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AN OVERVIEW OF ACID MINE DRAINAGE MITIGATION AND TEST WORK IN NORTHWEST QUEBEC

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ABSTRACT

The authors present an overview of the environmental concerns, existing treatment and mitigation approaches and new ideas being tested to resolve acid mine drainage problems at mines visited in a recent MEND Prevention and Control committee tour of the Rouyn-Noranda/Val D'Or region (Abitibi) of Quebec. The mining areas visited were: Ste. Genevieve's Norebec-Manitou site, the Crown owned (Quebec), abandoned East Sullivan tailings impoundment, Minnova's Millenbach tailings impoundment and Mine Doyon, operated by Lac Minerals and co-owned by Cambior. To minimize or replace costly collection and treatment, the sites visited are testing various surface covers (clay, organic, non-pyritic tailings and water). Research projects carried out at Mine Doyon and Waite Amulet have been and are providing valuable new information about the processes operating in acid generating waste rock dumps and tailings. In addition to the projects observed during the tour, the paper references similar test work being carried out in other areas of Ontario and Quebec.

Introduction

This paper describes the acid mine drainage works and research being carried out at a number of sites visited during a MEND Prevention and Control (P & C) committee tour of operating, closed and abandoned mines in the Rouyn-Noranda/Val D'Or region of Quebec. While British Columbia has been very active in acid rock drainage (ARD) research, a great variety of work has also been carried out in Eastern Canada. The objectives of this paper are to describe the types of acidic drainage problems in the Abitibi region, and to provide an overview of remediation work that may be of interest to mines west of the Rockies.

The Rouyn-Noranda-Cadillac-Malartic-Val D'Or corridor occurs along the southern edge of the heavily mineralized Abitibi volcano-plutonic belt in Northwest Quebec (Simard et al., 1990). The region is remarkable both for the number of mines (Figure 1) and the amount of production; for example, the region has produced 70% of all the gold mined in Canada. Other commodities mined in the area are silver, copper and zinc. While many of the mines are now closed, there remains significant activity, and Teck Corporation is presently developing the large Louvicourt deposit just west of Val D'Or. Most of the region's ore contains high sulphide mineral concentrations, and consequently the major environmental problem faced by developing, operating and closed mines is acidic drainage and the associated concerns about high concentration of metals and trace elements at discharge.

The field tour was organized for the Prevention and Control committee of MEND (Mine Environmental Neutral Drainage), a cooperative research program whose objective is to reduce the environmental impacts and the financial liabilities of acidic drainage (Feasby et al., 1991). Overall coordination, management and organization of the MEND research program is carried out by the Secretariat, who are hired by, and are working in the offices of, CANMET in Ottawa. Direction and funding for MEND comes from contributing mining companies and the provincial and federal governments, all of whom are represented on the various committees. An organization chart for MEND is shown in Figure 2. The nuts and bolts of the MEND program (setting priorities, vetting proposals, writing statements of work, managing projects, reviewing reports, etc.) occurs in the four main technical committees: Prediction, Prevention and Control, Treatment, and Monitoring. Copies of the 1992 MEND Revised Research Plan can be obtained from the MEND Secretariat at CANMET.

To effectively manage the wide range of the Prevention and Control issues, the P & C committee has divided the subject into the five research areas listed bellow (Hope, 1992):

- Underwater Disposal (Unoxidized Tailings).
- Wet Barriers (Oxidized Tailings).
- Dry Barriers.
- Waste Rock.
- Others (e.g. Disposal Options, Pretreatment).

Each of these major research areas consists of a number of specific research programs. For example, for underwater disposal research, separate research programs exist for natural and man-made lakes. The natural lakes program includes research at a number of British Columbia lakes. The waste rock research, which also includes British Columbia projects, is divided into research looking at covers to exclude precipitation and oxygen (for example, the cementitious cover research at Westmin), studies of rock disposal in flooded pits and work done on segregation and blending (for example, the work done at Kutcho Creek and Samatosum). Like the other technical committees, the Prevention and Control group holds several meetings a year. Often these meetings are preceded by field tours, like the one providing the incentive for this paper.

