing new flow monitoring weirs and flumes to measure flow.
- Constructing a new water treatment plant.

The relocation of tailings within TMA-1 was done with a floating dredge. The dredge cutter head could be hydraulically lowered to effectively dredge up to 6 m depths and the dredge itself required relatively low 1 m of draft. Slurry was discharged through 300 mm HDPE line. A second slurry pump was used in series midway between the dredge and the spigot to increase slurry pressure over long distances. A discharge barge was positioned at the spigot point to spread slurry evenly over the discharge area.

The water cover concept was implemented at both TMA-1 and TMA-2; however, the process of implementation was unique to each TMA. Constructing large dams would not have been economical in TMA-2 nor sustainable within a small watershed. As a result, tailings were removed from TMA-2 in order to lower the elevation and meet the requirements of a water cover. The tailings were relocated to two areas (TMA-1 and the underground workings) using hydraulic monitors and slurry pumping.

The appearances of TMA-1 and TMA-2 before and after decommissioning are illustrated by pairs of photographs (Figures 9 and 10). The final stage of the decommissioning process was to establish a self-sustaining vegetation community. In 1997, limited vegetation was present in the TMAs; however, since that time a greater diversity of plant species have been established over a larger surface area (Figure 11).

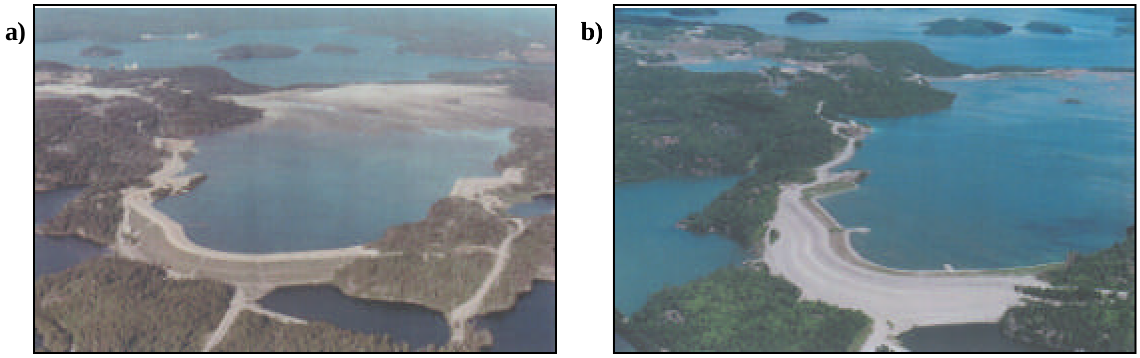


Figure 9: Denison TMA-1 a) Before (1992) and b) After (1998) Decommissioning

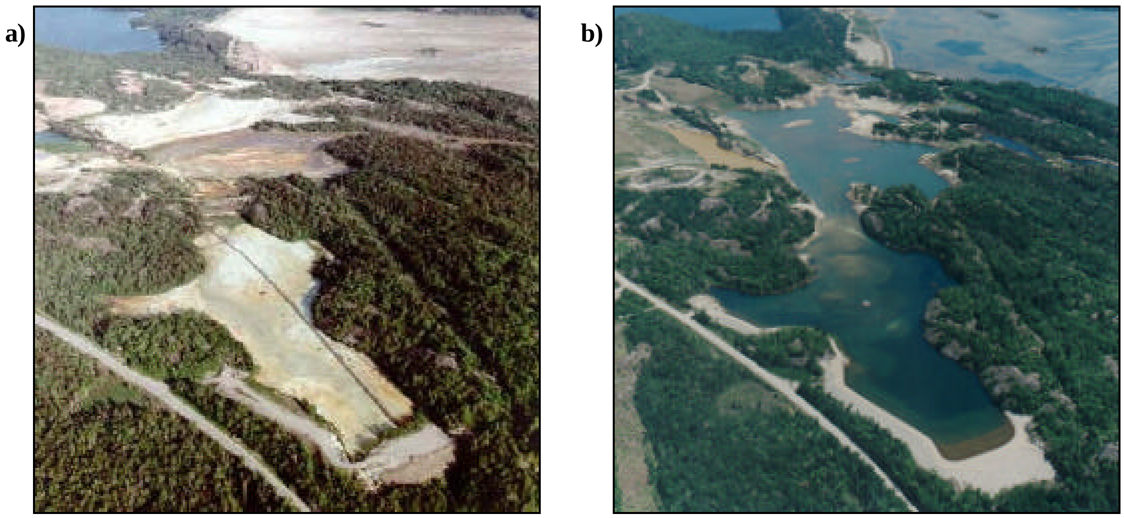


Figure 10: Denison TMA-2 a) Before (1992) and b) After (1998) Decommissioning

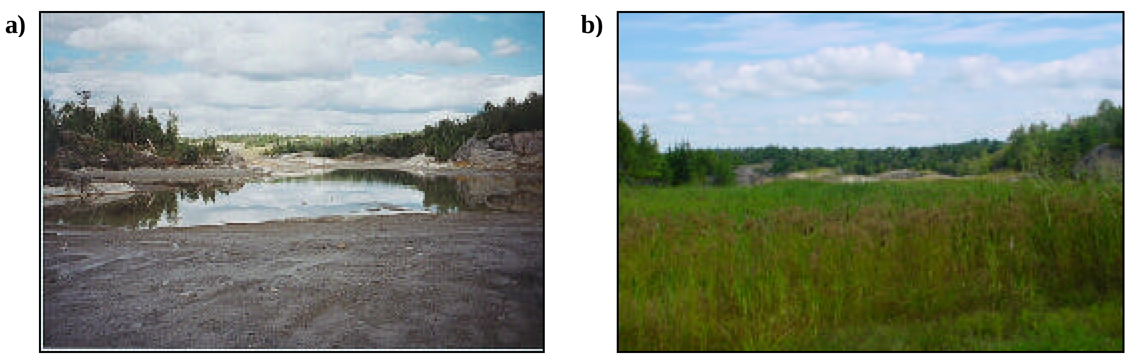


