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Decommissioning of Mercury Cell Chlor-Alkali Plants in Canada

Canada

Economic and Technical Review
Report EPS 3-EP-83-5

Environmental Protection Programs Directorate
November 1983

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DECOMMISSIONING OF MERCURY CELL CHLOR-ALKALI PLANTS IN CANADA

by

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EPS 3-EP-83-5
November 1983

Cat. No. En 48-3/83-5E
ISBN 0-662-12917-2
BEAUREGARD PRESS LIMITED

SUMMARY

This report reviews in detail the procedures followed by six companies in dismantling, decontaminating and restoring, or converting their mercury cell chlor-alkali plants. Methods used to confine mercury-contaminated wastes from these plants in secure burial sites are described.

This report deals only with closure procedures, although the safety and health of the workers was also emphasized during discussions with plant personnel. At each plant the activities were planned to minimize the possible exposure to mercury and frequent regular personnel monitoring was undertaken even though the wearing of face masks was mandatory if the concentration of mercury in the air was greater than 0.05 mg/m^3. The monitoring included urine testing and workers were temporarily removed from exposure if the mercury levels rose above the normal permitted. Work clothes were washed daily and high standards of personal cleanliness were maintained. Special emphasis was placed on the prevention of spills and prompt cleanup action if they occurred. Cell rooms were well ventilated and atmospheric monitoring for mercury was carried out. Hand tools were used whenever cutting of mercury-contaminated metal was necessary.

Two plants, at Dryden and Saskatoon, were converted to the membrane process; however, the techniques used to decontaminate the brine circuit were substantially different. At Dryden, where rock salt is used for brine makeup, it was necessary to remove all mercury-bearing sludges from the brine circuit, replace certain pieces of equipment, and decontaminate the remaining equipment. In comparison, at Saskatoon, where closed-cycle salt wells are used, it was not necessary to remove mercury-bearing sludges or decontaminate the equipment as the mercury present in the circuit was absorbed on solids present, or formed a precipitate that settled out on the bottom of the salt cavity. As a result, the mercury present in the brine circuit dropped from a concentration of around 4 mg/L, at the time of closure, to an undetectable amount within two and one-half years. In spite of all the precautions taken at Dryden, mercury in products remained higher for a longer period of time than at the Saskatoon plant. Both plants have reduced mercury losses to process effluents plus storm runoff to very low levels, i.e., an average of less than 5 grams per day. No significant improvement can be expected in the future although a gradual reduction will likely occur over the coming years.

At ALCAN (Jonquière) and CIL (Shawinigan) total closure procedures were used. At Shawinigan initial plans called for the reuse of the cell building; however, extensive studies of mercury contamination of the plant and surrounding area by an engineering firm determined that complete restoration could only be accomplished by total dismantlement of the plant, and the removal of a further 125 000 cubic metres of brine solids, sand, clay and topsoil from the waste ponds, ravine and under the plant floors at a cost of $3.5 million. All the mercury-contaminated equipment and material was placed in a secure burial site. This excellent job of restoring a potentially long-term hazardous area to nearly normal conditions has reduced mercury in runoff to around 4 to 6 g per day. Further reductions will likely occur with time.

The plant at Jonquière was dismantled, decontaminated and then sealed to prevent mercury escaping from the building and basement that housed the plant. The restoration of the plant to new office space and light maintenance work has resulted in very low mercury releases in atmospheric emissions and liquid effluents. These good results should prevail as long as the concrete and asphalt seals used to prevent the release of residual mercury are not damaged.

The mercury-contaminated sludges produced in the ALCAN plant between 1971-76 were sulphided and then disposed of in two abandoned red mud ponds covering an area of 14 hectares. These same ponds were used to bury the contaminated equipment

from the plant. Dredged coarse sand from an adjacent red mud pond was used to cover the disposal area to a depth of 1.3 metres and a layer of 0.6 m of impermeable argilaceous clay is now being added. After grading, a layer of topsoil will be added and sown with grass. The mercury content in the runoff and seepages from the ponds is presently very low, less than 5 grams per day. If mercury losses increase due to a drop in pH, then further steps to prevent the dissolution of mercury will be required.

A partial dismantling has been implemented at Domtar's Lebel-sur-Quévillon chlor-alkali plant. All mercury has been removed from the plant and the equipment has been decontaminated; however, the cells, pumps, decomposers, tanks, etc., are still in place. The brine was run down before closure and treated for mercury removal before being slowly released; all the equipment on standby, except for the chemical storage tanks, is empty. Although the mercury cell chlor-alkali plant has ceased operations, the adjacent pulp and paper mill still requires the chemicals that were produced or used in the chemical plant, i.e., chlorine, caustic soda, sodium chlorate and sulphuric acid, and the storage facilities for these chemicals, which are transported to the plant in bulk, have been maintained.

The Domtar plant has always been plagued with high runoff and seepages, which tended to leach mercury that had escaped to the subsoil under and adjacent to the plant, particularly if chemicals were present. During the unloading and transferring of chemicals from the tank cars to the storage facilities chemical losses occurred which resulted in relatively high mercury losses from this plant from 1978 to 1981 (i.e., an average of about 65 grams per day). By isolating each chemical circuit to prevent losses to the subsoil and old sewers, mercury losses have been reduced to around 26 grams per day.

The mercury-contaminated sludges, waste anodes, etc., that were produced in this plant between 1971 to 1976 were placed on top of a layer of lime in the disposal site and then covered over with lime, followed by a layer of soil. In 1976, a layer of sulphur/sand followed by a 60 cm layer of impervious clay and top soil was used to seal off this area. A new disposal site with a hypalon liner was constructed in a clay area. All solids entering this area, which is still in use, have been sulphide treated. Monitoring wells have been placed around both areas.

At American Can of Canada's chlor-alkali plant in Marathon the chemical holding facilities are also required to serve the adjacent pulp and paper mill; however, most of the other equipment in this plant has been decontaminated and buried. Prior to closure of the plant, one of the two salt holding facilities was decontaminated so that mercury-free brine would be available for the sodium chlorate plant which remained in operation (the chlorate plant did not use mercury in its operation). After the chlor-alkali plant ceased operations, the brine was treated for mercury removal and then slowly released. All mercury-contaminated sludges were placed in barrels and buried in the disposal site.

The cells plus the ancillary equipment were then dismantled, decontaminated and buried in a cement bunker at the disposal site. All sludges from the cells, tanks, sumps, etc. were also placed in drums and buried at the disposal site. All washwaters were treated for mercury removal before being released. The floor in the cell room was then capped with cement. This area is now being used for dry storage.

The chlorate plant ceased operations in September, 1982. The equipment in the brine process area is now being dismantled and buried in the disposal area and the floors will be capped with cement. The only remaining equipment will be the chemical storage tanks which were decontaminated when the chlor-alkali plant was shut down. These tanks are isolated and any spills are recycled; thus no losses which could leach mercury from the soil in the surrounding area should occur.

All of the closed and converted plants monitor for mercury in the effluents, runoff and seepages from the original plant sites and burial areas. If any increase in mercury releases and migration are noted, corrective action will be taken immediately. All mercury removed from the closed and converted plants was sold to reputable dealers.

The dismantling, decontamination and restoration of a plant site varies somewhat from plant to plant depending upon the extent of mercury contamination around the plant, the topographical location of the plant, the type of soil around the plant, the availability of a salt cavern, whether the plant suspends operations or converts to a non-mercury process, etc. No two plants will likely use the same procedures to restore a site to a condition to accept further development without risk to the environment. The procedures outlined herein, however, should be helpful in ensuring that a plant closure is conducted in such a manner as to protect both the environment and the health of the employees.

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1 INTRODUCTION

Mercury gives rise to environmental problems of a very complex nature. The element appears to have been a part of man's environment for a long time, but human activity has increased the overall quantity of biologically available mercury in the environment. In specific local areas, unacceptably high levels have been found.

It was proven beyond doubt in early 1965 that the presence of mercury in industrial effluents might result in elevated concentrations of mercury in fish downstream from the point of discharge. Concern became acute when this observation was combined with the finding soon afterwards that virtually all mercury in fish is present as a methyl mercuric complex, irrespective of whether the origin is metallic, inorganic or organic.

Early concern in Canada seemed to arise after studies had been conducted in 1969, first at the University of Saskatchewan and then at the University of Western Ontario. These studies showed a high mercury level in fish taken from the South Saskatchewan River Drainage Area and Lake St. Clair, respectively. There was then only one conclusion possible: the use of mercury for industrial or other purposes involves an obvious risk of environmental poisoning and must therefore be made subject to severe restrictions. The first result was the almost immediate closure or partial closure to fishing of 16 water bodies across Canada after extensive surveys of mercury levels in Canadian waters revealed significant mercury contamination.

In 1969, 14 chlor-alkali plants were producing chlorine by the mercury cell process. (Canso Chemicals started production in 1970 bringing the total to 15 plants). Chlorine production in 1969 by the mercury cell process was around 500 000 tonnes, produced in plants ranging in capacity from 30 to 230 tonnes per day. Mercury consumption was in the order of 110 000 kg per year, with an estimated 62 percent going directly into water streams and the remaining 38 percent being lost to the atmosphere, products and solid wastes.

In 1970-71, all mercury cell chlor-alkali plants, through working agreements with the federal and provincial governments, ceased discharging mercury-contaminated brine treatment solids to sewers, separated contaminated wastewaters from relatively clean wastewaters, recycled as much of the contaminated wastewaters as practical, and treated the remainder. These revised operating practices reduced mercury discharges in liquid effluents by more than 99 percent.

In 1972, Environment Canada issued chlor-alkali mercury regulations stipulating that mercury in liquid effluents from a plant may be deposited in waters frequented by fish if the quantity deposited by the plant in any day does not exceed 0.005 pounds per ton of chlorine produced by the plant in that day (2.50 grams per tonne of chlorine produced).

Several economic factors such as the age and value of their plants, the number of plants operated, and their production technologies resulted in different approaches by the chlor-alkali companies to the mercury problem. For example, Dow Chemical of Canada, Ltd. felt itself able to convert to the diaphragm process at both of its plants in Sarnia (1972) and phase out its Thunder Bay operation in 1973, even though these plants were meeting the Provincial and Federal Government requirements. On the other hand, Reed Ltd. at Dryden and Prince Albert Pulp and Paper Ltd., which met the Chlor-Alkali Mercury Liquid Effluent Regulations, felt that the cost of meeting the Chlor-Alkali Mercury National Emission Standards Regulations (to control mercury emissions to air), which were issued in 1975, could be too expensive for their small operations, and converted their plants to the membrane process in 1975 and 1978, respectively. Canadian Industries Limited closed two mercury cell plants and increased production at their new diaphragm plant to make up for production losses. ALCAN and American Can of Canada closed their plants, and Domtar mothballed its plant. The three companies are now purchasing their chlorine and caustic needs.

Because of the environmental hazards associated with mercury, it was necessary to ensure that plant conversions or closures were conducted in such a manner as to protect the environment, by removing all mercury-containing wastes and contaminated equipment to an approved burial site and by restoring the plant site to a condition acceptable for further development without risk. It must be pointed out, however, that even though the amount of mercury being discharged from these closed or converted plants is extremely low, much of the mercury discharged to the rivers in the years prior to 1969 is still present in the sediments and will cause moderately high levels of mercury in fish for some years.

The two Dow Chemical of Canada, Ltd. mercury cell chlor-alkali plants in Sarnia were dismantled and decontaminated in 1973. Mercury-contaminated sludges were sent to a salt cavity that was no longer used, or were buried, along with mercury-contaminated equipment, in a pit of heavy clay soil, covered with a concrete pad followed by top soil to form part of the green belt at the plant. Mercury migration from the disposal site has not been detected during monitoring carried out over the past nine to ten years.

The Dow Chemical of Canada mercury cell chlor-alkali plant at Thunder Bay was dismantled and decontaminated in 1973. All buildings and equipment associated with the chlor-alkali process were sent to the company's Sarnia plant for disposal. In October 1973 the company was granted by the Ministry of the Environment for Ontario a Certificate of Approval to dispose of mercury-contaminated sludges in a disposal cell lined with an impervious layer of clay plus polyethylene film. These sludges had accumulated at the plant prior to closure. Prior to disposal in the cell the sludges were "Chemfixed" to further reduce chances of mercury migration and their susceptibility to leaching. The cell was covered with clay and soil, the area was fenced and groundwater monitoring wells were established at the site. Monitoring of the wells by both the Company and the Ministry of the Environment has indicated no significant change in the mercury levels to groundwater.

At the Canadian Industries Ltd. (CIL) Hamilton plant, extensive sampling for mercury contamination in the trenches, sumps, cement floor, painted girders, etc., was carried out based on schemes designed for other sites within the company and the parent group, Imperial Chemical Industries. Based on these results the mercury was first removed from the cells, decomposers, piping, etc., and the plant equipment was dismantled, decontaminated and removed. The walls and roof of the cell room were then washed with water under high pressure. All wash waters were treated for mercury removal before being discharged. The equipment that was removed was sent to the CIL plant in Cornwall. Some of this equipment was reused, the rest was buried in an approved burial site at Shawinigan. As sampling had revealed that mercury contamination was fairly extensive in the trenches and sumps, the cement floors in these areas were removed, crushed and mixed with sludges to be treated.