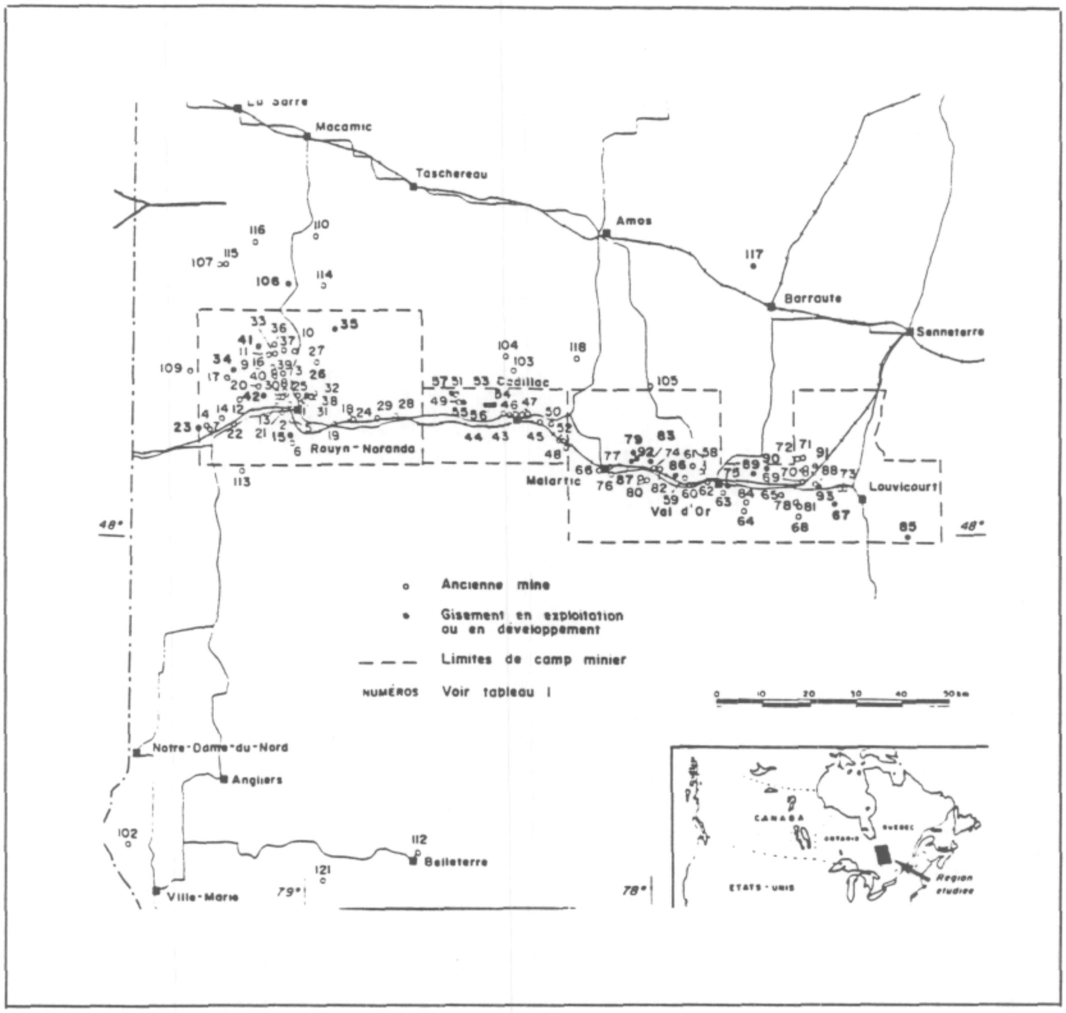

FIGURE 1 MINES ALONG THE ROUYN-NORANDA/VAL D'OR CORRIDOR (FROM LULIN, 1990).

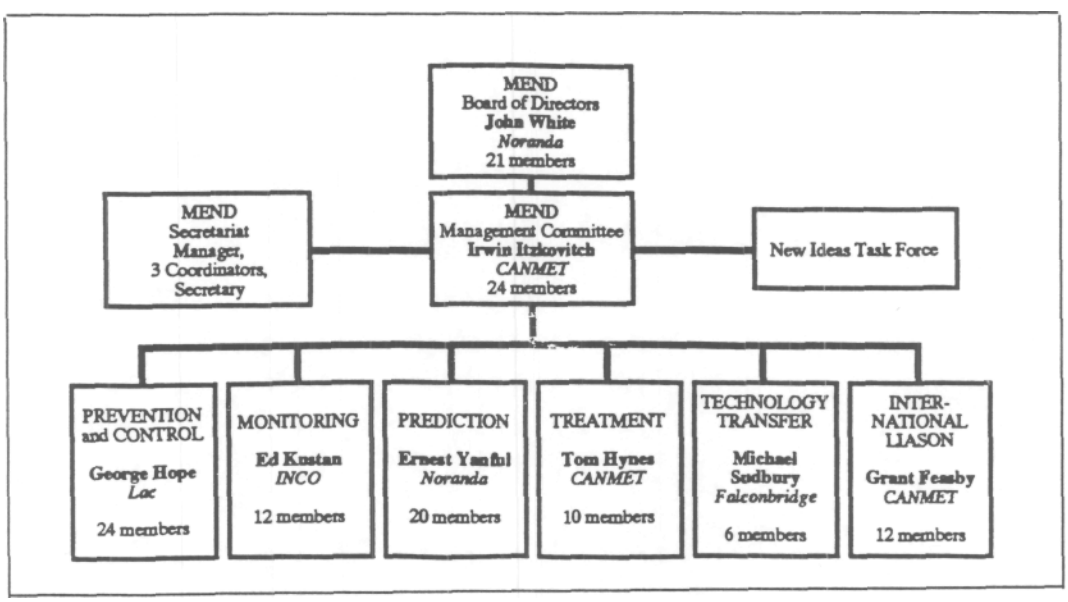

FIGURE 2 ORGANIZATIONAL FRAMEWORK OF MEND

Norebec-Manitou

The Norebec-Manitou mill, underground workings and associated tailings are located approximately 10 km east of Val D'Or (Figure 3). From 1942 to 1979 the mine milled ore from its own deposits (e.g. Manitou and Louvem). From 1979 to 1989 additional ore was milled under contract (e.g. Destor and Belmoral). Presently, there are 12 million tonnes of tailings stored above ground and one million tonnes underground. During the first 10 to 14 years the mine operated, the tailings were deposited in the adjacent shallow, swampy valley without any containment structures. The first sign of a tailings dam can be seen in 1956 air photographs. Subsequently, a number of dam structures were constructed, the latest being in the early 1970's. After 1979, all tailings were placed underground.

Surface deposited tailings cover about 180 hectares. The 12 metres deep engineered tailings impoundment is estimated to have an area of 42 hectares. The remaining 138 hectares of tailings follow the Manitou stream, from the tailings impoundment to the Bourlamaque river, in a path 200 to 300 metres wide, 6.1 km long and several metres deep (Figure 3). The proportion of tailings lost into the Bourlamaque river is thought to be significant. As the Manitou stream has cut a path through the uncontained tailings, this process is undoubtedly ongoing.

The sulphide content of the tailings is approximately 20% and this results in significant acid generation. There are no water management works to treat drainage from the tailings, which has a pH value of 3 when it enters the river.

Although the mill is now closed, the company plans a pilot project to test the recovery of gold, silver and perhaps zinc from a 40,000 tonne sample of a rich zone in the tailings pile. Gold values are typically in the 0.015 oz/tonne. The project is scheduled to run from April to June 1993. If the economics prove favourable, the mine will proceed with a 500,000 tonne sample. If this also proves to be viable, the remaining stockpiled, high concentration tailings will be treated in an eight-year, 5,000 tonnes/day operation.