Figure 11: Pond A of Denison TMA-2 Post Closure in a) 1997 and b) 2002

4.2 Stanrock TMA-3

The *"In Situ* Management Plan" was chosen as the preferred option for decommissioning the Stanrock TMA. The reasons for selecting this option included:

- the majority of the acid generating tailings would be stored below the water table,

- airborne dust and radon releases would be reduced,
- surface water quality would be within accepted loadings,
- no new areas are required and the present impacted area would be reduced through remedial clean-up,
- the basin would be returned to conditions similar to those of pre-mine development.
- cost effective option that addressed all concerns within the existing TMA, and
- the future risks of major system failures were minimal.

The Stanrock TMA is located 0.6 km southeast of the Stanrock mine site (Figure 12). It has a surface area of 52 ha and contains 5.7 million tonnes of tailings. Since 1964, there have been no additions of tailings into TMA-3. There were four pervious tailings structures (Dams A, B, C, and D) that retained the tailings. Seepage from these dams was collected and treated prior to release. Additional structures present at the site include: Dam G collects seepage from Dams B and C; Dam J constructed at the west end of Beaver Lake to eliminate drainage to Quirke Lake and collect seepage from Dam D; and Dams K and F located at the outlet of the Moose Lake polishing pond.

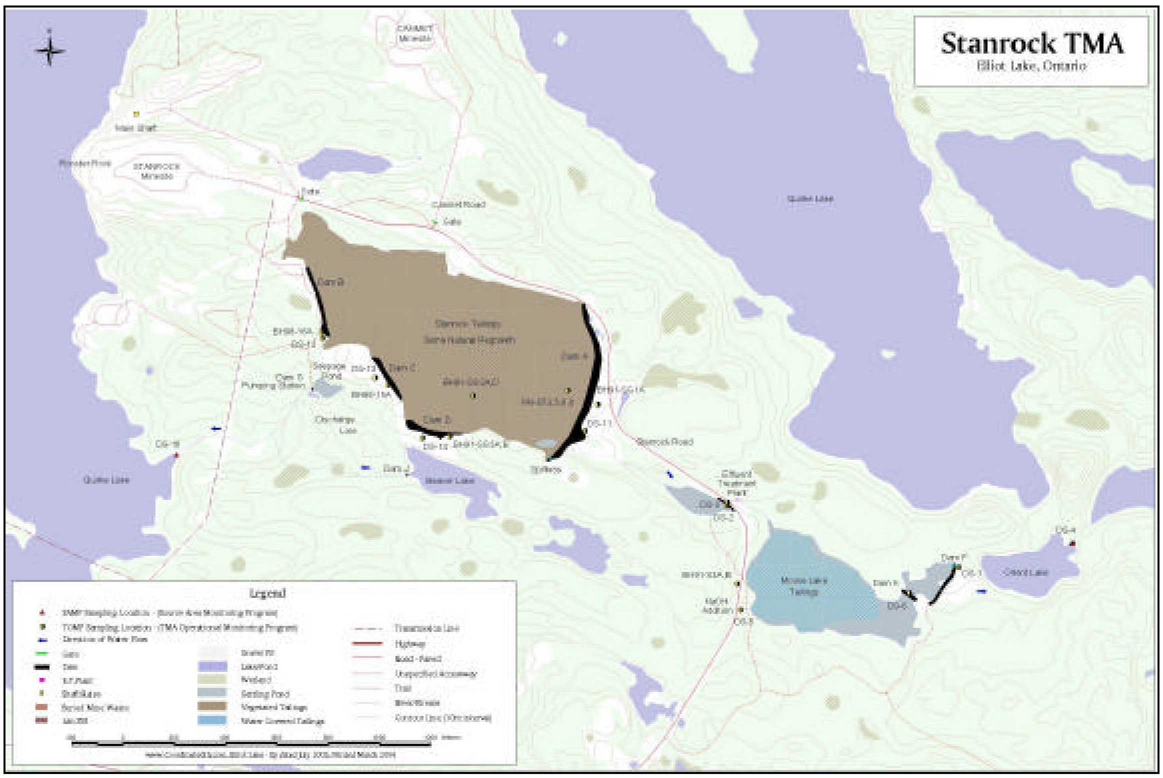


Figure 12: Stanrock Site Map

In accordance with the decommissioning plan, the following major activities were completed to decommission the Stanrock TMA:

- Constructing a new rock cut spillway near Dam A.
- Constructing of new low permeability engineered Dams A, B, C, and D.