Mercury-rich sludges were sent to CIL Cornwall for mercury recovery by retorting. Sludges with less than 10 ppm mercury, e.g., brine treatment sludge from the disposal area used prior to 1970, and the sludges from the lined pond that were collected subsequent to the control order to contain mercury discharges were fixed using a sodium sulphide, sodium silicate, lime process. The consistency of this mixture was poor, so the material was stored in an asphalt lined pond. Subsequently the material was mixed with calcium oxide which resulted in a gravel type hard aggregate. Leaching tests on this aggregate indicated very little leaching of mercury occurred; however, since the disposal of this material to a land fill site was prohibited, it was trucked to the Goodfellow disposal site in Sarnia.

Before and subsequent to a steel company taking possession of the property, CIL provided guidance and assistance in the disposition of mercury-contaminated dredging spoil and the filling in and recovery of a section of the land bordering the plant, to ensure the protection of the environment.

Since the plants in Sarnia, Hamilton and Thunder Bay have been dismantled and decontaminated for over nine years, and since monitoring for mercury releases and migration from both the original site and burial pits has not shown any environmental transgression, they are not discussed further in this report. The procedures used to dismantle, decontaminate the plant sites and dispose of the contaminated material from the other six closed or converted plants in Canada are described in detail.

2 GENERAL APPROACH AND METHODOLOGY

To assess the effectiveness of the procedures used by the different plants in eliminating the mercury problem inherent in their past operations, the approach taken was to first review Environmental Protection Service (EPS) Headquarter files on the six companies, discuss the program and obtain any information that was available in provincial and federal regional offices, and then initiate plant site visits with company personnel. The following paragraphs briefly describe the major study tasks and their results as they are presented in this report.

2.1 Review of EPS Files on the Six Companies

As required by the Chlor-Alkali Mercury Regulations, all companies had to monitor mercury losses to liquid effluents each day and report such losses on a regular monthly basis. After the plants ceased production or converted to a non-mercury process, all plants surveyed in this report, except ALCAN Ltd., continued to submit monthly reports on mercury discharges to liquid effluents from their operations. The results of this monitoring are reported in the body of this report.

In addition, over the past 10 years the companies have submitted letters, plant drawings, and other data on procedures taken to reduce mercury losses to the environment and on the disposal of mercury-containing wastes. Personnel in Environment Canada and from provincial environmental ministries had also visited these plants on a number of occasions and written site visit reports. All of these documents were reviewed before the sites were revisited, in order to better understand what was involved in the dismantling and decontamination decisions and the effectiveness of waste disposal procedures.

2.2 Discussion with Regional Personnel

Before companies dismantled and decontaminated their plants, they submitted plans to their respective provincial environmental ministries. In addition, at some plants, provincial environmental personnel or consultants oversaw the dismantling procedures and issued reports. EPS regional personnel were helpful in obtaining copies of these reports for perusal and arranging contacts with provincial personnel and site visits.

2.3 Site Visits

The closed and converted chlor-alkali plants in Quebec, Ontario and Saskatchewan were visited by engineers from Environment Canada. In Ontario, Environment Canada was assisted by engineers from the Ontario Ministry of the Environment.

At each plant the personnel from the environmental agencies met with plant engineers to discuss the procedures used to dismantle, decontaminate and convert or restore the plant sites. The converted or restored sites and burial areas were inspected and the monitoring facilities were noted. Further discussions covered such topics as worker protection during dismantling, decontamination and restoration procedures.

Prior to or during the decommissioning procedures the companies had engaged engineering firms or consultants to evaluate the burial sites, current emission values and/or the extent of mercury contamination. The plant personnel were very cooperative in supplying copies of reports on these evaluations.

3 SITE VISIT REPORTS

3.1 Saskatoon Chemicals' Closed Mercury Cell Chlor-alkali Plant at Saskatoon (converted to membrane process)

3.1.1 Historical Operation. Saskatoon Chemicals' (originally Northern Industrial Chemicals Ltd.) chlor-alkali plant commenced operations in 1962 with a rated capacity of 25 tonnes per day (tpd) and expanded in 1968 to 90 tpd. Prior to 1971, mercury-contaminated brine treatment solids were discharged directly to sewer; however, in 1971 a decision was made to send these solids to a pond, where the solids settled out and the liquid was recycled to the brine wells. In 1972 the brine treatment solids were re-directed to the brine wells and contaminated wastewaters were recycled or treated for mercury removal before being discharged. Mercury in air emissions were reduced by cooling the hydrogen gas using indirect water coolers; the recovered mercury was recycled to the process.

In the mid 1970's, old sludge and debris from the toe of the river bank, where the plant's effluent entered the South Saskatchewan River, was removed and buried in a disposal area about 500 metres north of the plant. Later this material, along with the sludge from the sludge lagoon, was buried in a pit nearby. The bottom of the pit was covered with a layer of clay-bentonite, then scarified and compacted to form an impermeable seal. A layer of peat moss was added, followed by the mercury-contaminated sludge. A layer of clay and topsoil was added to seal off the area.

3.1.2 Dismantling, Conversion and Decontamination Procedures. On November 2, 1978, Saskatoon Chemicals, a Division of Prince Albert Pulp and Paper Co., suspended operations of their mercury cell chlor-alkali plant at Saskatoon and converted to a membrane cell process, which re-opened on November 10, 1978.

When the mercury cell plant ceased operations, it was dismantled and decontaminated with the concurrence of the Saskatchewan Environment Department. A consultant was hired to design and check the disposal site and to supervise and certify disposal of the equipment. About 36 000 kg of mercury was removed from all the equipment and an additional 800 kg was recovered from the waste pit. This mercury was cleaned, bottled and sold to a reputable dealer. The equipment that was no longer required, such as the cells, decomposers, end boxes, etc., was dismantled and decontaminated using squeegees and water under high pressure. The equipment was then buried in a disposal pit and the wash water treated for mercury removal or recycled to the salt cavity.

A new cell room was built adjacent to the old mercury cell room to house the new membrane cells. It was not necessary to decontaminate the brine circuit, i.e., brine upwells, reaction tanks, clarifier, pumps, degasifier and holding tanks, since the closed brine circuit to the brine wells was maintained. Over a relatively short period of time, mercury present in the brine sludges, brine tanks and other equipment worked its way out of the system and is now deposited in a sludge layer on the bottom of the salt cavity. In November 1978, the mercury concentration in the brine being pumped from the wells was in the order of 1 mg/L, while that in the depleted brine going to the wells was around 4 mg/L. In July 1979, the mercury concentration in the brine system was about 0.5 mg/L; by December 1979 it had dropped to 0.2 mg/L; by June 1980 to 0.05 mg/L; and by early 1981 the mercury concentrations were below the detectable limit, as shown in Figure 1. This phenomenon is substantiated by mercury decreases in the products (i.e., caustic, hypo and HCl) from around 1.5 kg/month in November 1978 to 0.1 kg/month or less at present.

The old hydrogen system was scrapped and replaced with a new cooler. The caustic receiving tanks and caustic filters were scrapped; however, the caustic storage

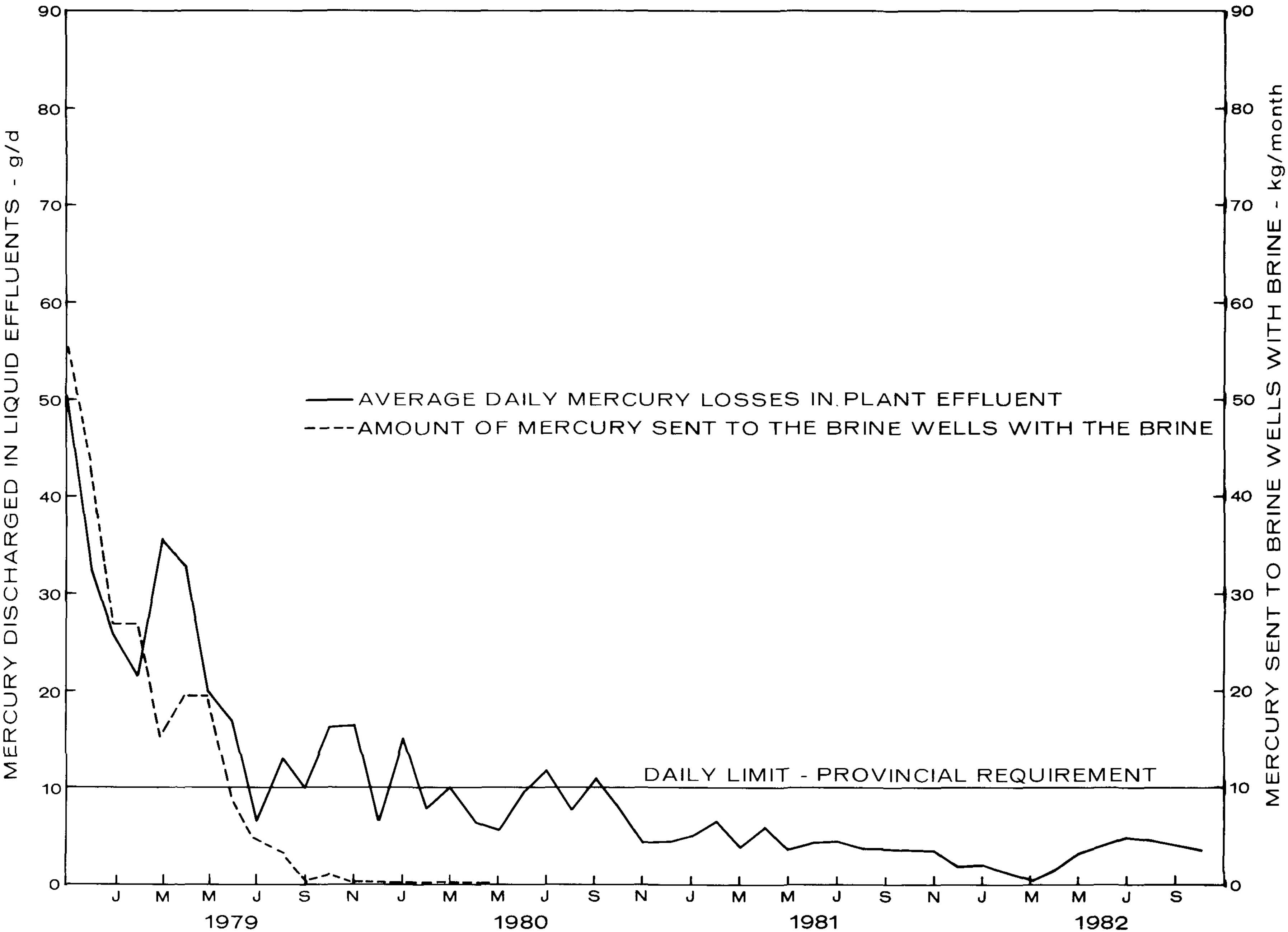


FIGURE 1 MERCURY DISCHARGED IN LIQUID EFFLUENTS FROM SASKATOON CHEMICALS' SASKATOON PLANT

tanks were retained. Most of the chlorine system such as the coolers, driers, sulphuric acid mist eliminator, compressor, liquefiers and storage tanks, was retained.

All mercury-contaminated solids from the plant and from the storm water and effluent ponds were buried in the disposal area or discharged to the brine wells. The cement cell room and basement floors plus about 1 metre of soil from beneath the cell room area were removed and buried in the disposal area. Clean backfill was added followed by a new cement floor and sewer system. The steel beams, girders, etc., in the old cell room area were sand blasted and then painted.

The flooring in the brine treatment area (excluding the area for the tanks and pump bases) was removed, as well as a small amount of soil from under this area. This material will be buried in an expansion of the mercury disposal pit. An area on the north side of the building was overlaid with concrete and a railway spur installed. Any spills or runoff from this area goes to the brine down well via the sodium chlorate sump.

Appendix A provides a complete description and drawings of the disposal area. Test monitoring wells were strategically placed around the disposal area to check on the migration of mercury from the disposal area into the surrounding groundwater.

3.1.3 Monitoring. The plant is situated on the west bank of the South Saskatchewan River approximately 30 metres above the river level. A study undertaken by J.D. Mollard and Associates Ltd. (1975) established that groundwater flow should be toward the river rather than inland.

Monitoring wells between the mercury-contaminated materials disposal pit and the river, and the plant and the river have shown a decline in mercury concentrations since the plant was converted (i.e., from around 20-45 µg/L Hg in 1974-78 down to 2-10 µg/L Hg in 1979-81).

A number of monitoring wells in the area of the sludge disposal pit have frequently been dry over the past three years. When groundwater is present, mercury levels averaging about 2.5 µg/L have been found, which implies that the mercury in the sludges has been retained by the peat, bentonite and clay.

The company engaged Beak Consultants Ltd. to evaluate the current effluent from the Saskatoon Chemicals plant. Their main conclusions pertaining to the plant closure were:

a) The current average mercury loss of about 2 g/d is well below federal and provincial guidelines, and is already well below the level obtainable incorporating Best Available Technology proposed for chlor-alkali plant effluent by the U.S. Environmental Protection Agency for 1984. In 1984, it is projected that mercury losses from the plant will reach 1 g/d.

b) It would not seem to be necessary, and may not be possible, to control mercury losses further by installing auxiliary effluent treatment at the plant. Rather, periodic monitoring, maintenance and clean-up procedures should accomplish sufficient control of mercury losses to the river system. Handling procedures should ensure that hypochlorite and acid spills are as infrequent as possible.

c) Future expansion and construction on the site should take into consideration the possible resulting mobilization of mercury. Clean-up and monitoring procedures are suggested if such work is to be undertaken.