Remilling of the tailings will first involve a flotation and gravity separation to remove sulphides, followed by a cyanide leach phase to produce the gold, silver and possibly zinc concentrate. The barren sulphide residue will be placed underground in the flooded cavities of the former ore bodies. During the tour, a question was raised about the mobility of cyanide pumped underground with the sulphide tailings. Mining company officials explained that in the past, 1.2 million tonnes of cyanide tailings had been placed underground and no dispersal of cyanide had been detected in the groundwater monitoring wells. It was pointed out by a member of the committee that if a problem did occur, it would be very difficult, if not impossible, to remediate.

The wide distribution likely precludes the remilling of the spilled tailings. One possible remedial measure for the unimpounded tailings is to cover them with a layer of non-sulphide tailings. Hypothetically, the non-sulphide tailings would be created during the remilling of the impounded tailings and would be sufficiently impermeable to act as a barrier to infiltration and oxygen diffusion. This concept has not been tested and important characteristics remain to be determined. For example, how high can the sulphide content be without the tailings generating acid. Manitou personnel suggested that following flotation, the tailings will be nine times more basic than acidic. Some research on this topic is being carried out by the USBM in Reno, Nevada, and in a MEND project at I'Ecole Polytechnique linked to Norebec-Manitou and looking at non-acid generating tailings as a cover material.

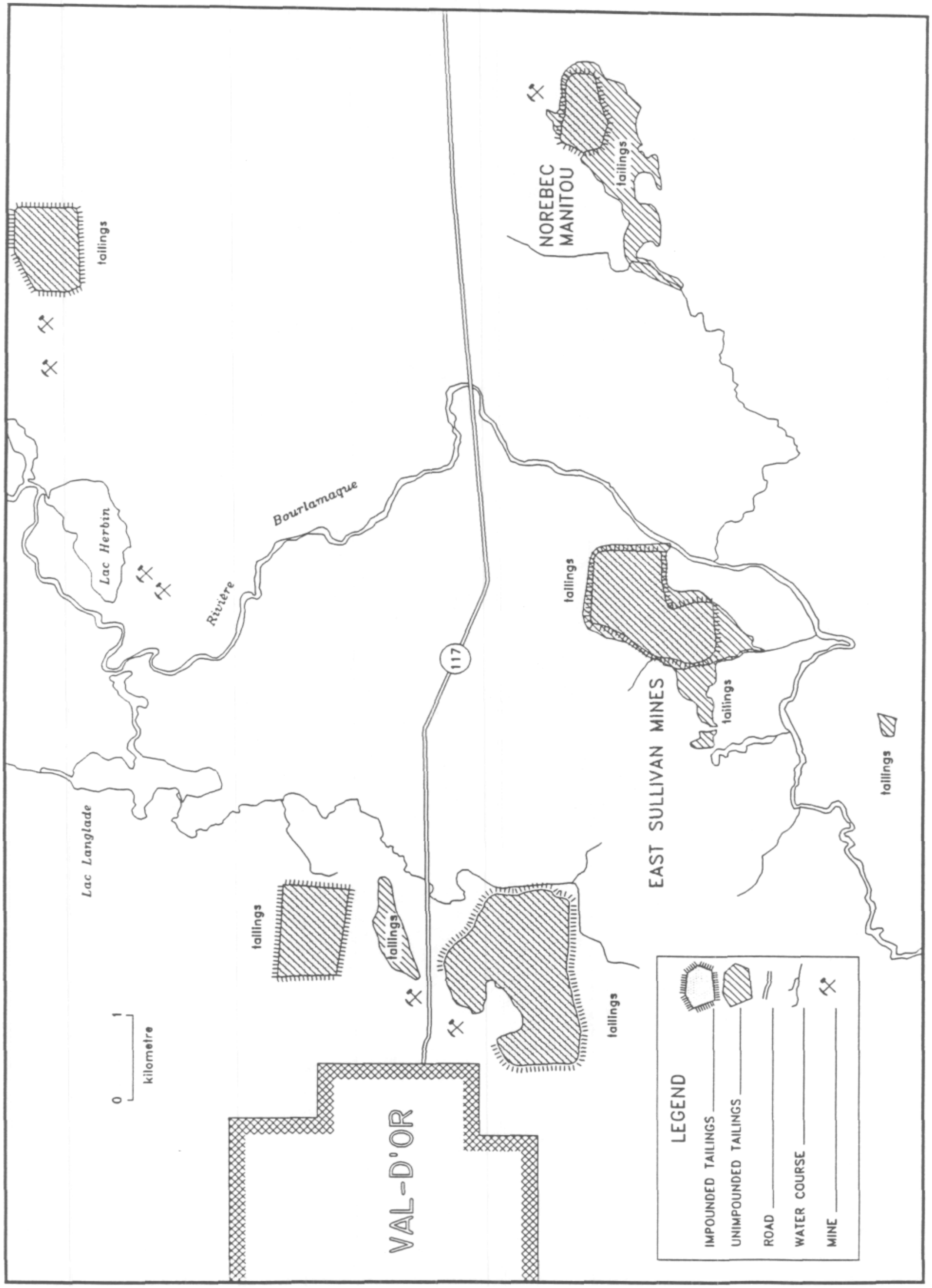

FIGURE 3 LOCATION OF THE NOREBEC-MANITOU AND EAST SULLIVAN TAILINGS.