- Reconstructing Dam K to provide additional sludge storage and relocation of sludge within Moose Lake.
- Upgrading Dam F to ensure long-term stability.
- Upgrading Orient Lake outlet berm
- Remediation of spilled tailings.
- Establishing rock lined channels for surface drainage.
- Vegetation of the tailings.
- Installation of new monitoring piezometers in the new dams and tailings to measure water levels.
- Constructing a new and improved water treatment plant that includes storage of untreated water and improved reagent mixing with untreated effluent.

The new containment dams were constructed downstream of the existing structure. The dams incorporate a water retaining core of compacted till that is founded on bedrock. The bedrock foundation beneath the dam core was grouted to minimize seepage. Filter and drains were provided to prevent internal erosion and a build-up of porewater against the dam. Although there is a small headpond, water is generally not impounded in the TMA, but drains from the surface and passes through a spillway in Dam A to the new treatment plant. Seepage from all the dams is collected and also flows to the treatment plant.

Although building the new dams has raised the water table, it could not be raised high enough to completely cover all of the tailings, as anticipated in the planning process (SENES 1997). Un-oxidized tailings above the water table still react to form additional acid, which is flushed out along with the acid already present. Modelling has shown that it may take up to 50 years to deplete the entire contained acid inventory.

5. MONITORING PROGRAMS

5.1 General Care and Maintenance Programs

Each of the TMAs were upgraded to ensure that they meet current standards for the protection of health, safety and the environment. There are a number of programs in place to ensure the continued safe operation, care and maintenance of these decommissioned sites. The general programs 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. The Inspection Programs are discussed below.

5.1.1 Annual Inspection by a Geotechnical Engineer

The objectives of the annual inspection by a professional engineer are 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 TMA associated with the operation of a Canadian Nuclear Safety Commission (CNSC) licenced facility is inspected annually by a qualified

Engineer. To date, there have been no issues at any of the structures and the TMAs and basins are operating as designed.

5.1.2 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 the 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.

5.2 Environmental Monitoring Programs

Denison has undertaken extensive environmental monitoring programs since the early 1970s. At the time of closure, each mine had its own environmental monitoring program conducted under an operating licence from the CNSC (formerly, the Atomic Energy Control Board (AECB)) or a Certificate of Approval (C-of-A) from the Ontario Ministry of Environment (MOE). In 1997, both Denison and Rio Algom (responsible for the other mine sites in the area) reviewed their existing monitoring requirements in terms of their relevance to current environmental data and predictions of changing conditions associated with decommissioning as outlined in the Environmental Impact Statement (Denison Mines Limited 1995). The evaluation resulted in the development of an integrated strategy designed to manage the cumulative effects of all 11 mine sites in the Serpent River Watershed. The integrated strategy is subdivided into four programs that supersede the monitoring requirements listed in the licenses and C's-of-A for the TMAs. The monitoring programs include:

- Serpent River Watershed Monitoring Program (SRWMP) – developed to replace the various, mine-specific receiving environment monitoring programs with one comprehensive program focused on water and sediment quality, benthos and fish health, and radiation and metal doses to humans and wildlife (Beak 1999 and Minnow 2002a).
- In-Basin Monitoring Program (IBMP) – developed as a companion program to the SRWMP to assess the health risks to biota potentially feeding at each of the aquatic and vegetated management areas (Beak 1999 and Minnow 2002a)
- Source Area Monitoring Program (SAMP) – developed to monitor the nature and quantities of contaminant releases to the watershed (Minnow 2002b)
- TMA Operational Monitoring Program (TOMP) – developed to generate the data that tracks TMA performance and supports decisions regarding the management and discharge compliance of the TMAs (Minnow 2002c)

Each program was designed to directly complement the other three programs in terms of monitoring locations, parameters, and sampling frequency, and thus ensure that the overall monitoring framework is comprehensive and interpretable. These programs are object-driven and allow for modification to be made over time in response to changes in the conditions at the sites and the results of on-going data collection. The SRWMP and IBMP are conducted on a five-year cycle with Five Year Interpretive Study Reports issued at the end of each cycle. The first cycle of both programs was undertaken in the fall of 1999 and the reports were completed in 2001 (Minnow and Beak 2001a, b). The second cycle of the SRWMP and IBMP was conducted in the fall of 2004 and the reports are expected to be completed in the summer of 2005. Annual water quality reports are also prepared for each of the four programs to summarize all monitoring data and discuss any concerns and necessary remedial actions.

6. WATER QUALITY

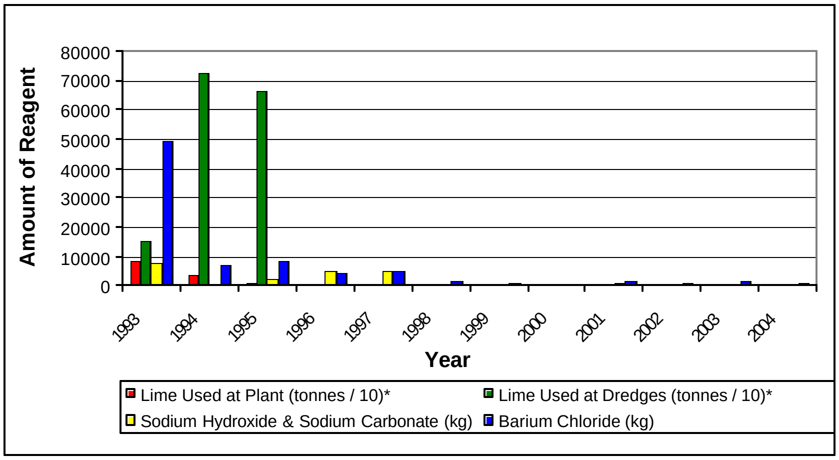
Since the decommissioning of the Denison uranium facilities was completed, there have been noticeable improvements in the quality of water within the TMAs, as well as in the receiving waters.