3.1.4 Further Action in Progress or Planned.

1) The floors, sewers and sump in the chlorine liquefaction area are to be upgraded.

2) The chlorine drying towers are to be moved and replaced. A retaining wall and sump will be installed. Any spills will be collected and recycled to the mill or neutralized and sent to the brine wells.

3) The sodium hypochlorite scrubbers are to be moved and replaced. A retaining wall and sump will be installed to collect any spills. The spills will be treated to destroy the hypo and then sent to the salt cavity.

4) Some areas around the plant, in the storm sewers and in the storm pond, still contain relatively high mercury concentrations (greater than 10 parts per million). These solids will be removed and buried.

5) A study will be undertaken to determine the best way of segregating and collecting spills from the products loading station. These products will be recycled or sent to the salt cavity.

3.1.5 Conclusions.

1) A closed-cycle brine circuit to underground salt cavities has helped this plant attain low mercury discharges to liquid effluents, i.e., a daily average of 1-5 g per day in process wastewater plus storm runoff.

2) Once the plant renovations have been completed, i.e., when the soil containing high mercury levels has been removed and buried and chemical losses to sewer have been eliminated, mercury losses to effluent from this plant should be consistently low, around the 1 g/d level.

3) Mercury levels in monitoring wells around the plant and disposal site have shown a decline since the closure of the mercury cell plant. Since the mercury waste disposal area is only around 250 m away from the river, close monitoring control should be maintained.

3.2 Domtar Inc.'s Closed Mercury Cell Chlor-alkali Plant at Lebel-sur-Quévillon

3.2.1 Historical Operation. Domtar's mercury cell chlor-alkali plant at Lebel-sur-Quévillon commenced operations in 1967 with a rated capacity of 75 tonnes of chlorine per day. Prior to 1971 mercury-contaminated solids and wastewaters were discharged directly to sewer. In 1971 systems were installed to limit mercury losses in liquids, in solids and to the atmosphere. Mercury-contaminated wastewaters were segregated from non-contaminated wastewaters and some of the contaminated wastewaters were recycled, limiting the volume of wastewater needing treatment. A treatment system including sodium sulphide, sand filters and carbon filters was installed. A new sampling station was built which included samplers and flow measuring devices which recorded the total plant wastewater discharge, i.e., surface water, process water, storm water, cooling water and sanitary water. The contaminated solids generated in the plant were deposited in a sludge disposal area. Lime and sodium polysulphide were spread over the solids in order to maintain an alkaline pH at the site. To reduce losses to atmosphere primary and secondary coolers were installed on the hydrogen system. Purifiers were placed on the caustic and hydrogen stacks.

3.2.2 Partial Dismantling and Decontamination Procedures. On May 15, 1978, Domtar mothballed its mercury cell chlor-alkali plant. Since the suspension of operations, a number of steps have been taken to reduce mercury losses from this plant. The prevention program has been mainly successful; mercury losses to sewer have been gradually decreasing since 1978 as shown in Figure 2.

At this plant, mercury was removed from all the equipment and sold to a reputable dealer. All the mercury-rich solids, e.g., the graphite from the decomposers, the used anodes, etc. were placed in barrels lined with plastic bags and shipped to the United States.

Solids with high mercury concentrations, i.e., caustic filter solids, activated carbon and mercury sulphide from the water treatment system, mercury butter, sludges from the cell room trenches and holding tanks, etc., were removed, placed in barrels and shipped to St. Catharines for mercury recovery. Mercury recovered from these solids totalled 750 kg.

All the cells, decomposers, mercury pumps, etc., were washed using water under high pressure. Plastic was placed on top and the covers were replaced and bolted down. The piping from the cells, pumps, decomposers, hydrogen and caustic headers, etc. was removed, drained of mercury and then washed with water under high pressure. Some of this piping was sent to the disposal site; the rest was cut into short lengths, placed in barrels and then shipped to the U.S.A. for burial. All the wash waters were treated for mercury removal. Close to 1 500 kg of mercury were recovered during the cleaning of the caustic, brine, chlorine and chlorate systems.

All the tanks and sumps were emptied and decontaminated. Certain pieces of equipment are still in use. Other tanks plus other equipment were removed and are stored in an area adjacent to the plant.

Cracked floors at cell level were removed and placed in barrels. The other floors were cleaned, repaired and re-covered with a protective coating.

The building was washed twice with water under high pressure. Tests indicate that mercury concentrations in air are quite low (<0.01 mg/m^3).

Although the mercury cell chlor-alkali plant ceased operations, the pulp and paper plant still requires chlorine, caustic soda, chlorate and sulphuric acid. These chemicals are now transported to the plant in tank cars which are unloaded into the existing caustic, chlorate, chlorine and sulphuric acid holding tanks. Over the past four years chemical losses, normally occurring during the unloading or transferring operations, have leached mercury from the old sewers or contaminated soil under the chemical plant, causing above-normal mercury losses to liquid effluents. Acid losses have also increased the temperature of the effluent in the PVC sewers causing them to rupture.

An assessment of the reasons for mercury losses remaining around the 95 g/d level was made and it was concluded that the major reasons were: losses of chemical products that leached mercury from the soil, sewer pipes, etc.; breaks in the underground sewer lines allowing wastewaters containing acids, alkalis and oxidants to leach mercury from the contaminated soil; and problems with the operation of the wastewater treatment system for mercury removal.

To correct these problems, the unloading area was levelled, a cement apron coated with an epoxy resin was installed under the entire area, and each unloading section was separated by a low wall. Any chlorate leaks now join the process sewer after the mercury treatment system; any acid and SO_2 leaks drain to the effluent holding sump; and any caustic soda leaks drain to the used cooling water sewer. Sulphuric acid, which is received in tank cars, is unloaded to the acid holding tank. The overflow from the acid tank now goes to an old weak brine tank. If this tank were to overflow the acid would go to the wastewater holding sump.

Some sewer lines have been reoriented and/or replaced, and made water-tight, and additional instrumentation such as high and low level alarms has been installed to reduce the chances of chemical overflows. The sanitary sewer has been isolated from the

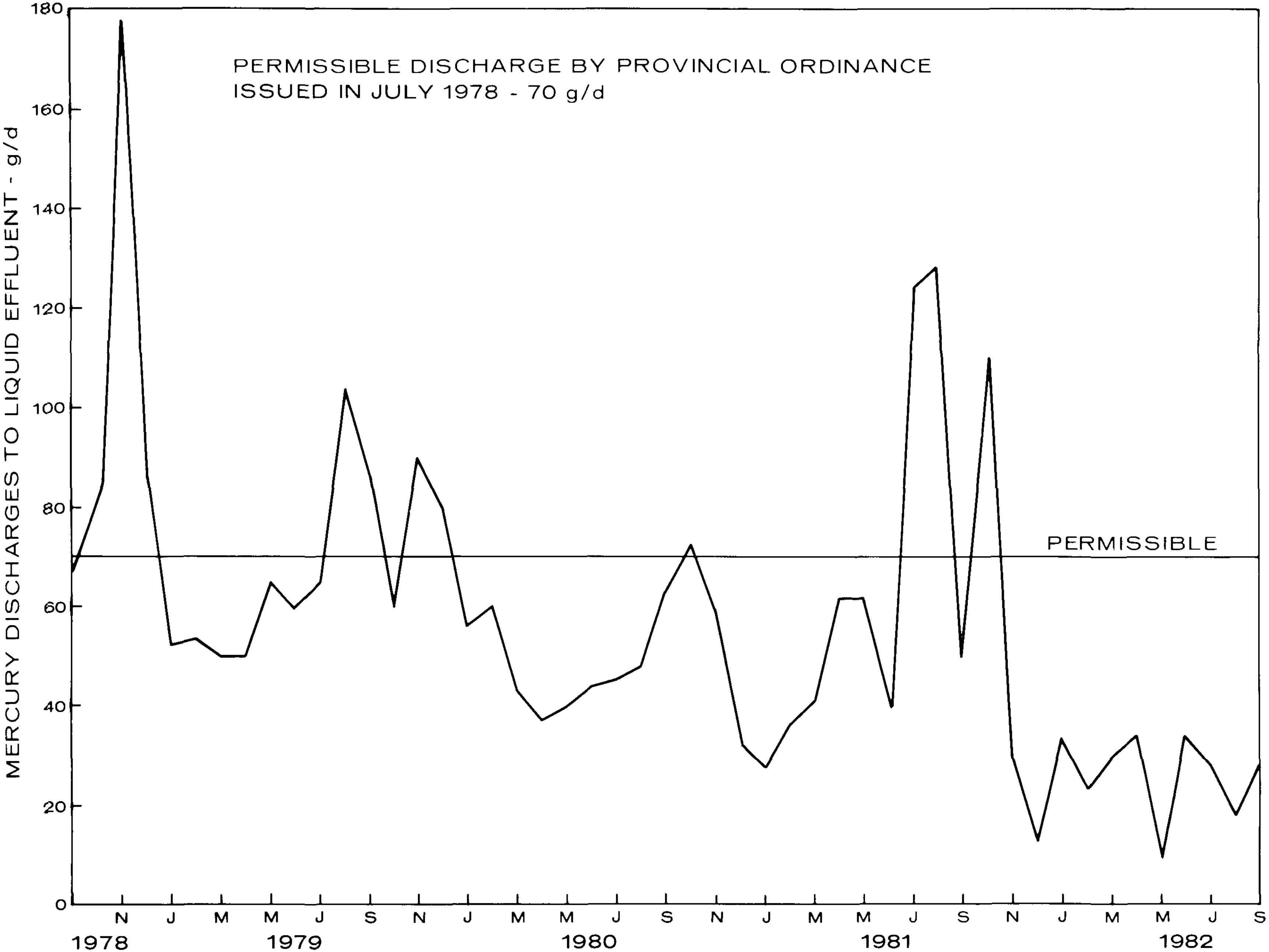


FIGURE 2 MERCURY DISCHARGED IN LIQUID EFFLUENTS FROM DOMTAR'S LEBEL-SUR-QUÉVILLON CHLOR-ALKALI PLANT

storm sewer, and effluent from the septic tank now bypasses the treatment system. Figure B.1, Appendix B, shows the plant area sewer system.

To eliminate one of the causes of wide swings in pH in the storm sewer, the wastewater from the H_2SO_4 filter is now mixed with wastewater from the chlorine dioxide generators and is used in the recovery of kraft cooking liquor. The acid sewer has been blocked off and isolated. The effluent in the acid sewer is now pumped to the wastewater treatment system. An overflow line was installed from the acid head tank back to the unloading tank, and the floor drain under the acid head tank drains to the wastewater retention sump. All these changes have isolated the acid circuit from all other areas, eliminating an important cause of high mercury losses to liquid effluents.

Overflows from the 50 percent and 10 percent caustic soda holding tanks now goes to the used cooling water sewer. A retaining wall surrounding the sodium hypochlorite reactor is joined to a sump which allows all discharges to be collected. The collected hypo is recycled to the reactor. The overflow from the hypo storage tank is connected to the cooling water sewer. Pump seal water from the acid and effluent pumps is sent to the chlorine dioxide section. Pump seal water from the hypo is sent to the cooling water sewer.

All the sanitary, process and cooling water sewers needing repairs were replaced and the remainder cleaned. All effluents high in mercury are treated for mercury removal. Studies made by Domtar's Research Centre indicated that chlorate present in the effluent increased the mercury levels in the wastewaters and made it extremely difficult to remove mercury from the liquid effluent. Changes were made to the sewer lines to try to prevent the addition of chlorate to the wastewater to be treated.

A recirculation system was installed on the storm water sewer treatment system. In the presence of oxidants such as NaOCl or $NaClO_3$, the water in the sewer is recirculated and hydrazine is added to destroy the oxidants. An oxidation-reduction potential control system automatically recycles the wastewater if oxidants are present. An alarm on the control panel indicates the presence of oxidants in the sewer.

Drainage water from around the building enters a manhole and is pumped to a settler. An oxidation-reduction potential electrode is located in this sewer; when a loss of hypo or chlorate is detected, sufficient hydrazine can be added to destroy the oxidants present. An automatic pH controller maintains the wastewaters at a pH of 11 to 11.5 with the help of NaOH. The water in the acid sewer and from the cell room is collected and neutralized. The supernatant from the settler is sampled and the flow measured using a weir. Solids removed from the bottom of the settler are sulphided and sent to the disposal area.

Mercury-contaminated solids that were not sent to the U.S. for burial, plus some contaminated equipment, were buried in a disposal pit. Appendix B provides a description and drawings of the sludge disposal area which was used between 1971 to 1977, and the sludge disposal pit that is still in use.

3.2.3 Monitoring. Test monitoring wells are strategically located around the two disposal areas to check on the migration of mercury from the disposal areas into the surrounding groundwater. Monthly samples are taken for sodium and mercury analysis.

Samples are taken from a number of points in the plant as well as from the total effluent discharge, which is the combined cooling water, process water, sanitary effluent, surface runoff and storm drainage water. The results of daily monitoring for mercury discharges from the plant are submitted to the provincial and federal environmental agencies each month.

3.2.4 Further Action in Progress or Planned.

1) A retaining wall is to be placed around the sodium chlorate storage tanks. Any leaks or overflows will be collected in a sump and recycled.

2) The system for storing the reagents and transporting the solid wastes to the sludge disposal area is to be improved.