East Sullivan

The East Sullivan site is located between the Norebec-Manitou property and Val D'Or (Figure 3). According to the Quebec Ministry of the Environment, East Sullivan operated for 17 years, creating 15 million tonnes of tailings which cover 122 hectares in a layer 5 metres deep. The site was abandoned in 1980, and the Quebec Ministry of Energy and Resources (MER) is looking after its rehabilitation. The main environmental problem is the stability of the dams, which reach 10 metres high, and in places are highly eroded. Last year, MER calculated that the total distance around the base of the tailings dams is 5 km. When the mine first operated, much of the tailings were not contained in any structure, and flowed south towards the Bourlamaque River. The amount of tailings in that area has increased as a result of a dam failure on the south portion of site.

To dispose of the wastes and to create an oxygen consuming barrier that will prevent oxygen diffusion into the tailings, fifteen to twenty-five percent of the tailings surface have been covered with a thick layer of organic waste products. The material initially applied had a mixed composition with a high proportion of large particles (particle board, chip board, broken planks and logs). The material presently applied comes from lumber yards and consists of 1% logs, 98% conifer bark and 1% sawdust.

To test the moisture retention and oxygen penetration characteristics, the Centre de Recherches Minerales (CRM) set up a 10 m x 10 m wood waste test cell, bordered by an impermeable membrane and with piezometers for water sampling. The resulting report is available from MEND or the CRM (INRS - Georesources, 1991).

Based on the results of the test cell, a more detailed trial consisting of five experimental and a control plot was recently constructed by Roche Enviromental. The study is designed to evaluate the effect of organic and inorganic waste on the rate of acid mine drainage and on the quality of the surface and ground water. The test plots were located on the previously untreated southern part of the tailings pond to eliminate the possibility of contamination by the leachate from the wood waste piles on the northern area. The trial includes one and two metres deep piles of wood waste, and measurements are made of gases, temperature, infiltration, and water quality. As the trial will only run for three years, it is unlikely to find a significant change in tailings pore water quality. More information about this project can be obtained from the proposal distributed in late August to members of the P & C Committee. Additional information pertaining to organic covers can be found in Brown et al. (1988), Brown (1991), Kasam (1991) and Pierce (1992).

Rouyn-Noranda Tailings Impoundments

Since Noranda started operating the Home smelter in 1927, a total of sixty million tonnes of tailings have been deposited in the Rouyn-Noranda area. Of the tailings impoundments in the area, Noranda #1, #2 and #3 were filled by 1950, while Pelletier #4, #5 and Quemont #2 are still active (Figure 4). Much of the tailings came from rock mined over the fifty-year operation of the Home Mine. Closing in 1976, the Home Mine produced very reactive tailings, with up to 40 to 60% pyrrhotite and 15 to 20% pyrite (plus silicious and gangue materials), sulphide levels high enough to ignite.

The first site visited during the tour was **Pelletier #4**, a 32 hectare tailings impoundment constructed in a shallow depression. Dams for the impoundment were constructed from waste rock, with clay cores and a concrete spillway. Most of the tailings in the pond are flooded. The remaining exposed materials have been covered with slag tailings. Trials are ongoing to find a