6.1 Denison Site

The effectiveness of decommissioning activities is indicated by the reduction in the amounts of reagents that have been used at the effluent treatment plants or directly within the TMAs. Minor to no effluent treatment (*i.e.,* the addition of lime or sodium hydroxide) has been required since 1997 to maintain neutral pH within TMA-1 and TMA-2 (Figures 13 and 14). This is the result of both the lime addition undertaken during tailings relocation (1994 and 1995) and the effectiveness of the water cover in inhibiting further acid generation. Barium chloride for radium^{226} removal has been added in proportion to flow from the treatment plants. The addition rate of barium chloride was reduced after closure as a result of lower concentrations of radium in the TMA. Therefore, the reduction in consumption of barium chloride since 1993 reflects both lower flow through the treatment plants and decreased radium^{226} concentrations in the basins.

Decommissioning activities were also effective in reducing the concentrations of heavy metals, and sulphates in the TMAs, as indicated by the trend of decreasing concentrations present in pre-treated water collected from TMA-1 between 1992 and 2004 (Figure 14). However, with the reduction in annual mean sulphate concentrations from 787 mg/L in 2000 to 232 mg/L in 2004, there is a slight increase in annual mean radium^{226} concentrations from 0.208 Bq/L in 2000 to 0.400 Bq/L in 2004. This observation is not surprising based on initial modeling. This has been further demonstrated by recent studies that have shown increased mobility and release of radium^{226} in pyritic uranium tailings when sulphate ion mobility control has been depleted for both on-land and underwater disposal scenarios (Davé 1999a, b and Davé *et al.* 2002). The decommissioning of TMA-1 and TMA-2 has been successful in addressing the primary concern of acid generation and has resulted in improved water quality; therefore, future management of the TMAs will focus on the possibility of increased radium mobility with the depletion of sulphate over time within the basins.

a)



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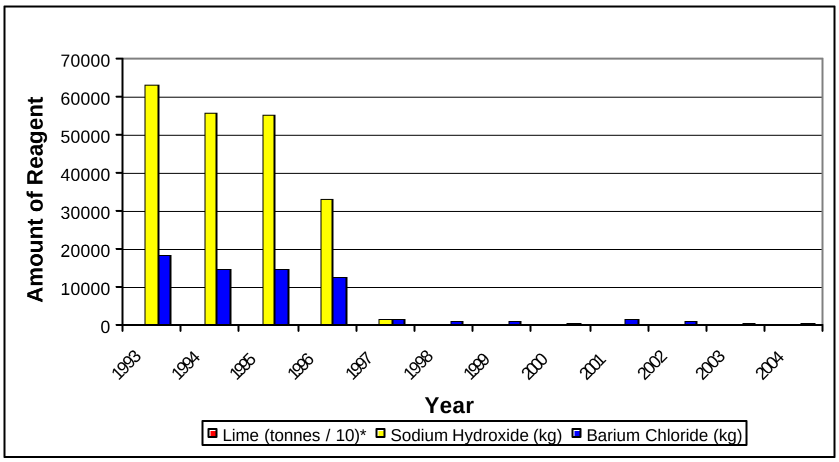

Figure 13: Annual Reagent Consumption at a) TMA-1 and b) TMA-2

*The amount of lime used is the value shown divided by a factor of 10.

Currently, water quality is monitored at the final points of release from TMA-1 (Station D-2) and TMA-2 (Station D-3) in accordance with the SAMP and TOMP requirements. Historical monitoring was also conducted following a site-specific monitoring program. Results indicate that concentrations of the majority of "mine indicator" parameters, substances clearly associated with the mine sites (Minnow 2002b), have decreased since decommissioning was completed in 1996. Water quality has also continued to improve as conditions in the basins have stabilized over time. In fact, annual mean concentrations of $radium^{226}$ and iron are below the Provincial Water Quality Objectives (PWQO) established for the protection of aquatic life. pH has also consistently met the PWQO at the final points of release from 1992 through 2004 (Figure 15).

Water quality is also measured at the final points of release, D-2 and D-3, under the Uranium Mine Decommissioning Licence issued for the Denison site by the CNSC. Monthly mean concentrations of $radium^{226}$, copper, nickel, lead, zinc, total suspended solids, arsenic and pH have been in compliance with discharge limits during the last five years of monitoring. In addition, concentrations of the majority of parameters are one to three orders of magnitude below the established limits. The data collected during 2004 is provided in Table 2.