3) The remaining piping from the plant has been cut into 1-metre lengths and placed in metal barrels. It will be forwarded for disposal in the U.S.A. The barrels will be identified with the company name and contents.

3.2.5 Conclusions.

1) The actions taken by the company to reduce mercury losses to liquid effluents have resulted in a gradual reduction over the past four years.

2) Domtar's Research Centre has evaluated a membrane filtering system to reduce losses of mercury coming from the perimeter sewer. This system has presently been set aside due to the favourable reduction in mercury losses obtained from the improvements made in 1981-82. If mercury losses increase in the future due to increased seepages and/or runoff then the membrane system or a suitable wastewater treatment system that will provide for greater flow, pH and oxidation-reduction variations should be installed as soon as possible to reduce mercury losses to liquid effluents. This system should remain in force until losses are reduced to less than 5 g of mercury per day.

3) Efforts should continue, to locate, remove and bury (in the approved burial site) soil from around the plant that contains high mercury levels.

3.3 Aluminum Company of Canada Ltd. Closed Mercury Cell Chlor-alkali Plant at Jonquière

3.3.1 Historical Operation. ALCAN's mercury cell chlor-alkali plant commenced operations in 1947 with an initial capacity of 36 tonnes/day. Subsequently a series of expansions raised the production capacity to 90 tonnes of chlorine daily (1965 onwards). Prior to 1970, mercury-contaminated brine treatment solids, cell room muds, etc., were discharged directly to sewer. Used anodes, worn-out equipment, etc., were buried in the plant's solid waste disposal area. In light of information about the dangers created by mercury discharges, action was initiated in 1970 to reduce these losses.

From 1971 to 1976 all mercury-contaminated brine treatment solids were collected in a sump, treated with sodium sulphide and impounded in two red mud ponds about 1.6 km southeast of the plant. These ponds were formed between 1940-50 to dispose of residue (iron, silicon, titanium oxides) resulting from the production of alumina from bauxite (see Figure C.1 in Appendix C). Mercury-contaminated wastewaters that could not be recycled were treated for mercury removal using Na_2S and were then filtered. The caustic produced in the plant was also filtered for mercury removal. These two dry filter cakes along with used anodes plus other solid residues contaminated with mercury were impounded in the red mud ponds. Mercury to air was reduced by the installation of a refrigeration unit and a Brinks demister unit on the hydrogen gas stream.

On June 2, 1976, the chlor-alkali plant at Jonquière ceased operations due to a strike that lasted four and one-half months. This plant never re-opened after the end of the strike, and it was decided in February 1977 to permanently abandon production. Dismantling and decontamination procedures were established in concurrence with the Québec Department of the Environment.

3.3.2 **Predismantling Studies Performed.** In 1977, studies were carried out by the company to determine the mercury absorption properties of red mud. The studies indicated that the red mud has certain absorption-chelating properties. To verify these conclusions, the company commissioned Couplan Inc. to study the complexing properties of mercury with red mud. Couplan Inc. studies indicated that:

i) The complexing properties reach equilibrium very rapidly.

ii) At pH 13, the concentration of ionic mercury in the water phase was about 2.5 ppm vs. 5 ppm at a pH of 10 or lower (corresponding to the initial concentration of mercury in the solution added to the red mud).

iii) At pH 13 and an initial concentration of 41 ppb mercury, the transfer of mercury from solution to solids lowered the ionic mercury in the liquid phase from 41 ppb to 11 ppb. For pH values of 7, 8, 9 and 10 the transfer of mercury from solution to solids was very weak.

iv) For mercury present in the metallic form, there was no transfer of mercury to the liquid phase at pH 13.

v) At pH 13, there is very little leaching of mercury that has been absorbed or complexed on red mud.

vi) At pH 7 there is no leaching of metallic mercury absorbed in red mud. At pH 13, there was very slight leaching (0.1 ppb).

vii) If the conditions in the ponds remain constant the concentration of mercury in the pond seepage water should remain below 10 ppb.

For these reasons the company believes that the mercury in the ponds is well stabilized. This opinion was confirmed in additional studies by Geocon Ltée which stated that:

i) The quantity of groundwater flow from pond 2 to the surrounding area is in the order of 135 to 180 m^3/d (not during the winter).

ii) The mercury concentration in the groundwater is in the order of 0.15 to 3.5 ppb.

iii) The estimated loss of mercury from pond 2, through groundwater flow, is around 0.4 g/d based on these flows and concentration.

The two red mud ponds contain over one million tonnes of red mud extending over an area of 14 hectares. Since an estimated 25 to 30 tonnes of mercury were already deposited in these two ponds and because of the complexing properties of the red mud, the company decided that the best plan was to impound the dismantled plant in this area.

3.3.3 Dismantling and Decontamination Procedures. After shutdown, the brine in the system was adjusted for pH, any residual chlorine was destroyed, and the brine was treated for mercury removal before being slowly released to the sewer.

All mercury was drained from the cells, end boxes, mercury pumps, decomposers, piping, etc., and put into steel bottles and sold to a reputable dealer. Mercury butter and other mercury-rich solids were placed in steel barrels with polyethylene liners and sold to a third party for mercury recovery.

All the brine saturators, settlers, tanks, filters, coolers, pumps, dechlorinators and lime absorbers were washed using water under high pressure and buried in the disposal area.

The equipment from the chlorine section, i.e., coolers, drying towers, booster fans, pumps, acid separators, mist eliminators, filter, acid coolers, storage tanks, calcium chloride coolers, compressors, and liquefiers, which was only slightly contaminated with mercury, was sent to the scrap yard for recuperation.

The cells, decomposers, old graphite anodes, mercury pumps, end boxes, side boxes, brine headers, soft water headers, hydrogen header, hydrogen coolers, traps, hydrogen compressor, hydrogen scrubber, hydrogen blower, HCl storage tanks, HCl absorber, caustic receiving tanks, caustic storage tanks, caustic pumps, and many miscellaneous items such as piping, valves, and hangers, were washed with water and buried under several metres of red mud in the centre of the mud ponds.

Some pieces of equipment, such as copper busbars, the titanium cooler, the emergency generator, the Freon compressor, some heat exchangers, U.S. and Fonda filters, titanium pumps, fibre glass tanks and scrubbers and several electric motors, were cleaned and sold or reused.

After all equipment was removed from the south end of the plant, the walls, roof, beams, and floor were washed using water under high pressure. The sumps were filled with gravel and capped with cement, the drains were washed out and sealed with cement and all washwaters were treated for mercury removal.

The cement pillars and the mezzanine floor in the cell room were broken and buried in the red mud ponds. The walls and roof of the old cell room were washed with water. The floor was decontaminated and washed with water. All sewers, sumps and trenches were filled and capped with cement. The tunnels under the basement floors which were used to collect and treat wastewaters were sealed with cement. The floors in both the north and south sections of the plant were then capped with about 0.5 metres of reinforced concrete. The walls in the north section were painted after being washed. The walls and ceilings in the new office space (part of the south section) were covered with material to blend into the office decor. The other section was painted after the walls and ceilings were washed.

The top 10 to 12 cm of topsoil were removed from both the east and west court yards. The storm runoff sewers were capped off and new sewers installed. An asphalt layer was then placed over the whole court yard to prevent infiltration.

The wastewater treatment and filtration system was operational until the dismantling and decontamination of the chlor-alkali plant was completed. All mercury-contaminated wastewaters resulting from this operation were treated before being discharged. The equipment used to treat the wastewaters was then buried in the waste disposal area.

Appendix C provides complete details and drawings of the mercury-contaminated material burial site.

3.3.4 Monitoring. Ambient mercury concentrations have been measured in the maintenance area, offices and court yard. The readings were well below 0.05 mg per cubic metre. Monitoring of mercury to liquid effluents is periodically carried out in the sewers near the dismantled plant and from the waste disposal area (red mud ponds 2 and 3A). Mercury losses average from two to five grams per day.

3.3.5 Further Action in Progress or Planned. Samples of wastewaters discharged from around the dismantled chlor-alkali plant site will be periodically analysed for mercury to verify that no leaching of mercury is occurring. Samples of runoff and seepages from the waste ponds where the mercury-contaminated material was buried will be analysed periodically to ascertain that no leaching or migration of mercury is taking place.

3.3.6 Conclusions.

1) The chlor-alkali plant, which has been dismantled and decontaminated, and is now used for new office space and light mechanical maintenance, should not contribute significant mercury contamination to the environment if this area remains undisturbed. If at some future date the area is required for other activities, then the basement floor, tunnel sections and the soil under the plant will require excavation and burial in an approved landfill site.

2) The layer of top soil and grass over the two ponds should help to dry out these ponds and thus reduce runoff and seepages. If the pH of the subsurface water becomes acid, due to the leaching of acid from gypsum deposits in the pond area, then mercury leaching could become a problem that would require corrective action such as improvement to the impermeable clay dome, or an impervious wall along the perimeter of the ponds, or the treatment of the runoff water for mercury removal.

3.4 Great Lakes Forest Products Limited Closed Mercury Cell Chlor-alkali Plant at Dryden (converted to membrane process)

3.4.1 Historical Operation. Great Lakes Forest Products Ltd. chlor-alkali plant (formerly Reed's subsidiary, Dryden Chemicals Ltd.) commenced operations in 1962 with a rated capacity of 33 tonnes per day of chlorine. Prior to 1970, mercury-contaminated brine filter solids and brine sludge entered the Wabigoon River via waste streams, which resulted in the contamination of sediments downstream of the plant.

In March, 1970, a control order from the Ontario Water Resources Commission was issued directing Dryden Chemicals Ltd. to conduct in-plant modifications for wastewater recycling and for treatment of mercury-contaminated wastes.

All mercury-contaminated wastewaters that could not be recycled were sulphide treated. Sludge from the effluent treatment tanks, sludge from brine filtration, graphite from the cells and other smaller amounts of mercury-contaminated solids were mixed with concrete and sand and buried in a special disposal pit lined with polyethylene and covered with compacted clay. Mercury emissions to air were also curbed by cooling cell vent gases, the hydrogen gas stream, and other gas streams.

3.4.2 Dismantling, Conversion and Decontamination Procedures. On October 21, 1975, the mercury cell chlor-alkali plant at Dryden Ontario suspended operations. The plant was converted to an ionic membrane cell process, and re-opened on November 19, 1975.

The dismantling and decontamination of the plant was carried out in two phases. The first phase was the recovery and sale to a reputable dealer of as much mercury as possible, followed by the removal of mercury-contaminated sludges from all tanks, sumps, trenches, etc. This sludge was mixed with sand and cement and buried in polyethylene-lined pits.

Much of the equipment in the brine circuit was reused (i.e., saturators, settlers, filters, holding tanks, dechlorinated brine tank and air degasifier), after having been cleaned using water under high pressure. All cleaning waters were collected and treated for mercury removal before being discharged. The brine heat exchanger was acid cleaned and then flushed with water. Other equipment in the brine circuit, i.e., pumps, brine receiver tank, vacuum degasifier and most piping, were replaced. With the exception of the compressor and separator, the hydrogen system was completely replaced. No changes were made to the sodium hypochlorite system; however, checks were made to ascertain that no mercury was present. New piping and drying towers were installed in the chlorine circuit. All other equipment such as the compressor, storage facilities, etc., was reused after being checked for mercury contamination. All piping from the decomposers to the caustic receiving tank, the receiving tank itself and the caustic filter were removed, cleaned and buried. The 50-percent caustic storage tank was cleaned and reused.

During the dismantling, the company recovered considerable amounts of mercury from the cells, decomposers, sumps, pumps, inlet and outlet boxes and caustic receiving tanks. Varying amounts of mercury were also recovered from the soft water head tank, caustic piping, hydrogen header, hydrogen filters, hydrogen coolers and separators, hydrogen vent, floor, trenches, and soft water lines.

The second phase entailed the decontamination of all equipment to be buried and its ultimate disposal, as well as the decontamination of items to be sold, i.e., copper busbars, motors, etc. All equipment that was not reused, e.g., cells, denuders, mercury pumps and coolers, tanks, hydrogen coolers and scrubber, piping, caustic filters, brine pumps, hydrogen header, mercury catch pots, etc., was washed with water under high pressure and buried in polyethylene-lined pits.

After all items were buried, the pits were filled with concrete, and a layer of plastic was placed over the dome and covered over with clay. One pit has a concrete bottom with a perforated hose beneath, the purpose of which is to collect any water for possible treatment, if ever required. Prior to and during the disposal activities, a representative from the Ontario Ministry of the Environment and a consultant were present to witness the proceedings. The site has test wells for monitoring for any possible groundwater contamination.

Additional steps taken to further reduce mercury losses were thorough washing and partial resurfacing of the basement floor; removal and replacement of the basement floor and top layer of subsoil from the caustic receiver tank and chlorine compressor areas; replacement of the tile-lined trench in the basement floor under the old cell room with a PVC sewer; washing and painting of some walls and girders in the cell room; and installation of new sewer lines between the chemical plant and the pulp and paper plant.

In July 1978, the causeway adjacent to the river was drained, backfilled with a high organic content fill, which should favour anaerobic conditions, and covered with an impervious clay layer followed by topsoil and grass. These protective measures should ensure that mercury from this area is not released to the river.

All the above noted steps have resulted in a substantial reduction in mercury losses from this plant as illustrated in Figure 3. Details on the disposal procedures are provided in Appendix D.