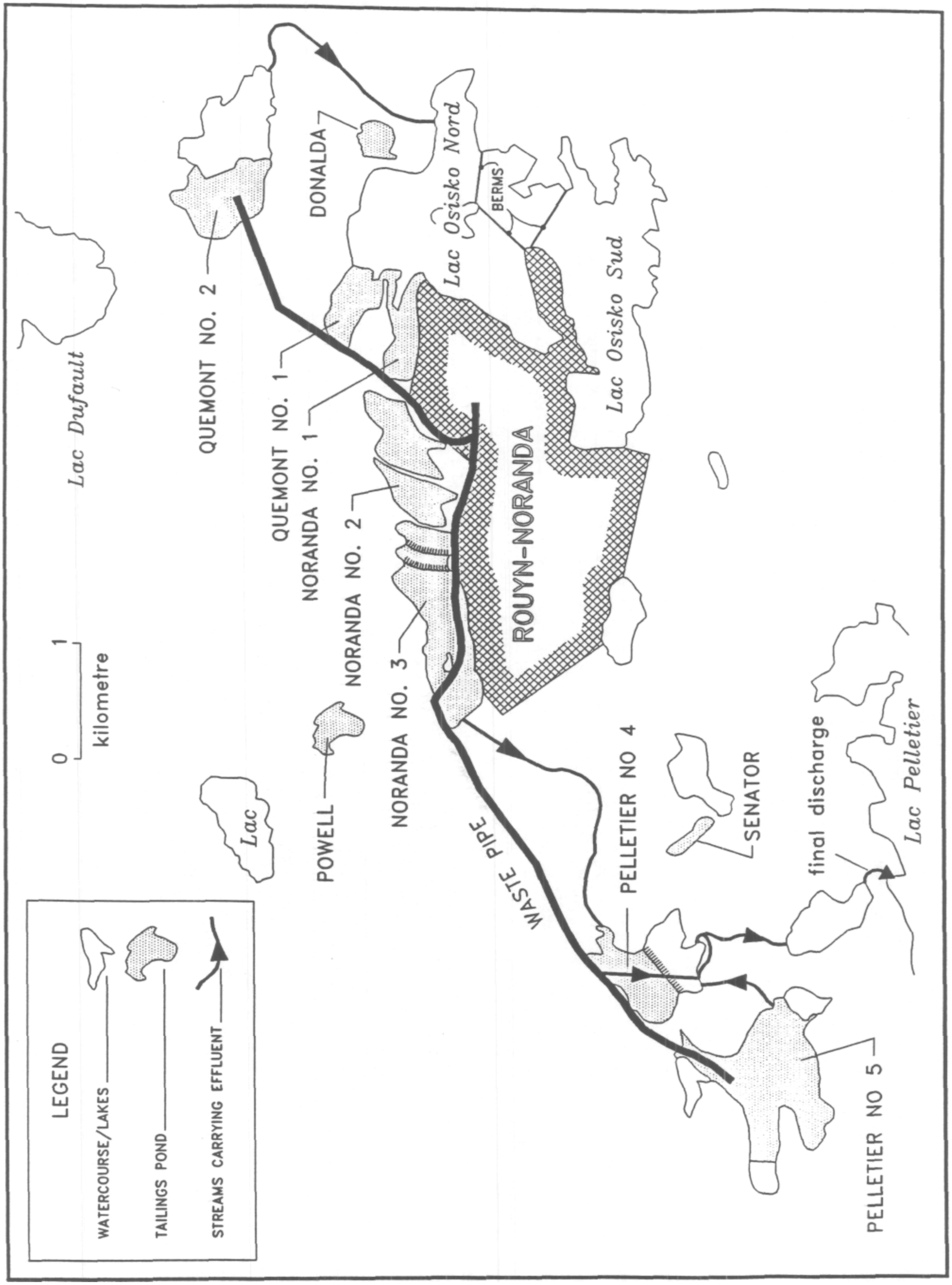

FIGURE 4 TAILINGS IMPOUNDMENTS IN AND AROUND ROUYN-NORANDA.

way of revegetating exposed slag tailings using mulched hay. Complete flooding is being considered when the site is closed (the dams will be raised).

Pelletier #4 is now used for emergency tailings disposal and as the first of two ponds for effluent treatment and polishing before final discharge to the environment. Effluent from two other tailings ponds (Noranda #3 and Pelletier #5) are decanted into pond #4. The rate of lime addition to Pelletier #4 to meet Guideline 019 (3 ppm Fe, 0.3 ppm Cu and 0.5 ppm Zn) at discharge is typically 1 tonne per day, resulting in a pH of 8 to 9. Prior to covering the reactive tailings with slag, the lime treatment required was 10 tonnes per day. The most problematic element with regards to water quality is zinc.

Natural drainage from the 650 hectares north of Pelletier #4 is diverted under the tailings pond in a 915 metre long 71 centimetre pipe. After several problems with beaver, a prison-like stockade has been constructed to protect the diversion drain inlet.

The next Noranda site visited was **Pelletier #5**, which has an area of between 70 to 80 hectares. The tailings line from the mill to impoundment #5 is 8,800 metres long. Due to their 40% pyrrhotite content, after three years of exposure, these tailings were noted to be strongly oxidized at the surface. To alleviate the subsequent acid generation problem, it was decided to cover the oxidized tailings with a 1.0 to 1.5 m deep layer of slag tailings. This commenced in 1973, with berms constructed in the original tailings to form cells for the placement of neutral slag. Some problems occurred when tailing in the berms caught fire. However, the capacity of the tailings area was increased because of these cells, and presently 98% of the sulphidic tailings are covered. Before being covered with slag tailings, the tailings had a pH value of 3 and the acidity was 2000 ppm. Presently, effluent from #5 has a near neutral pH. Tailings deposition into #5 stopped about one year ago. The last materials deposited were silicious tailings (14% lime) from Silidor Gold. Soil from the Noranda area contaminated by lead emission from the smelter has also been recently deposited in this pond. Flooding of the area is being considered for final closeout. However, the area remains available for possible future custom milling.

The **Noranda #3** tailings pond covers 80 hectares and is located on a drainage divide: the western portion draining to Pelletier #4, the eastern portion draining to Noranda #2 and eventually to North Osisko Lake. Noranda #3 has been constructed from a series of dams, creating a number of benches. The dams, built from tailings, were constructed in the 1930's. Tailings deposition occurred from 1935 to 1955. Notably, tailings from the Home deposit contain 0.025 oz Au/tonne (0.7 gram/tonne). At the drainage divide, the tailings are 12 metres deep. The main environmental problems for Noranda #3 are high metal effluent concentrations resulting from the strongly oxidized nature of the tailings.

Over most of the east, central and west portions of Noranda #3, the oxidized sulphidic tailings have been covered with 1 to 1.5 m of silicious low sulphur tailings containing 15% dolomite. In places, the silicious tailings were replaced by clay fill, and fill from construction projects in the area is presently being spread over the site. Revegetation by direct seeding has created a dense agronomic cover over the whole impoundment and in places thickets of trees and shrubs are up to twenty years old. The only vegetation die back has occurred in low lying areas subject to groundwater discharge.

Effluent from the west end of Noranda #3 discharged to Pelletier #4 has pH values from 6 to 7 and elevated Fe levels (50 ppm). As previously stated, seepage from the east end of Noranda #3 passes through Noranda #2 and flows into Lake Osisko. Lake Osisko is divided with berms into three sections, with the central section acting as the Rouyn-Noranda municipal sewage lagoon. In order to lower metal concentrations to meet provincial water quality standards, 2 to 3 tonnes of lime are added to the lake, raising the pH to between 8 and 9. Due to the highly weathered state of the tailings in Noranda #3, lime treatment is seen as the only long term means of protecting offsite water quality.

The **Quemont #2** tailings pond was originally built to handle 12 million tonnes of tailings from the Quemont Mining Corp. (1948-72). Since acquiring the dam, the Home Division has used the site to store tailings from custom milling projects, and by raising the dams it has increased the capacity by another 10 million tonnes. The new peripheral dams, constructed with a clay core to reduce seepage, are built on a clay foundation, and thus require stabilizing berms along the toe. In similar fashion to the Pelletier ponds, most of the original sulphide tailings have been covered with slag tailings, an action that has proven effective in preventing subsequent acid generation. The Quemont #2 pond is now used to store the slag tailings from the smelter and the various sludges produced by the metallurgical acid! plant.