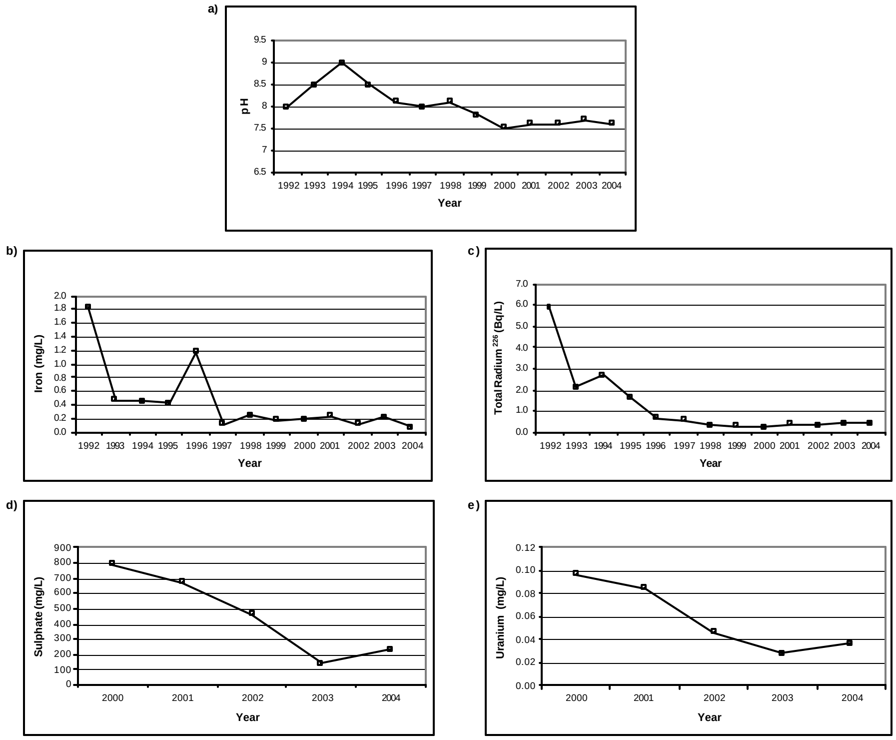

Figure 14: Pre-treatment Water Quality at TMA-1 - a) pH, b) Iron, c) Total Radium^{226}, d) Sulphate, and e) Uranium

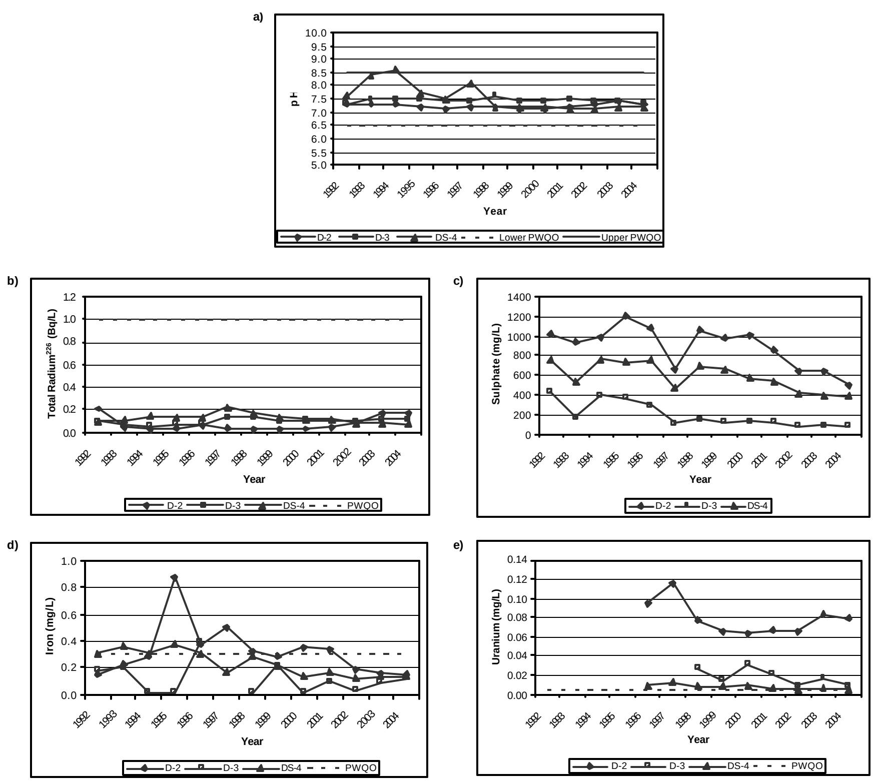

Figure 15: Water Quality at Final Points of Control from Denison and Stanrock TMAs - a) pH, b) Total Radium^{226}, c) Sulphate, d) Iron, and e) Uranium

Table 2: Comparison of 2004 Monthly* Mean Concentrations of Parameters in Effluent to Compliance Limits at Final Points of Control from Denison and Stanrock TMAs