3.4.3 Monitoring. Samples of effluent discharged from the converted chlor-alkali plant and surface runoff from south of the plant are collected daily and analyzed for mercury. Mercury losses average about 3 to 4 g/d. Samples taken semi-monthly by Beak

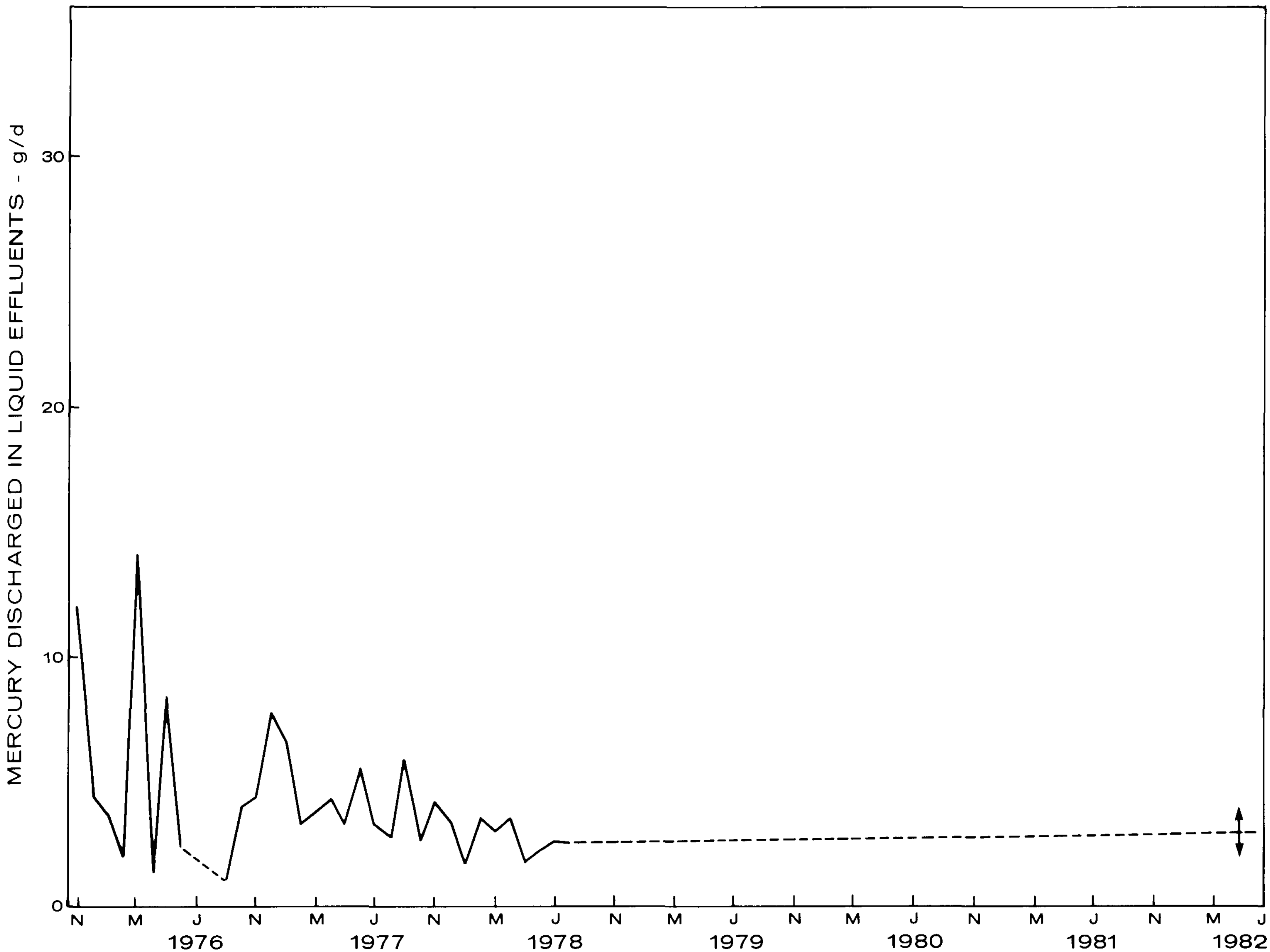


FIGURE 3 MERCURY DISCHARGED IN LIQUID EFFLUENTS FROM GREAT LAKES FOREST PRODUCTS LIMITED DRYDEN CHEMICAL PLANT

Consultants indicate an average 1982 mercury loss of 4 g/d from the chemical plant, which confirms the company's results.

Samples of seepages from the monitoring wells around the burial site are also analyzed by the Ministry of the Environment, Ontario, and by Beak Consultants three or four times per year. Mercury concentrations in the six monitoring wells has averaged around 7 micrograms per litre over the past five years.

3.4.4 Further Action Planned or Recommended.

1) The trench under the brine area has been partly replaced with PVC piping and is partly tile-lined. The company plans to eventually resurface the floor under the brine area.

2) Where possible, all old sewer lines should be removed or filled with cement, or the two ends should be plugged to prevent mercury losses due to infiltration.

3) Since the company is installing new membrane cells in the old chlorate cell room, it will be imperative that the resurfaced basement floor be kept in excellent condition to prevent mercury losses through leaching from the cement and from the soil under the floor.

4) Wastewaters from the eight sewers from the pulp and paper mill and chemical plant discharging to the causeway adjacent to the river were combined in a common header in September 1977. These effluents now go to a large clarifier. The underflow from this clarifier is vacuum filtered, and the relatively dry solids go to landfill. The filtrate is returned to the clarifier. Next year supernatant from the clarifier will go to a large, eight-day retention, aeration stabilization pond before entering the Wabigoon River.

3.4.5 Conclusions.

1) The restoration procedures used at the plant have reduced mercury losses to sewer in wastewaters and runoff discharged to around 4 g/d. This figure might decrease slowly with minor modifications in the future.

2) The mercury waste disposal area is on a small hill about 2.5 m above the water table. Plastic drain pipes have been placed under some cells and monitoring wells have been strategically placed around the burial site. To date, the migration of mercury from this area has been negligible. If need be, the seepages will be collected and treated for mercury removal.

3.5 American Can of Canada Limited Closed Mercury Cell Chlor-alkali Plant at Marathon

3.5.1 Historical Operation. American Can of Canada Ltd.'s chlor-alkali plant commenced operations in 1952 with a rated capacity of 34 tonnes per day. Prior to 1970, mercury-contaminated solids and wastewaters were discharged directly to sewer; however, since this plant used evaporated salt, the amount of solids and thus mercury discharges were less than from most plants. After 1972 the wastewaters that could not be recycled were sulphide treated for mercury removal before being discharged. From 1971 to 1977 brine treatment solids plus other solids contaminated with mercury (e.g., used anodes) were stored in drums and buried in an approved burial site. Some mercury-rich solids were retorted for mercury recovery.

Mercury emissions to air were reduced by the direct cooling of the hydrogen gas with water. The water was then recycled to the cells and eventually used as make-up water in the denuders.

3.5.2 Dismantling and Decontamination Procedures. On August 31, 1977, American Can of Canada Ltd. closed their mercury cell chlor-alkali plant at Marathon to meet a Ministry of the Environment of Ontario control order. Huron Chemicals' sodium chlorate plant, however, remained in operation until September 30, 1982, and since both the chlor-alkali and chlorate plant used the same brine treatment equipment this section of the plant remained in operation.

Following the closure of the chlor-alkali plant the dismantling and disposal of mercury-contaminated equipment and materials from the plant was carried out in accordance with the procedures agreed upon with the Ministry of the Environment of Ontario.

Prior to the closing of the chlor-alkali plant the east salt cavity was taken out of service and cleaning and decontamination procedures were initiated. All residual brine was treated for mercury removal and then slowly discharged. Sludges containing mercury and pockets of brine contaminated with mercury were then flushed out and treated for mercury removal or placed in drums and buried in an approved burial site. This operation, which took four or five months to complete, provided mercury-free salt storage for the continuing operation of the sodium chlorate plant. All other process equipment such as the brine clarifier, clarifier pump tank, filters, brine storage and head tank were subsequently cleaned out. All mercury-contaminated sludges were placed in barrels and buried in the disposal area.

Mercury in the cells, decomposers, pumps end boxes, piping, etc., was cleaned out by circulating hydrochloric acid through each cell for at least one hour, and then draining the equipment. About 40 500 kg of mercury was obtained and placed in steel bottles. Any mercury that spilled flowed to a sump in the cell room floor. At the end of each day the floor was hosed down to wash any remaining spilled mercury to the sump. A vacuum pump with a special small diameter nozzle was used to collect small pools of mercury found in the lips of the tank covers, and on the reactors and decomposers, and to clean down into cracks around seals and between anode plates. About 3 400 kg of mercury were collected from the sump and vacuum. The total mercury collected was sold to a reputable dealer. All scrap, copper and brass was cleaned to remove mercury contamination and then sold. A concrete bunker measuring 30.5 m x 7.6 m x 3.6 m was built to contain all the cells, decomposers, inlet and exit end boxes and seals, mercury pumps and motors, brine inlet and outlet headers, end box drain header, soft water header and piping, weak and strong caustic header, caustic receiving tanks, mercury catch pots, 240 250-L drums of sludge, hydrogen cooling tower, hydrogen header, and miscellaneous piping and other scrap. This bunker was then capped and sealed with high strength concrete.

All mercury-contaminated sludges were removed from all caustic storage tanks, from the cell room trenches and sumps and from the untreated effluent sump. This sludge was placed in steel drums and buried in the disposal site. The tanks, trenches, etc. were then cleaned using water under high pressure. The wastewater was treated for mercury removal before being discharged.

The west salt chest was subsequently cleaned. The brine was treated for mercury removal before discharge to sewer, and the mercury-contaminated sludges were buried at the landfill site. Some equipment that remained in place when the plant was closed became obsolete and has also been buried in the disposal site.

After all equipment was removed from the cell room, the walls and ceilings were washed with water under high pressure, the pillars, curbing, etc. were removed; the trenches and sumps were filled with aggregate and cement; and the whole area was capped with cement. This area is now used for the dry storage of pulp.

The mercury treatment system will remain in operation, and monitoring for mercury losses from the chemical plant area will continue until the chemical plant dismantling and clean-up is complete. More complete details of the disposal area are provided in Appendix E.

3.5.3 Monitoring. Samples of liquid effluents leaving the plant site are analyzed daily for mercury levels. As shown in Figure 4, mercury losses from the closed plant are very low, i.e., about 2-3 g per day. Samples of seepages from around the mercury-contaminated burial site are taken five or six times per year. The monitoring wells north and south of the burial site are normally dry. The monitoring well west of the burial site which is 2 m deeper than the north and south wells (i.e., 25 m deep) contains only one to two micrograms of mercury per litre of groundwater.

3.5.4 Further Action in Progress or Planned. On September 30, 1982 the sodium chlorate plant suspended operations. The cells from this plant, which has a non-mercury process, will soon be dismantled and shipped from this country. The dismantling and burial of other equipment, such as the brine clarifiers, pump tank, brine filters, brine storage tanks, polysulphide tanks and other equipment will then proceed.

After all the equipment has been removed and buried or sold, the old sewers and sumps will be filled with cement and new sewers will be installed within the existing sewer trenches, eliminating the possibility of dissolving any residual mercury which might be present in the sewers. The floors will then be capped with cement.

3.5.5 Conclusions.

1) Mercury losses to liquid effluents from this plant have been low over the past four years, i.e., around 2 to 5 g per day.

2) Since this plant is situated on the shore of Lake Superior it is impossible to determine if any mercury is entering the lake via seepages. The only sure way of minimizing mercury seepages is to complete the dismantling of all obsolete equipment and restoration of the plant and surrounding area as soon as possible.

3) The mercury waste disposal site is situated in an area containing mostly fine sand well above the water table; thus no contamination of the groundwater should occur. If monitoring of the test wells does indicate mercury migration then immediate corrective action will be required.

3.6 Canadian Industries Limited Closed Mercury Cell Chlor-alkali Plant at Shawinigan

3.6.1 Historical Operation. Canadian Industries Limited's chlor-alkali plant in Shawinigan commenced operations in 1938/39 with a rated capacity of 95 tonnes per day of chlorine. From 1939 to about 1960, this plant discharged mercury-contaminated brine sludges and wastewaters directly to sewer. From around 1960 to 1970, the waste sludges were retained in a pond, but the contaminated wastewaters still went directly to sewer.