To raise the pond pH, neutralized weak acid deposited in the pond (280 USGPM) is pre-mixed with slag tailings. While this achieves the objective of precipitating arsenic, pH values of 11.4 to 11.6 create problems with the anionic lead solubility. Research has shown that ferric sulphate can be used for arsenic precipitation at a pH to 9.0 to 9.5. A treatment facility using this process is expected to be in operation in the fall of 1992. The predominantly alkaline effluent from Quemont #2 is discharged by gravity to Lake Osisko, where it mixes with the seepage from Noranda #1, #2, #3, Quemont #1 tailings pond and the smelter cooling water. A lime slurry is added to the smelter cooling water to neutralize the acidic drainage from the Noranda #1, #2 and #3 tailings ponds. From Lake Osisko the water is discharged into the receiving environment (Lake Rouyn).

Millenbach

Minnova's Millenbach underground mine, which operated from 1971 to 1980, covers 8 hectares. Some of the tailings produced by this operation were returned underground as backfill. The main surface disturbance is a small one hectare area of acid generating tailings (17,500 cubic metres), which were relocated behind a small dam in a lagoon formerly used to store acid mine water. The tailings contain 20 to 30% sulphides, and are up to three metres deep.

In 1990 and 1991 the tailings were covered with a 1 to 2 m deep layer of waste rock. This in turn was covered with a 30 cm layer of coarse sand, a 60 cm layer of clay, a 30 cm layer of fine sand, topped by a 20 cm layer of organic topsoil and revegetated with agronomic species. The objective of the clay layer in this Waite Amulet-like multi-layer cover is to impede downward water and oxygen movement. Uncontaminated drainage is collected by drains upstream of the dam. However, judging from the seepage discharged at the toe, the diversion works are not entirely successful.

The performance of the cover is measured with piezometers and oxygen probes installed at five monitoring stations. Monitoring is carried out by the Noranda Technology Center (NTC) as a P & C associate project. During the first year after construction, the oxygen content beneath the cover decreased to between 7 to 8%, which is not low enough to limit sulphide oxidation. Additional work is planned to confirm the initial results, with a report expected by 1994.

To date there has been about a 50% improvement in water quality: pH values of 5 to 6 and Zn concentrations of 10 to 30 ppm. The failure to achieve lower Zn concentrations can be attributed to the short time since the cover was applied. Sulphide tailings in the Noranda area typically contain 0.1 to 0.5% Zn, and pH values of 7.5 to 8.5 are required to reduce seepage Zn levels to 0.5 ppm, the allowable discharge standard. At the Millenbach site, Minnova raises the pH to 9 to meet the Zn standard.

Waite Amulet

The six million tonnes of tailings in the Waite Amulet impoundment were deposited from 1940 to 1962 and cover 57 hectares; deposition was by spigotting during the summer and by end spill during the winter. The impoundment sits on gently undulating terrain and is contained by dams constructed from local till. Despite the acidic pH, and except for small areas affected by perched water tables, the plateau-like tailings and the upper portions of the dams support a dense, mixed, herbaceous/woody vegetative cover.

Previous research at the site suggests that precipitation falling on the impoundment seeps vertically through the tailings. At the base of the pile, downward movement is constrained and drainage flows laterally over the one to eight metre clay layer that covers the bedrock, eventually discharging into the perimeter ditch network ringing the dams. The discharge of acidic seepage leaves the lower dam surfaces barren, and the exposure and runoff have created abundant rilling. A detailed description of the hydrogeology at Waite Amulet is given in Yanful (1991) and in a final MEND report (1990), and Halbert et al., (1990) describes the use of RATAP at the site.

Drainage in the perimeter ditches flows to an equalizing pond, and from there it is taken to a HDS water treatment plant. Presently, the plant treats 60 litres per second from April to November, creating 3,400 cubic metres of sludge with a 34% solid content. To maintain the pH just below 9.5, the plant uses 600 tonnes of lime, costing $325,000 per year. Lime is mixed with the acid water and then flows to a second tank, where oxidation is promoted by air addition and a flocculant is added (Percol 90L from Allied Colloid) at 1 cc/tonne. The mixture then flows to a plate-pack clarifier containing a series of parallel plates to increase the settling area. The precipitated sludge is pumped into one of the three underdrained sludge settling ponds, each with about 3,400 cubic metres of volume. Sludge removal usually occurs daily and lasts about 45 minutes. A different settling pond is used every year. After two years of natural consolidation from processes such as natural drainage and freeze/thaw, the sludge reaches about 45% solids. In the third year the consolidated sludge is transferred by truck to the Quemont #2 tailings impoundment and the cell is again available for use.

With the objective of reducing water treatment costs, Noranda is testing clay and synthetic covers. The cover trial being carried out at Waite Amulet by the Noranda Technology Centre (NTC) consists of four test piles: 1. bare tailings 2. and 3. a 60 cm clay core sandwiched between two 30 cm sand layers, and 4. an HOPE liner. Conductivity measurements made on the clay layer in the cover are approximately $10^{\sim 7}$ m/sec. In an adjacent trial, where the clay was allowed to dry, the conductivity rose to $10^{\sim 4}$ m/sec.

Each pile is instrumented to measure oxygen, temperature, water entry and moisture content. Water entry is measured with lysimeters connected to a vertical drain. The moisture content is measured by three different methods: TDR (time domain refractometry), gypsum blocks and ceramic blocks. TDR measures the soil dielectric content and relates it to the water content. Problems are associated with each measurement: TDR is affected by the ionic content of the water, gypsum blocks are easily coated, and the ceramic blocks have calibration problems. To date, NTC concludes that the TDR method is the most dependable.

Data loggers collect the monitoring information, storing it on a magnetic tape, which can store up to three months' information, and is retrieved manually. The data loggers run on solar power, with regular battery power as a backup. The monitoring results have been encouraging, showing almost 0% oxygen and no drainage water penetrating through the impervious clay layer. The HOPE liner used on the fourth test plot also prevented oxygen penetration. Costs have been estimated at $250,000/hectare for the clay and much more for the HOPE system. Notably, both systems are more expensive than the present water treatment.