Parameter	Monthly Compliance Limit	Station	January	February	March	April	May	June	July	August	September	October	November	December
pH	6.5 - 9.5	D-2	7.2	7.1	7.1	7.1	7.5	7.7	7.4	7.4	7.4	7.4	7.4	7.5
		D-3	7.3	7.2	7.2	7.2	7.4	7.4	7.3	7.2	7.4	7.3	7.4	7.6
		DS-4	7.1	7.0	7.0	7.2	7.3	7.3	7.2	7.2	7.2	7.1	7.4	7.5
Ra^{226} (Bq/L)	0.37	D-2	0.071	0.059	0.137	0.146	0.250	0.334	0.193	0.242	0.148	0.168	0.144	0.093
		D-3	0.106	0.112	0.111	0.077	0.111	0.116	0.142	0.250	0.190	0.109	0.11	0.116
		DS-4	0.060	0.066	0.056	0.047	0.053	0.082	0.085	0.116	0.096	0.084	0.058	0.043
TSS (mg/L)	25.0	D-2	1.5	1.0	< 1.0	1.3	1.8	2.0	2.3	1.0	1.0	1.0	1.0	< 1.0
		D-3	< 1.0	< 1.0	1.0	< 1.0	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
		DS-4	< 1.0	< 1.0	1.0	< 1.0	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.3
Cu (mg/L)	0.3	D-2	< 0.001	< 0.001	< 0.001	0.008	< 0.001	0.001	0.001	0.003	< 0.001	< 0.001	< 0.001	0.001
		D-3	< 0.001	< 0.001	< 0.001	0.006	< 0.001	< 0.001	0.002	< 0.001	nm	< 0.001	< 0.001	< 0.001
		DS-4	< 0.001	< 0.001	< 0.001	0.008	0.004	0.003	0.002	0.002	< 0.001	< 0.001	< 0.001	0.006
Ni (mg/L)	0.5	D-2	0.0022	0.0023	0.0022	0.0011	0.003	0.0024	0.0018	0.0025	< 0.0003	0.0027	< 0.0003	0.0033
		D-3	0.0009	0.0005	0.0013	0.0005	0.0005	0.0008	< 0.0003	0.0011	nm	< 0.0003	0.0008	0.0006
		DS-4	0.0037	0.0034	0.0029	0.0019	0.0015	0.0007	< 0.0003	< 0.0003	< 0.0003	< 0.0003	0.0003	0.0009
Pb (mg/L)	0.2	D-2	< 0.0006	< 0.0006	< 0.0006	< 0.0006	0.0017	< 0.0006	0.0010	0.0034	< 0.0006	< 0.0006	< 0.0006	< 0.0006
		D-3	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006	nm	< 0.0006	< 0.0006	< 0.0006
		DS-4	0.0006	< 0.0006	< 0.0006	< 0.0006	0.0008	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006	< 0.0006
Zn (mg/L)	0.5	D-2	0.001	0.001	< 0.001	0.003	0.003	0.004	0.002	0.002	< 0.001	0.001	0.005	0.004
		D-3	0.002	0.003	< 0.001	< 0.001	< 0.001	0.004	0.004	0.008	nm	< 0.001	0.003	0.003
		DS-4	0.005	0.005	0.005	0.004	0.002	0.003	0.003	0.013	< 0.001	< 0.001	0.001	0.003

*Monthly mean concentration is the average value of the concentrations measured in samples collected over the month.

nm = not measured

6.2 Stanrock Site

Reagent addition to water from Stanrock TMA-3 has been greatly reduced as a result of decommissioning activities (Figure 16). Prior to the construction of the new dams, the TMA surface run-off and the combined seepages were neutralized with large quantities of lime in a water treatment plant. The new treatment plant was constructed in 1998 and includes a water storage dam, so that the plant is only run when required and can be shut down during low flow conditions. The consumption of neutralizing agents and barium chloride have all decreased since this time. Decommissioning activities have also resulted in a substantial decrease in tailings water acidity, as well as reductions in heavy metal and radium^{226} discharges (Figure 17). Annual mean concentrations of iron and radium^{226} increased slightly in 2002, likely due to low precipitation; however, levels have decreased again during the last two years.

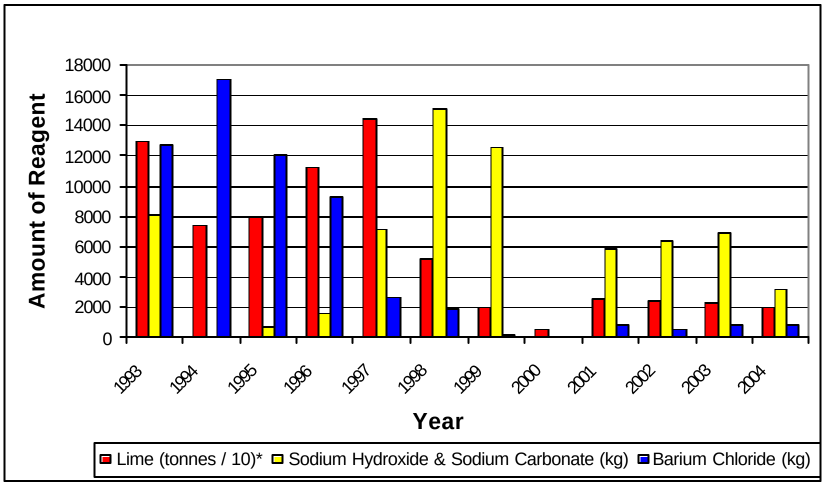

Figure 16: Annual Reagent Consumption at TMA-3
*The amount of lime used is the value shown divided by a factor of 10.

Currently, water quality is monitored at the final point of release from Stanrock TMA-3 (Station DS-4) in accordance with the SAMP and TOMP requirements. Historical monitoring was also conducted following a site-specific monitoring program. The results are similar to those for the Denison TMAs, indicating that concentrations of the majority of "mine indicator" parameters have decreased since decommissioning was completed in 1998. Water quality has also continued to improve as conditions in the tailings area have stabilized over time. For example, annual mean concentrations of radium^{226}, iron and uranium are below the PWQO. In addition, pH has met the PWQO at the final point of release between 1995 through 2004 (Figure 15).