In 1970, the pond was enlarged so that both the contaminated wastewaters from the cell room floor washings, hydrogen condensate, cell washings, etc., and sludges

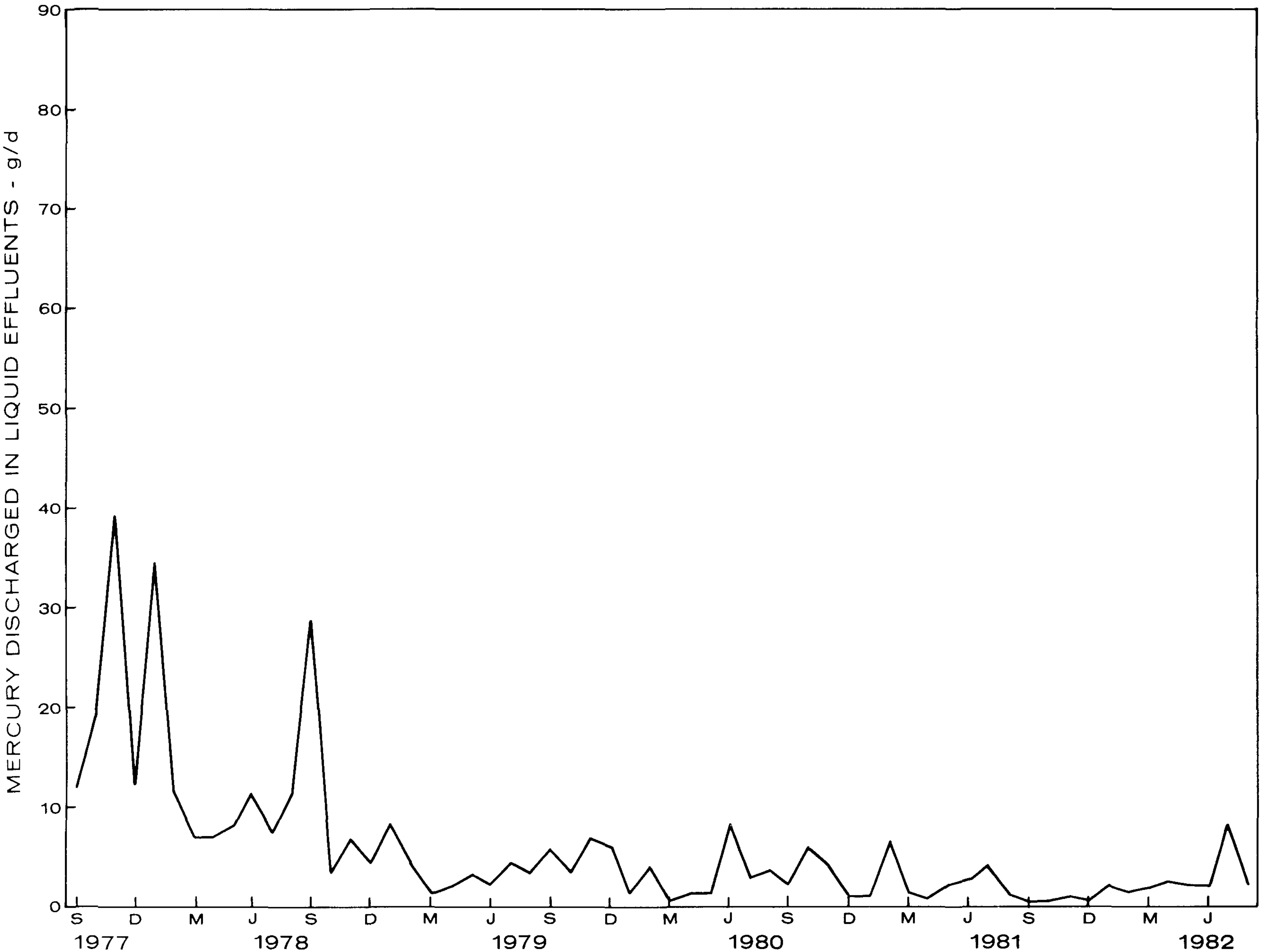


FIGURE 4 MERCURY DISCHARGED IN LIQUID EFFLUENTS FROM AMERICAN CAN'S MARATHON PLANT

could be accommodated. Studies carried out by both the company and a consultant showed that there was a 3 to 5-m layer of sand over a thick layer of clay in the pond and adjacent area. Seepages from the bottom and sides of the pond flowed parallel to the clay interface and entered the ravine west of the pond. The solids were retained and the mercury in solution was adsorbed on the brine sludges as well as on the sand and clay particles, which resulted in an effluent with a maximum mercury concentration of 0.5 mg/L.

The mercury-contaminated sludge from the pond was removed periodically and buried in an area adjacent to the pond. Other solids buried in this same area included retort solids, used carbon electrodes, graphite from the decomposers, rejected pieces of equipment, pieces of contaminated cement, etc.

Mercury in the caustic filter sludge, cell room muds, and mercury butter was recovered by retorting.

Steps were also taken to reduce mercury emissions to the atmosphere.

3.6.2 Dismantling and Decontamination Procedures. On January 29, 1979, CIL's mercury cell chlor-alkali plant at Shawinigan was closed. Dismantling of the plant and decontamination of the surrounding area was accomplished with the concurrence of the Québec Department of the Environment. Prior to closure engineering firms were commissioned to determine the extent of contamination and the suitability of a site for the disposal of all the mercury-contaminated waste and used equipment. A site at St. Boniface (about 5 km from the plant) was chosen. The site is composed of very dense clay several metres thick, with a permeability of about 10^{-7} cm/s.

Before final shutdown, the brine contained in the system was run down to minimum levels. The remaining brine was adjusted for pH and chlorine levels and then treated for mercury removal before discharge.

All mercury was drained from the cells, lines, pumps, traps, etc., and put into steel bottles. All mercury-rich solids from the cells, caustic tanks, and other equipment were retorted to recover mercury. All this mercury was then sold to a reputable dealer or transferred to another of the company's mercury cell plants.

All the equipment from the brine area, cell room, hydrogen section, caustic soda section, and chlorine area, e.g., cells, decomposers, mercury pumps and boxes, brine header, caustic header, hydrogen header, chlorine header, soft water header, coolers, pumps, brine and caustic tanks, piping, with the exception of a few expensive pieces of equipment that could be decontaminated and reused and scrap copper that was acid cleaned and sold, was buried in the St. Boniface disposal area. Before the equipment was buried, it was washed with water under high pressure to remove residual salts and mercury. These washwaters plus all other washwater, including the effluent that went to the pond, were treated for mercury removal before final discharge.

All the mercury-contaminated mud, silt, etc., in the pond, in the adjacent burial site and for about 35 m down the ravine from the pond was removed and buried in the disposal area. The sewer from the caustic finishing plant, which passed under the pond, was tied into the new city sanitary sewer. The old sewer was removed. All solids down to the clay were removed. There was a high mercury concentration at the clay-silt interface. By removing about an additional 15 cm of clay the mercury concentration dropped down below 10 ppm - the cutoff point. The new city sanitary sewer was not removed since it is still in operation; there are likely some solids with a mercury concentration greater than 10 ppm left in the vicinity of the new city sewer line. The pond area and the ravine were backfilled with clay containing no mercury, which was trucked in from the new waste disposal site (clay removed from the burial holes).

The company planned to reuse the plant buildings; however, they decided that a proper restoration program could not be accomplished without a complete knowledge of the contaminated area. An engineering firm was commissioned to study the soil and subsurface water in the vicinity of the plant buildings. As a result of this study, it was decided to completely demolish the buildings, including all the cement floors, and bury them at the St. Boniface site. All the soil under the plant was removed down to about 30 cm into the clay layer and buried in the same site. The area where the plant had been was backfilled with mercury-free dense clay followed by top soil. This area plus the surrounding area was then levelled and seeded.

In all close to 142 000 m^3 of material containing around 23 000 kg of mercury were buried in six disposal holes at the disposal site.

New sewer lines to the workshops, warehouses, rectifier building (now storage), hypo building, caustic storage area, and the old salt storage building were installed. About 300 m of piping which had been used to carry hydrogen and HCl to a neighboring plant are buried underground. These pipes were pumped full of cement to prevent further use. More complete details of the disposal procedures are provided in Appendix F.

3.6.3 Monitoring. Monitoring for mercury losses from the restored plant site is carried out on a daily basis. As shown in Figure 5 mercury losses have been decreasing over the past three years and are presently around 2 to 7 g per day.

Studies have shown that mercury migration from the burial pits will be extremely low. There are no data available yet to show that migration has or has not taken place.

3.6.4 Further Action in Progress or Planned. Samples of water flowing towards the ravine will be analyzed monthly and the results will be forwarded to the Ministry of the Environment for Quebec. If the amount of mercury being discharged is significant and the flow can be measured a flow measuring device will be installed.

3.6.5 Conclusions.

1) Since this was a very old plant, mercury contamination of the area around the sludge pond, ravine and plant site was quite entensive. The company should be congratulated for completely restoring a potentially long-term hazardous area.

2) The confinement of mercury in the waste disposal area at St. Boniface should remain secure as the area contains very dense clay with a low permeability. Monitoring of test wells will be carried out periodically, however, to verify the security of the site.

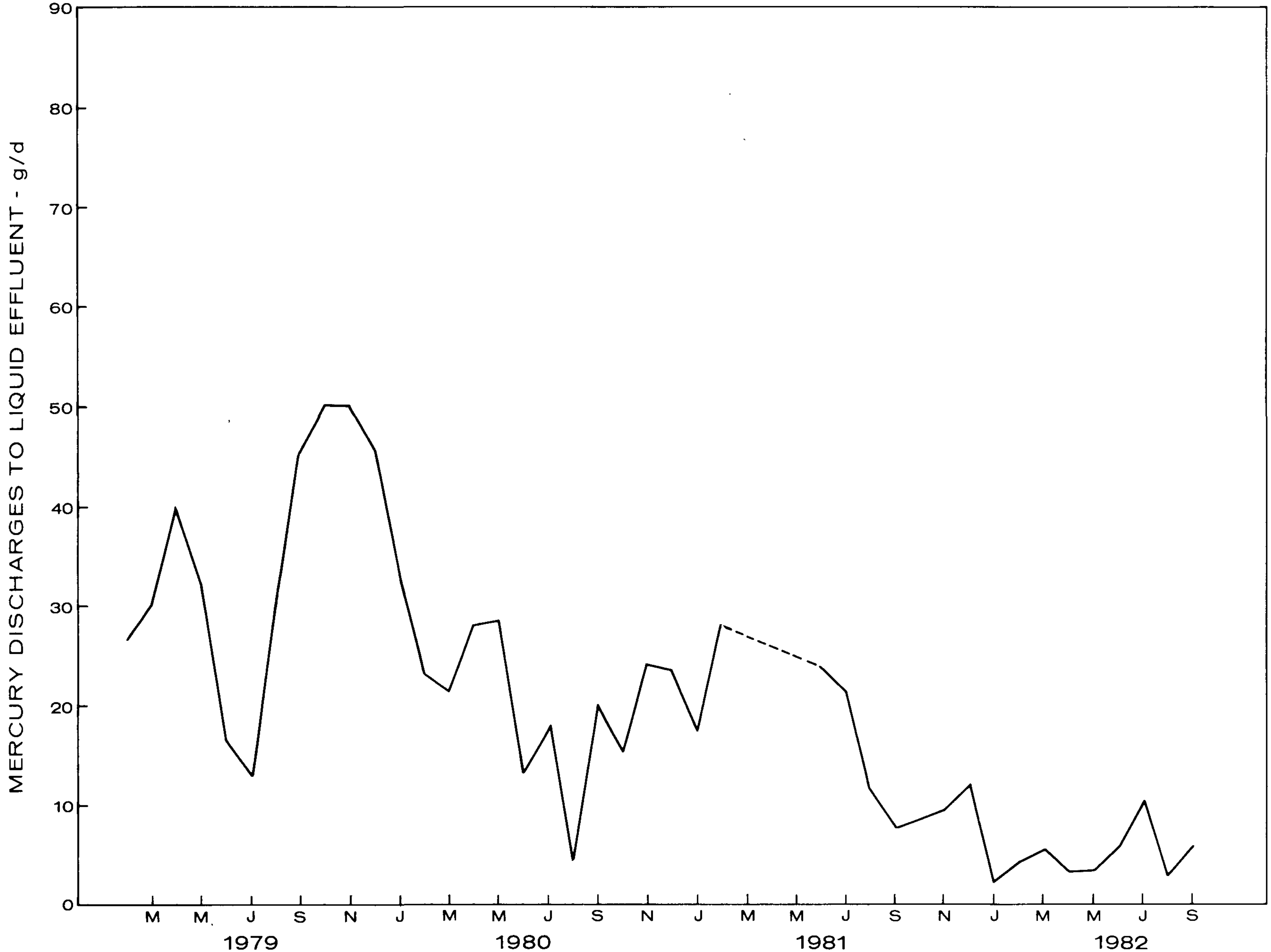


FIGURE 5 MERCURY DISCHARGED IN LIQUID EFFLUENTS FROM CIL'S CLOSED CHLOR-ALKALI PLANT AND CAUSTIC SODA CONCENTRATOR AT SHAWINIGAN

4 OVERALL CONCLUSIONS

1) As summarized in Table 1 below, all but one of the plants have been able to reduce mercury losses to the aquatic environment to levels ranging from 2 to 10 g per day. This accomplishment is remarkable considering that during the life-span of these plants, large quantities of mercury escaped through the cell floors, to the sewer systems, and to the atmosphere which resulted in mercury contamination of the topsoil for large areas around the plants.

TABLE 1 SUMMARY OF PRESENT MERCURY DISCHARGES FROM CLOSED MERCURY CELL PLANTS AND COSTS INCURRED TO RESTORE SITES

Plant Site	Average Daily Mercury Discharges to Liquid Effluents from the Chemical Plant Site (grams/day)	Costs Expended to Restore Site and Contain Mercury Wastes	Future Costs
Lebel-sur-Quévillon	26	\$0.51 M	\$0.17 M
Jonquière	2-5	\$3.2 M	\$0.3 M
Marathon	2-5	\$0.4 M	--
Dryden	4	\$0.10 M	\$0.03 M
Saskatoon	1-5	\$0.35 M	\$0.05 M
Shawinigan	7	\$3.5 M	--

2) Current liquid effluent from all closed and converted chlor-alkali plants has lower mercury content (2-10 µg/L) than the treatability (20 µg/L) and best practical control technology limits for the sulphide precipitation/filtration process.