More detailed descriptions of the composite cover trial (Yanful & St-Arnaud, 1991) and of the theoretical basis for its design (Yanful & Nicholson, 1991) can be found in the Waite Amulet references. References are also provided for similar cover work on waste rock at Heath Steele Mines (Bell et al., 1991) and for the creation of a saturated tailings cover (Nicholson et al., 1991). A final report on the three-year composite cover trial at Waite Amulet (design, construction and monitoring results) will be published by MEND in 1993.

Dry cover options presently being tested in British Columbia include work on till covers at Equity Silver and Sullivan, cementitious covers at Myra Falls and Mount Washington, and asphalt geotextile covers at Mount Washington.

East Malartic

The **East Malartic** site is located in Malartic, about 25 km west of Val D'Or. While the mining operations ceased in 1979, the East Malartic mill is still treating ore from other Lac properties (e.g. Doyon for seven years and now Bousquet I and II). With the generation of potentially acidic tailings from the high sulphide ore from Bousquet II, a decision was made to place the tailings underwater in man-made lakes. Impoundments are also being built to create water covers on the existing tailings. Information regarding the use of wet covers is presented in Balins et al., (1991) and Dave and Michelutti (1991).

Mine Doyon

Mine Doyon is a gold mine situated between Val D'Or and Rouyn, and adjacent to the Bousquet River. From 1978 to 1989 the mine operated primarily as an open pit operation. During this period some 7.5 million tonnes of ore and 47 million tonnes of overburden and waste rock were excavated from the open pits. Above ground activity continues in the west pit (drilling of crown-pillar), but with the exception of material from the low grade stockpile, the ore now comes from underground. Estimated underground reserves of 11 million tonnes have been identified to date.

Overburden and waste rock removed from the open pit were placed in two waste dumps, designated the north dump and the south dump. Both dumps contain about 20 million tonnes of waste rock and overburden, with the remaining approximately seven million tonnes of material used throughout the site as fill. The north waste dump covers an area of about 40 hectares and is 20 to 30 metres deep. The south dump covers about 53 hectares and is 30 to 40 metres deep.

Rock types found in the waste rock include intermediate tuffs, volcanoclastics, schists, diorite and alaskite, with pyrite concentrations ranging from a low of 1.5 percent in the diorite to 7 percent in the sericite schists (Firlotte et al., 1991). The reactivity of the pyrite is accentuated by the friable nature of the sericite schist, which rapidly exfoliates in the presence of water. As a result of its incompetent nature, the zone of schist on the south wall of the Main Zone pit has had to be intensively rock bolted. According to Firlotte et al. (1991), the highly reactive sericite schists make up 50% of the composition of the south dump.

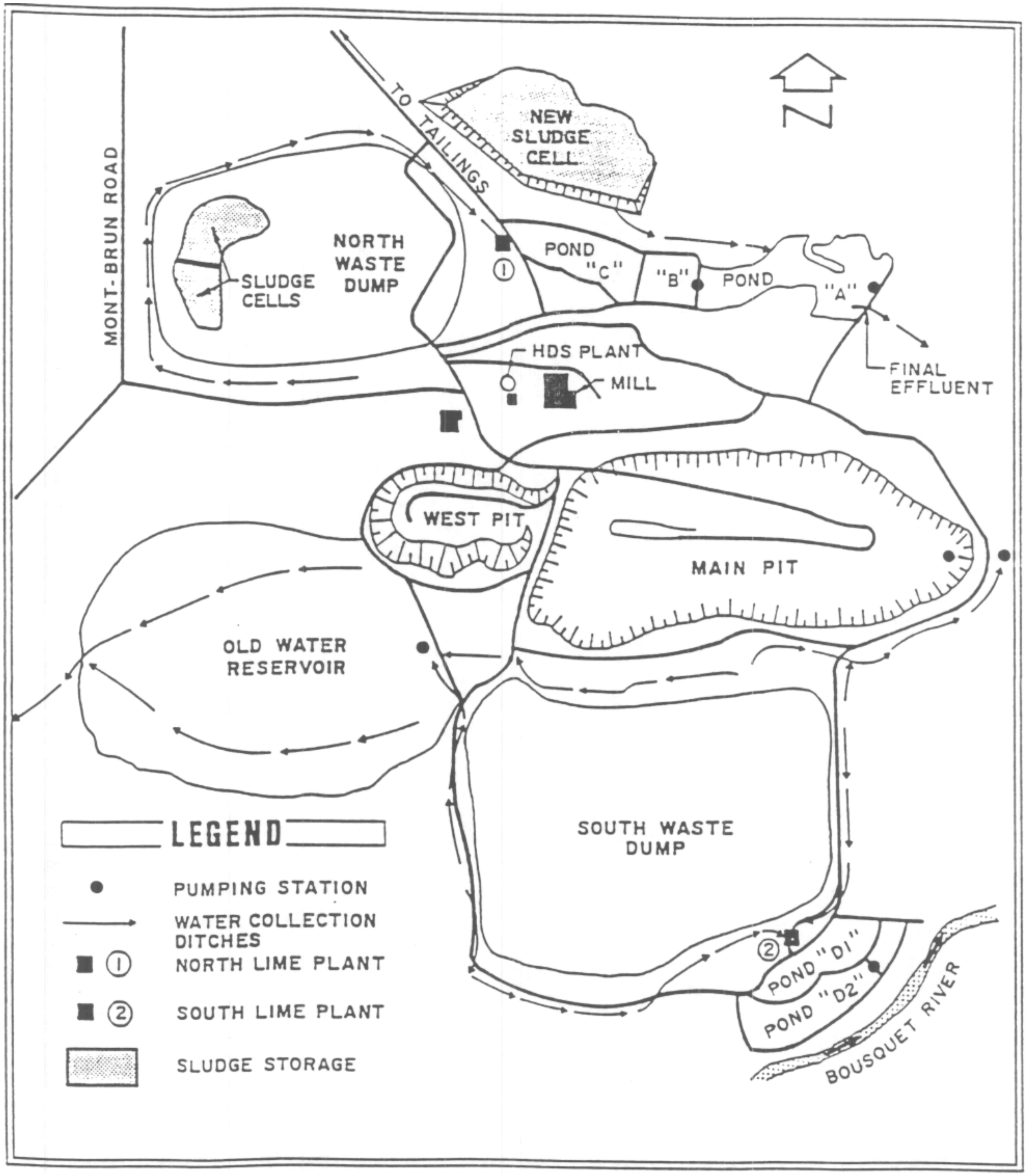

FIGURE 5 A SCHEMATIC PLAN OF MINE DOYON.