Water quality is also measured at the final point of release, DS-4, under the Uranium Mine Decommissioning Licence issued for the Stanrock site by the CNSC. As was the case for the Denison TMAs, monthly mean concentrations of radium^{226}, copper, nickel, lead, zinc, total suspended solids, and pH have been in compliance with discharge limits during the last five years of monitoring. The data collected during 2004 is provided in Table 2.

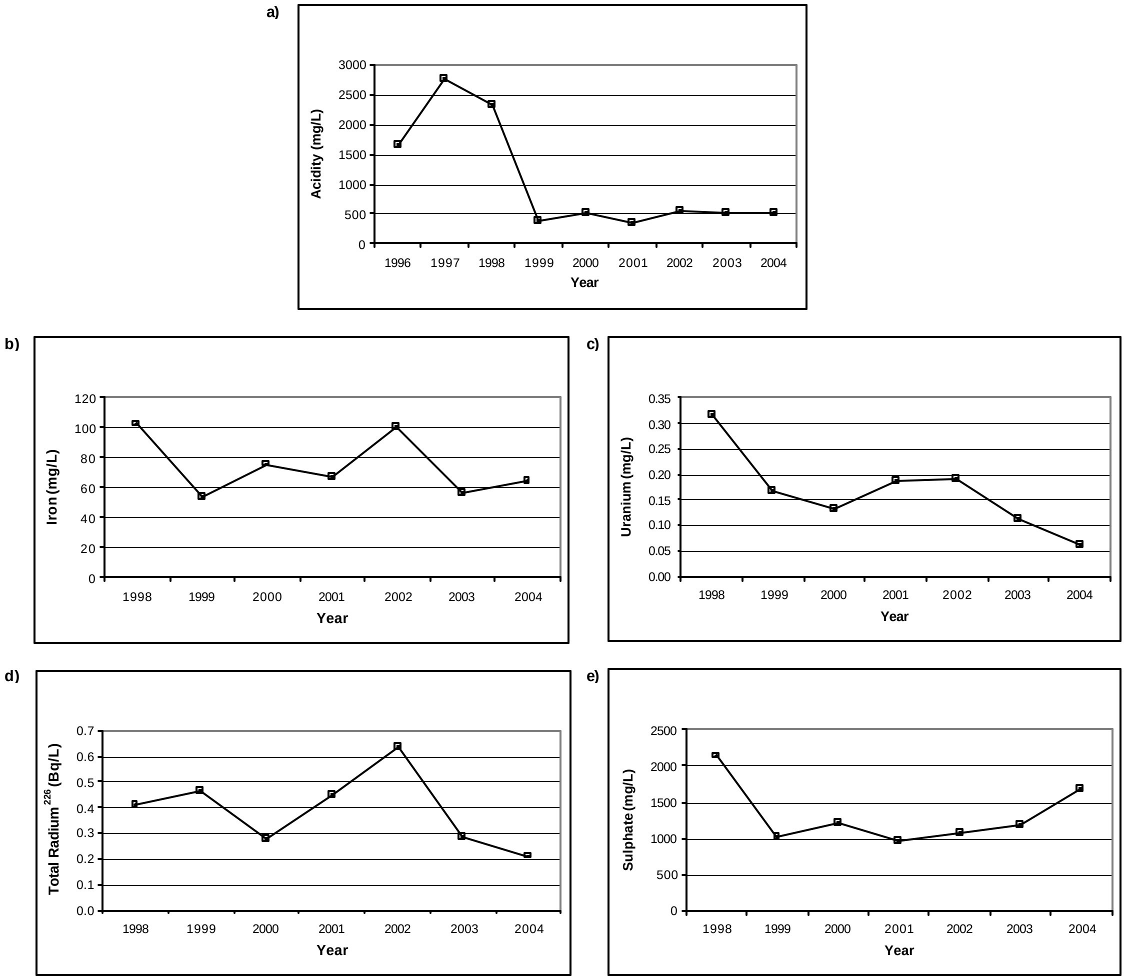

Figure 17: Pre-treatment Water Quality at TMA-3 - a) Acidity, b) Iron, c) Uranium, d) Total Radium^{226}, and e) Sulphate

6.3 Receiving Waters

Water quality at stations downstream of the Denison and Stanrock TMA discharges are monitored in accordance with the SRWMP requirements (Figures 8 and 12). Locations in the Serpent River that receive discharges from the Denison site include D-5 (downstream of TMA-1, TMA-2 and Quirke TMA discharges) and D-6 (downstream of TMA-1 seepages). D-5 and D-6 are both classified as near-field stations. Station DS-18 is located downstream of Stanrock TMA-3 at the outlet of Halfmoon Lake. It is also classified as a near-field station.

Data collected between 1999 and 2004 indicates that water quality is good at each of these stations (Figure 18). In most cases, the concentrations of "mine indicator" parameters have improved or remained consistent over time. Annual mean concentrations of iron, cobalt, selenium, uranium and radium^{226} were all below the PWQO in 2004 and most of these metals have been below the PWQO since 2000 at all stations. Annual mean manganese concentrations at all stations have been below background levels since 1999, with the exception of D-6 in 1999. pH measurements at these stations have also met the PWQO for the last six years.