3) As noted in Table 1, the companies have expended large amounts of capital to restore their plant sites. This approach of permanently removing the contaminant at the source rather than treating any effluent and runoff for mercury removal will prove to have better cost-benefit advantages. The companies should, however, continue to monitor their sites to detect small areas of relatively high mercury deposits which are responsible for continuing low mercury releases and/or mercury migration from secured areas.

4) In the dismantling and decontamination of mercury cell plants, each case is site specific, and the costs involved to restore a site can vary significantly, depending upon many factors such as the extent of mercury contamination, whether both the plant and buildings are dismantled and buried or the buildings are to be used for other purposes, whether conversion is planned, etc. As shown above, costs varied

from around \$150 000 for a plant that converted to a non-mercury process to \$3 500 000 for a plant where complete restoration involved the removal and burial of 142 000 m^3 of contaminated material (including the equipment, buildings, etc.) and backfilling with mercury-free soil.

5) No standard procedures can be established for the dismantling and restoration of a plant site; however, many salient procedures that should be considered follow:

- Special care should be taken to protect the health and safety of workers. High standards of personal cleanliness should be maintained. Workers should be temporarily removed from possible contact if mercury in urine rises above the normal permitted.

- No burning of mercury-contaminated metal should be permitted and hand tools should be used whenever cutting is necessary.

- The cellroom should be ventilated and the atmosphere continuously monitored for mercury.

- Special emphasis should be placed on the prevention of spills and prompt cleanup action should be taken.

- Before final shutdown, the brine in the system should be run down to minimum levels, treated for pH and chlorine levels, followed by treatment for mercury removal, before final discharge.

- The mercury and a hydrochloric acid solution should be circulated through the cells to reduce the sodium content of the mercury. The mercury should then be drained from all cells, lines, pumps, traps, etc., bottled and sold to a reputable dealer.

- A vacuum pump with a small-diameter nozzle should be used to vacuum up small pools of mercury and remove mercury found in lips of tank and cell covers, in cells, decomposers, pumps, etc., and to vacuum down into cracks around seals, between anode plates and floor cracks.

- At the end of each shift, after the floor has been hosed down, all mercury collected in the cellroom floor sumps should be collected and bottled.

- Thick mercury should be collected, treated and bottled or drummed and sold to a reputable dealer for mercury recovery.

- Solids rich in mercury should be stored for mercury recovery or placed in drums and buried in an authorized area.

- All mercury-contaminated equipment should be washed with water under high pressure, then buried in the authorized area.

- All water used during the dismantling and decontamination procedures should be treated for mercury removal before being released. The treatment system should remain in place until all work is finished and mercury losses are less than 10 g per day.

- If any tanks are to be retained (caustic storage, brine, etc.) they should be thoroughly cleaned before reuse.
- Any mercury-contaminated sludges rich in brine should be placed in drums containing a liner, salt and chloride resistant. These drums should be buried in a separate section of the burial site.
- After all the equipment has been removed, the walls and ceilings should be washed with water under high pressure.
- The operational floor should be removed and buried. The basement floor should be examined for cracks or broken areas if the building is to remain intact. Concrete should be broken away and removed until a solid footing is reached. A new layer of concrete should be poured up to the existing level. All sewers and sumps should be filled and capped and new sewer lines installed. Preferably, a new floor with a mininum of 15 cm thickness should be poured over the entire cellroom floor.
- The burial site should be in a remote clay area away from any private or public water supplies. Test wells should be strategically located around the burial site.
- A cement pit should be built to hold the equipment from the cell room. This tomb should be built below the frost line and should be built to withstand local earth tremors or faulting.

ACKNOWLEDGEMENTS

The author is grateful for the assistance so freely provided by all company plant managers and their staff in providing technical information on their plant closure proceedings.

Thanks are also due to provincial environmental personnel, EPS Regional personnel and company personnel who reviewed this report and provided corrections and comments.

Special thanks is also given to D. Wayne Bissett of EPS Headquarters who offered guidance and suggestions during this program.

Acknowledgement and appreciation is also given to Vicky Jones, who edited the report, to the EPS Word Processing Unit for their efforts in the processing of drafts and necessary revisions, and to the drafting division for the layouts.

APPENDICES

APPENDIX A DISPOSAL SITE AND PROCEDURES - SASKATOON CHEMICALS

In 1974 consulting engineers were engaged to locate a suitable site on company property for the disposal of some brine treatment solids and contaminated soil from the toe of the river bank just down stream of the plant's effluent discharge point. The investigation included soil sampling, test drilling and permeability testing as noted below.

Site Testing

Twenty-five 12.7 cm diameter test holes were drilled to a depth of 2.4 to 6.5 m. Two holes were drilled to a depth of 27.7 and 32 m, and the subsurface strata was checked by measuring the electrical resistance at different levels. Test hole drill logs were prepared describing their locations and the relative positions of the various soil strata encountered.

An examination of the cross-sections indicated that the site was overlain by about 15 cm of organic topsoil followed by alluvial deposits. This alluvial deposit consists of silty sand and/or silty, sand clay which extends to a depth of 1.7 m in the area just north of the pit. The alluvial deposit is underlain by glacial clay till which extends to a depth of at least 3.6 meters. The clay fill matrix is rich in clay containing from 20 to 55 percent silt and clay sizes particles. This stratum extends to a depth of about 9.1 m west of the site to 6.1 m east of the site.

When the test drill was completed, field permeability tests were conducted. The test results indicated that the permeability coefficient of the glacial till was between 6×10^{-6} and 1×10^{-4} cm/s. The majority of the results were in the order of 3×10^{-5} cm/s. There appeared to be no variation of permeability with depth within the glacial till. (The property of a soil that permits the movement of water through the soil is called permeability. The ratings are as follows: impervious, 1×10^{-6} cm/s; semipervious, 1×10^{-6} to 1×10^{-4} cm/s; pervious, greater than 1×10^{-4} cm/s).

Design of Sludge Disposal Pit

1) The organic topsoil was stripped and saved for future landscaping.

2) The disposal pit was excavated to a depth of about 2 m.

3) The keyway was excavated and the dykes constructed to enclose the disposal pit. The keyway and dykes were scarified to a depth of 30 cm, about 1 percent bentonite added, then mixed and compacted in two lifts to at least 95 percent of standard Proctor density.

4) Monitoring equipment, consisting primarily of a drain pipe embedded below the scarified and compacted section of the pit, was installed. The excavated trenches around the monitoring equipment were compacted.

5) Subsequent to the excavation and construction of the keyway, the base of the pit and pit sidewalls were scarified to a depth of 30 cm, pulverized, and water was added to achieve a moisture content to meet ASTM designation D-698-70 requirements. One percent dry bentonite was added and mixed uniformly. The mixture was then compacted in two 15 cm lifts to an average density of 95 percent of standard Proctor density.

6) The pit was then lined with 7.6 cm of compacted Northern Saskatchewan peat moss.

7) The mercury-contaminated sludge was then placed in the pit.

8) Fifteen centimetres of loose peat moss was then placed over the sludge followed by 0.3-0.9 m of earth fill and 10 cm of organic topsoil. The landscaped area was then seeded with a hardy grass.

When the plant was converted to the membrane process in 1978, mercury-contaminated equipment plus some sludges had to be disposed of. Since this material was virtually dry it was decided to dispose of the material at the existing sludge pit. The contaminated material was disposed of over a central area of approximately 35 by 80 m as shown in Figure A.1

Burial of Dismantled Plant Equipment

1) The organic topsoil over a central area of 35 by 80 m was removed from the existing sludge pit as shown in Figure A.1.

2) Most of the existing soil cover from this area was then removed.

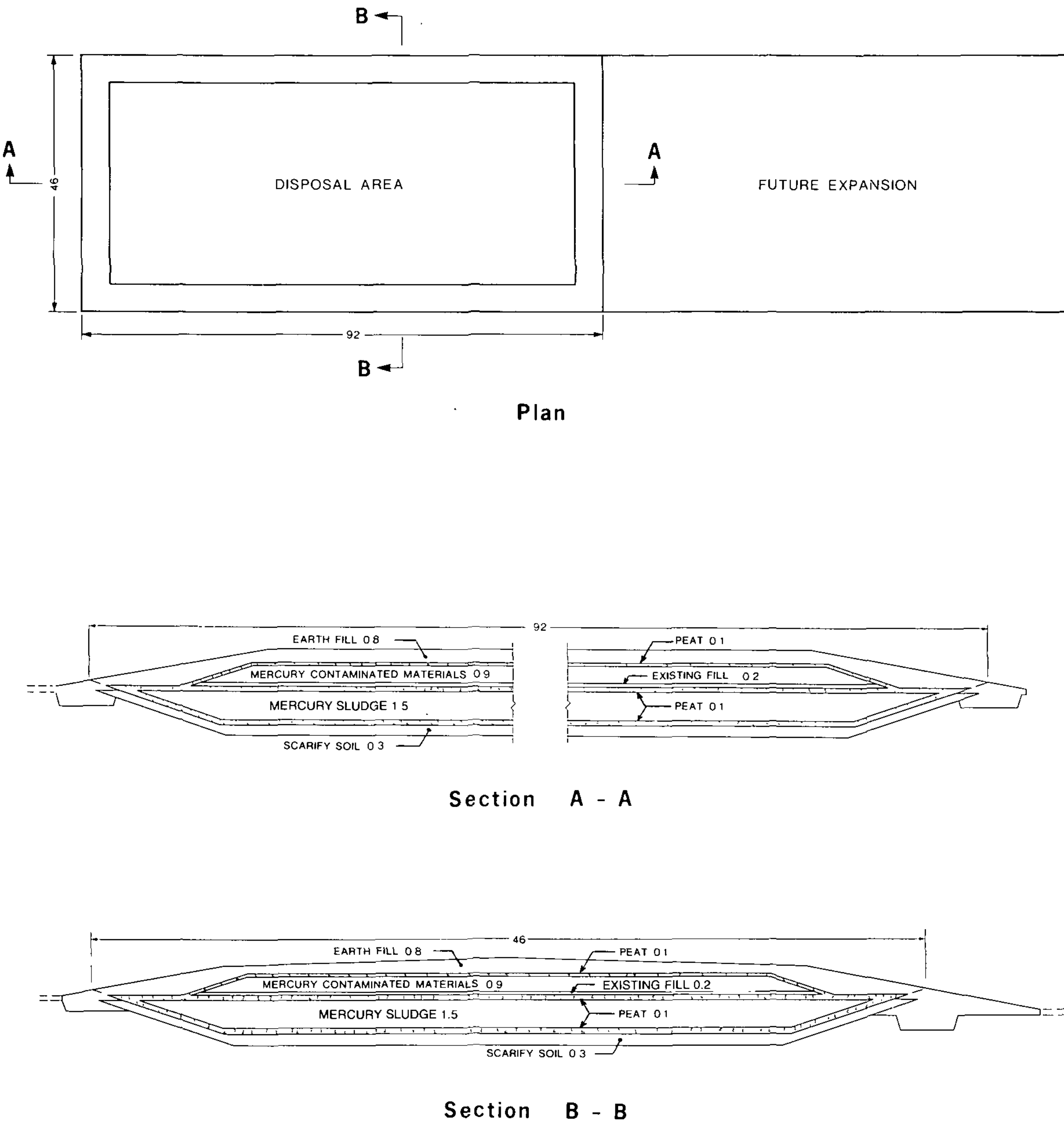
3) The brine header, cells, decomposers, inlet boxes and seals, end boxes and drain header, soft water tank, soft water headers and piping, mercury pumps and motors, chlorine gas header up to the coolers, hydrogen header, hydrogen cooler and piping, brine outlet header, hydrogen vent stack, caustic receiving tanks, caustic filter and piping, condensate lines, mercury pots, end box vent piping and coolers, anode adjusting stands, cell room floor plus some soil from under the cell room area, miscellaneous piping and valves, etc. were placed in the pit followed by sand such that all voids were filled with sand.

4) Fifteen centimetres of loose depth peat moss was added to the entire area, followed by 0.6-0.9 m of earth fill and 10 cm of organic topsoil. The area was then seeded with a hardy grass.

5) A four-strand perimeter fence was placed around the entire area.

Leachate Monitoring

A number of both shallow and deep monitoring wells were placed around the perimeter and under the disposal pit as shown in Figure A.2.