A major MEND Prediction committee research project investigating many aspects of acid generation is being carried out on the south dump (Firlotte et al., 1991; Gelinas et al., 1992; Lefebvre et al., 1992). Monitoring for the project occurs from six stations on the top and seven stations around the periphery. Measurements are made of air composition, temperature and water quality, both from mid-dump lysimeters and bottom leachate piezometers. Very sensitive barometers inserted in the dump have been used to show that barometric pressure gradients develop in the dump during storms. Monitoring shows temperatures as high as 70 degrees centigrade occur throughout the year. In the winter, the temperature typically ranges from -22 degrees at the surface, +15 degrees five metres deep, and +35 degrees at the bottom of the pile.

Air circulation within the pile occurs in a series of cells. The width of the cells is approximately equal to the pile depth. While weathering significantly increases the fines content, this does not appear to be sufficient to prevent convective air movement.

Roger Quay, a microbiologist at Laval University, claims to have identified three depth zones with distinct microbial ecologies and weathering reactions.

George Hope, of Lac Minerals, did not think that soil covers were a feasible remedial measure because several metres of differential settling can occur as the sericite schist rock deteriorates to sandy material and the dump consolidates. One possible close-out scenario being considered by Lac is to place the waste rock into the pit and flood it. The main concern with this would be with the short term water quality.

The accelerated acid generation in the south dump is similar to that expected in a heap leach operation. Surface water from the periphery typically contains 25,000 ppm Fe, 2000 ppm Al and 25,000 ppm acidity. One sample taken from the bottom of the dump contained 200,000 ppm Fe (20% solids!). At the treatment plant, peak flows of 5,000 to 6,000 gallons/minute and 5,000 to 6,000 ppm acidity are obtained at snow melt. Summer seepage rates are in the range of 1,000 to 1,500 gallons/minute.

Contaminated acid water is collected around the site and pumped to the "new" high density sludge treatment plant (Figure 5). The treatment and pumping system cost about $6 million dollars to construct, and about $1 million per year to operate. Pumping accounts for approximately 10% of the treatment cost. The plant uses both ferric and ferrous reactions to handle the effluent, which contains 80% ferric and 20% ferrous iron. Alkalinity is added to raise the pH to 4.5 in the ferric reactor. Aeration and alkalinity (pH 8.5) are added to the ferrous reactor. The final treatment stage, the thickener, is 275 feet in diameter and 25 feet deep, with a total volume of 6.7 million Canadian gallons. A simplified process flow sheet and the design characteristics for the HDS plant, which was designed by TETRA Technologies, is included in Firlotte et al. (1991).

The resulting sludge is discharged into the 300,000 cubic metre new sludge cell that was constructed in 1989 to receive the high density sludge (HDS). Typically, the sludge leaving the plant is 20% solids and rapidly consolidates to about 40%. After consolidation the annual volume of sludge is expected to be less than 50,000 cubic metres. This is a substantial reduction from the 200,000 cubic metres one would expect to create with the conventional treatment process. A person can walk on the sludge less than three months after its deposition! Since the introduction of the HDS plant, lime consumption has been reduced from 20,000 tonnes to 8,000 tonnes per year. At a cost of $100 per lime tonne, the plant is paying for itself.

Trace metals are not a problem at Mine Doyon, and consequently the treated water from the plant has a pH range of 8.3 to 9.0 when it is discharged into the water storage pond. In the water storage pond the pH naturally drops to between 7.0 and 8.3. When discharged offsite, except for elevated concentrations of calcium, sulphate, and occasionally magnesium, the water is drinkable.

The present tailings pond at Mine Doyon covers about 50 hectares, and contains 7.2 million tonnes of acid generating tailings. The tailings are typically 3 to 5% pyrite, and can contain up to 400 ppm cyanide. The surface pH is between 9 and 10, preventing cyanide volatilization. In spring the tailings pond is the first water in the area to melt, and the mine has to hire people to scare off migratory ducks by using horns and gun blasts. Silhouette hunters are used to scare away ducks during the rest of the year. Decreases in the cyanide concentration will occur through natural degradation, and thus this is not expected to be a problem when the site is abandoned.

The main long term problem for this site is with the potential for acid mine drainage. The height of the pond above the surrounding land and the porous nature of the dams constructed from waste rock and tailings allow seepage to escape at rates of 20 to 30 gallons per minute. Seepage is presently collected and pumped back into the pond.

When we visited the site, the present tailings impoundment was almost full, and the mine planned to start depositing tailings in the new impoundment on September 17, 1992. The initial capacity of the new pond is about 1.4 million tonnes. This will be augmented to 3.0 million tonnes following Phase II work. When completed (Phase III), the new tailings impoundment is expected to have an area of 170 hectares and a capacity for 15 million tonnes of tailings. One close-out scenario being considered for the new tailings area would be the creation of a depyritized tailings cover.

To prevent seepage loss, the dams in the new tailings impoundment will have impermeable grout curtains constructed down to the bedrock. According to George Hope, if properly deposited, fairly impervious dams can be created from the tailings themselves. The main impediment to this occurs when frost lens increase the porosity.

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