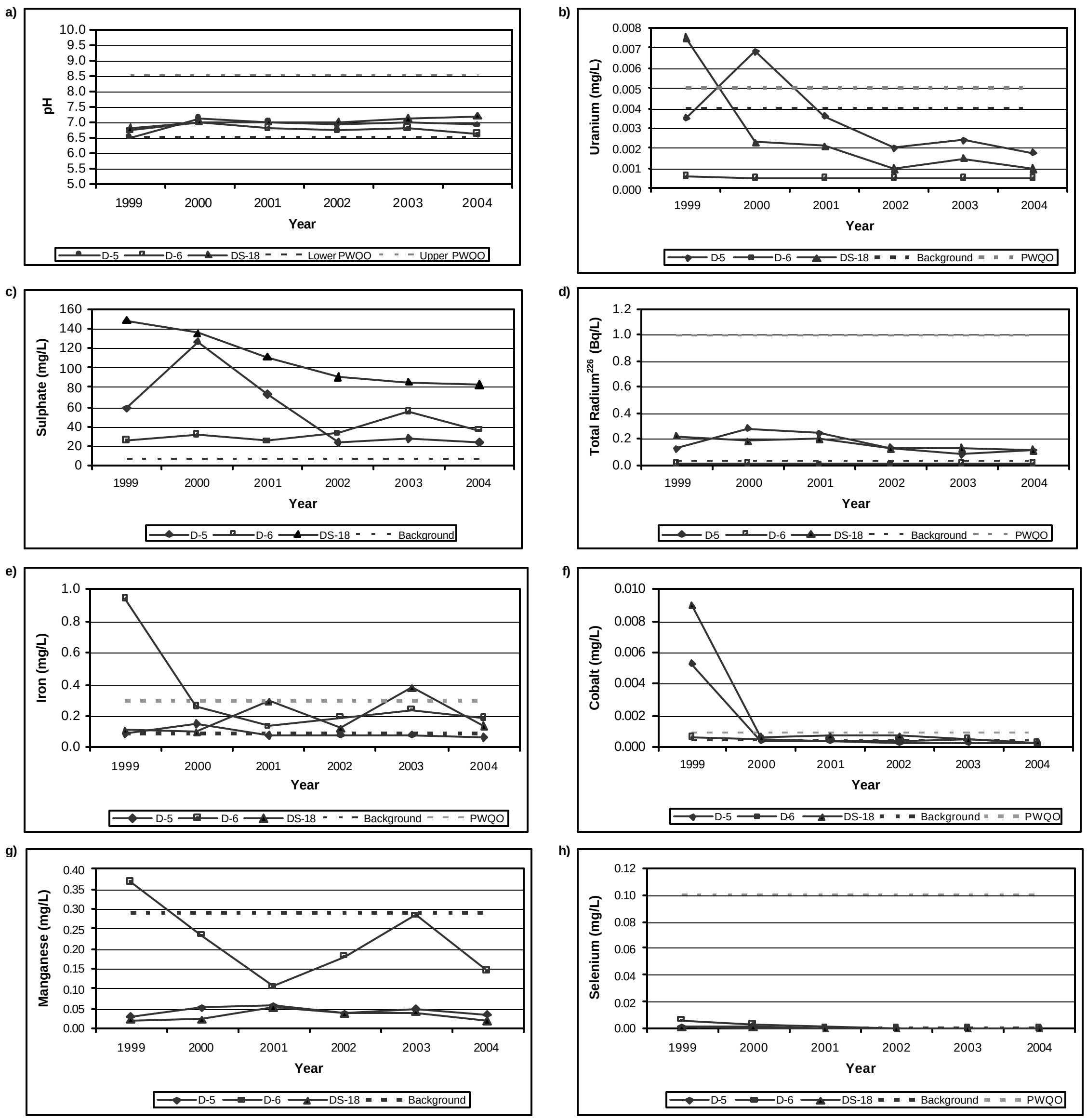

Figure 18: Water Quality at Stations Downstream of Denison and Stanrock TMAs - a) pH, b) Uranium, c) Sulphate, d) Total Radium^{226}, e) Iron, f) Cobalt, g) Manganese and h) Selenium

7. PUBLIC INFORMATION PROGRAM

Denison, in association with Rio Algom, has developed an extensive Public Information Program in order to ensure effective communication of site activities with local residents. A more intensive program was deemed necessary because of the changing demographics of the community. Elliot Lake is no longer a mining town, but it has become a leading provider of Retirement Living services. At mine closure both Denison and Rio Algom were instrumental in establishing the Elliot Lake Retirement Living Program. A significant part of the population is now elderly and from outside of the Elliot Lake area.

The public information program includes; site tours, public presentations, public awareness meetings, development of an information web site, newsletters and the release of reports. An Elliot Lake Rehabilitation Information Web Site link (found by going to www.denisonenvironmental.com) was recently developed and provides both historical information and current monitoring results. Bi-annual presentations are made to City Council and public meetings are held periodically to inform the public of important events. An annual newsletter is distributed through the local paper and is also available on the web site. All significant reports are provided to the town and are available to the public at the local library.

8. CONCLUSIONS

Decommissioning and rehabilitation of the Denison uranium facilities has been a success. The decommissioning options chosen for each site were implemented as planned and have resulted in many improvements to water quality within the TMAs and downstream in the watershed. A number of programs are in place to monitor the conditions of the sites and receiving waters. Denison will continue to care for and maintain the sites for the foreseeable future and may at some point in time choose to return the properties to the crown.

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