NOTE ALL MEASUREMENTS ARE IN METRES

FIGURE A.1 DISPOSAL OF MERCURY-CONTAMINATED MATERIALS, PRINCE ALBERT PULP CO. LTD., SASKATOON CHEMICAL DIVISION

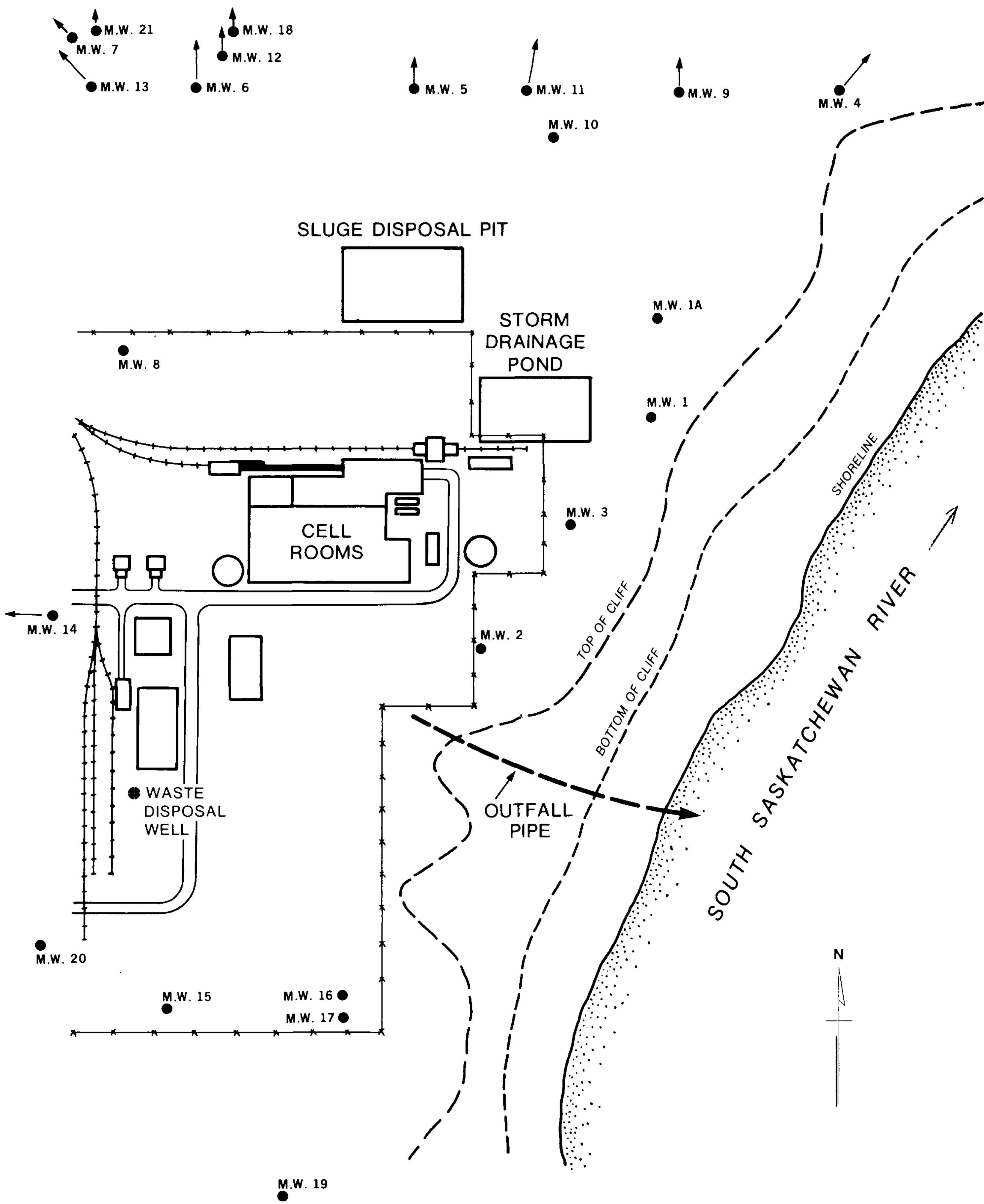


FIGURE A.2 GROUNDWATER SAMPLING LOCATIONS, SASKATOON CHEMICALS

APPENDIX B DISPOSAL SITE AND PROCEDURES - DOMTAR INC.

In 1970, when the severity of the mercury problem unfolded, Domtar ceased discharging mercury-contaminated brine treatment solids into the sewer system (Figure B.1) and directed these solids to a temporary impoundment lagoon. In 1971 a cement pit was built and the mercury-contaminated solids were sent there. The solids were filtered, the filtrate being recycled while the relatively dry filter cake was buried in a disposal area.

The sludge disposal area is located in an old abandoned sand/gravel pit on company property. An area approximately 100 m by 130 m was enclosed by a perimeter dyke of sand and gravel (see Figure B.2), which extended approximately 2.5 m above the surrounding ground level. The surface of the sludge in the pit is about 0.75 m below the crest of the perimeter dyke.

Between 1971 and 1977 brine treatment solids, saturator solids, water treatment solids, waste anodes, caustic filter solids and cell room muds were buried in this area. Lime was spread on the ground and the sludge and solid materials were lplaced on the lime blanket. This lime blanket was added to keep the sludges at an alkaline pH.

In 1977 a decision was made to close this sludge burial area. The abandonment procedures are noted below.

1) The surface of the material covering the sludge in the burial site was levelled and the top of the existing dykes were removed to the level of the top surface of the pit as shown in Figure B.2.

2) Ten centimetres of sand were placed on top of the levelled sludge pile and dykes followed by one metric tonne of elemental sulphur. The surface was then raked to thoroughly mix the sulphur with the sand.

3) Clay was then placed on top of the sand/sulphur layer to a minimum thickness of 60 cm and the surface was sloped from the centre to achieve a cross slope of about 1 percent. The clay was placed and compacted in layers not exceeding 30 cm in thickness. A compaction of 95 percent standard Proctor was used. The clay used for the impervious layer was local brownish-grey clay free from top-soil and organics.

4) The surface of the clay is protected by a 30-cm layer of sand and gravel.

5) A 7-cm layer of topsoil with seed and mulch treatment was added on top of the sand and gravel layer.

6) Three test wells, as indicated on Figure B.3, were installed near the south end of the sludge burial area. The groundwater flow is from north to south. Periodical samples of groundwater are taken from the wells for analysis to determine whether mercury is seeping into the groundwater.

In 1977 a new sludge disposal area about 400 m east of the plant was constructed in a clay deposit. Details of construction of this sludge pit and liquid compartment are shown in Figure B.3. A Hypalon membrane liner was installed in both the sludge pit and liquid compartment. All mercury-contaminated solids were sulphided to stabilize the mercury before being deposited in the sludge pit. When the plant has been completely decontaminated and liquid effluent no longer requires treatment for mercury

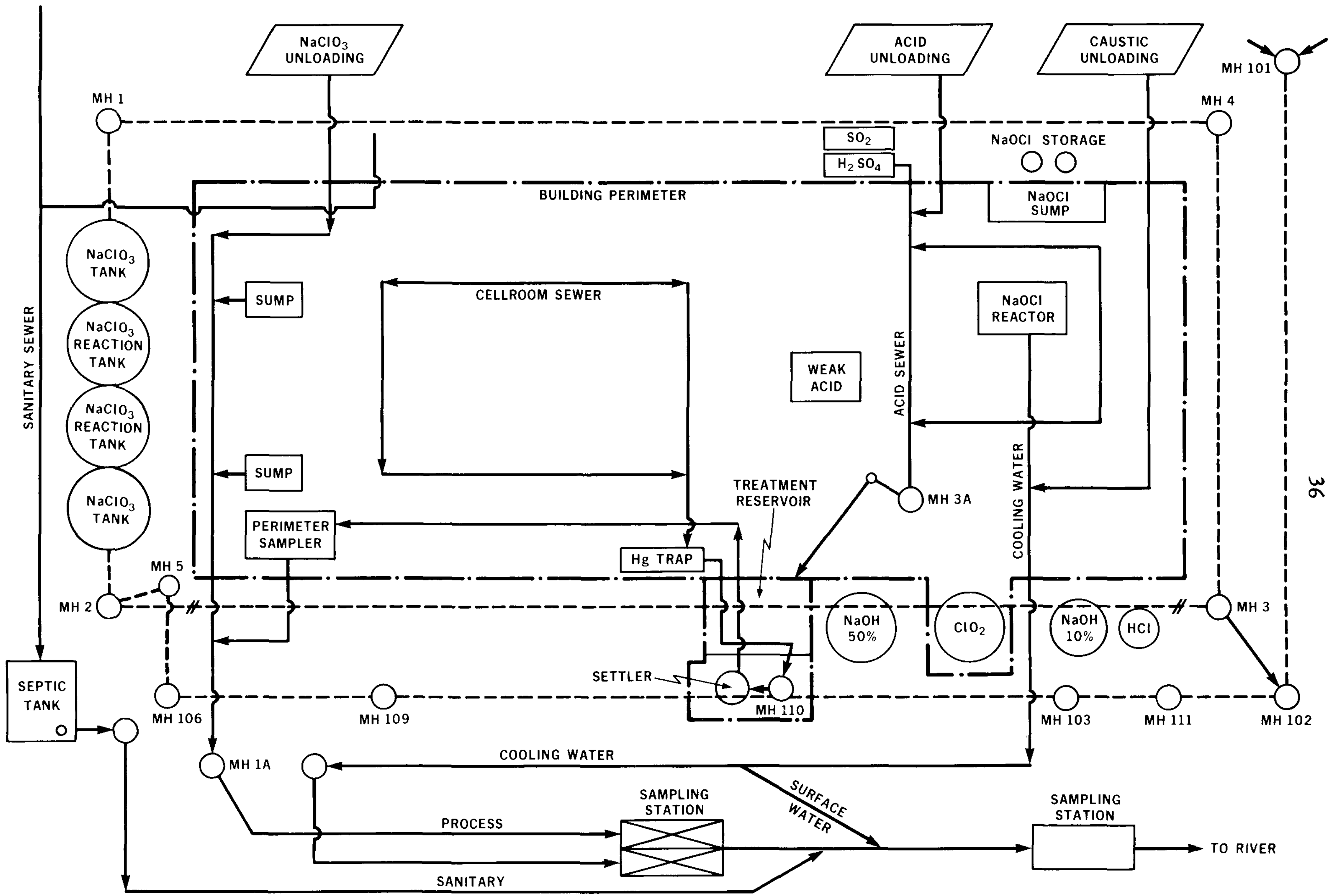


FIGURE B.1 SEWER SYSTEM - DOMTAR CHEMICAL PLANT - QUÉVILLON

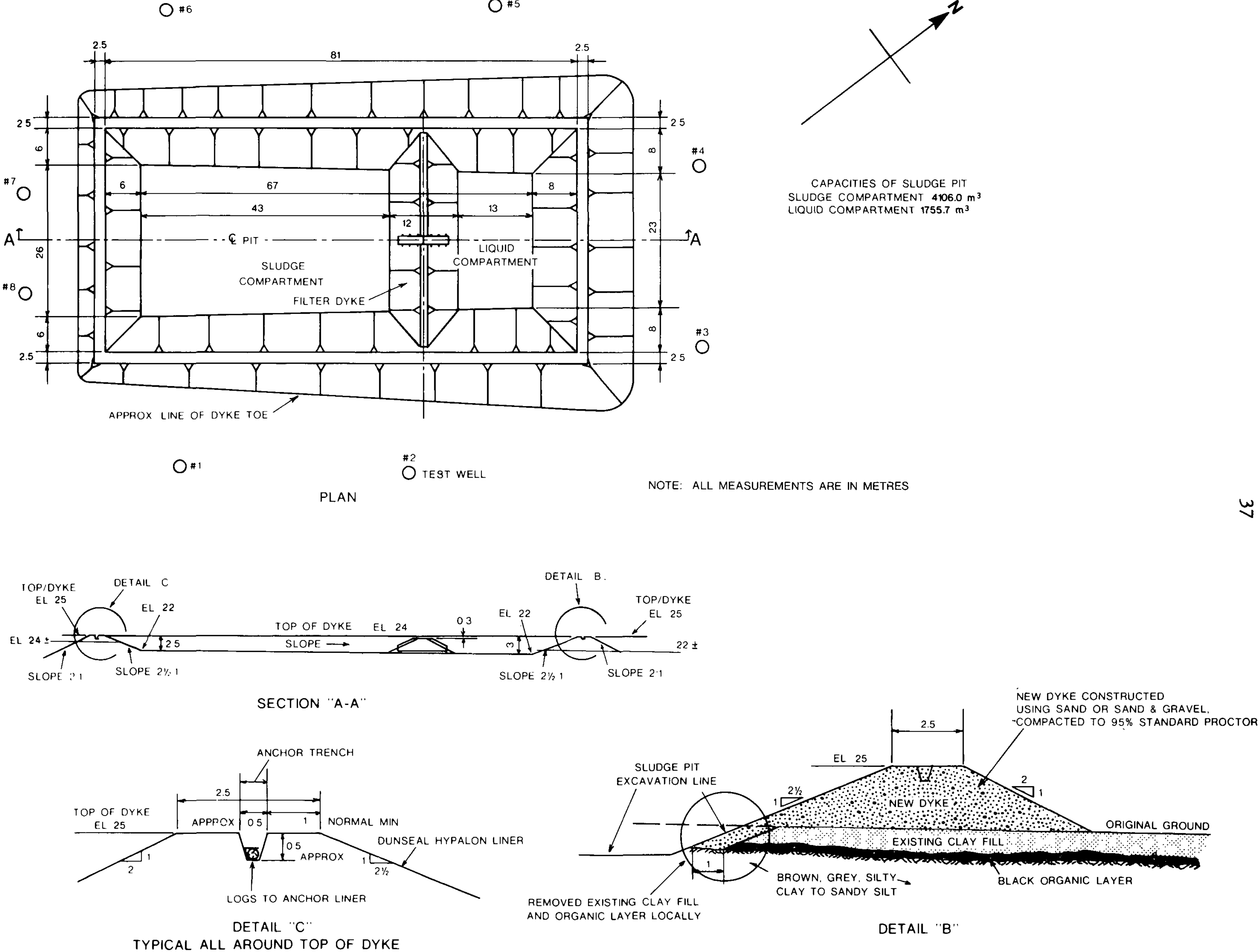
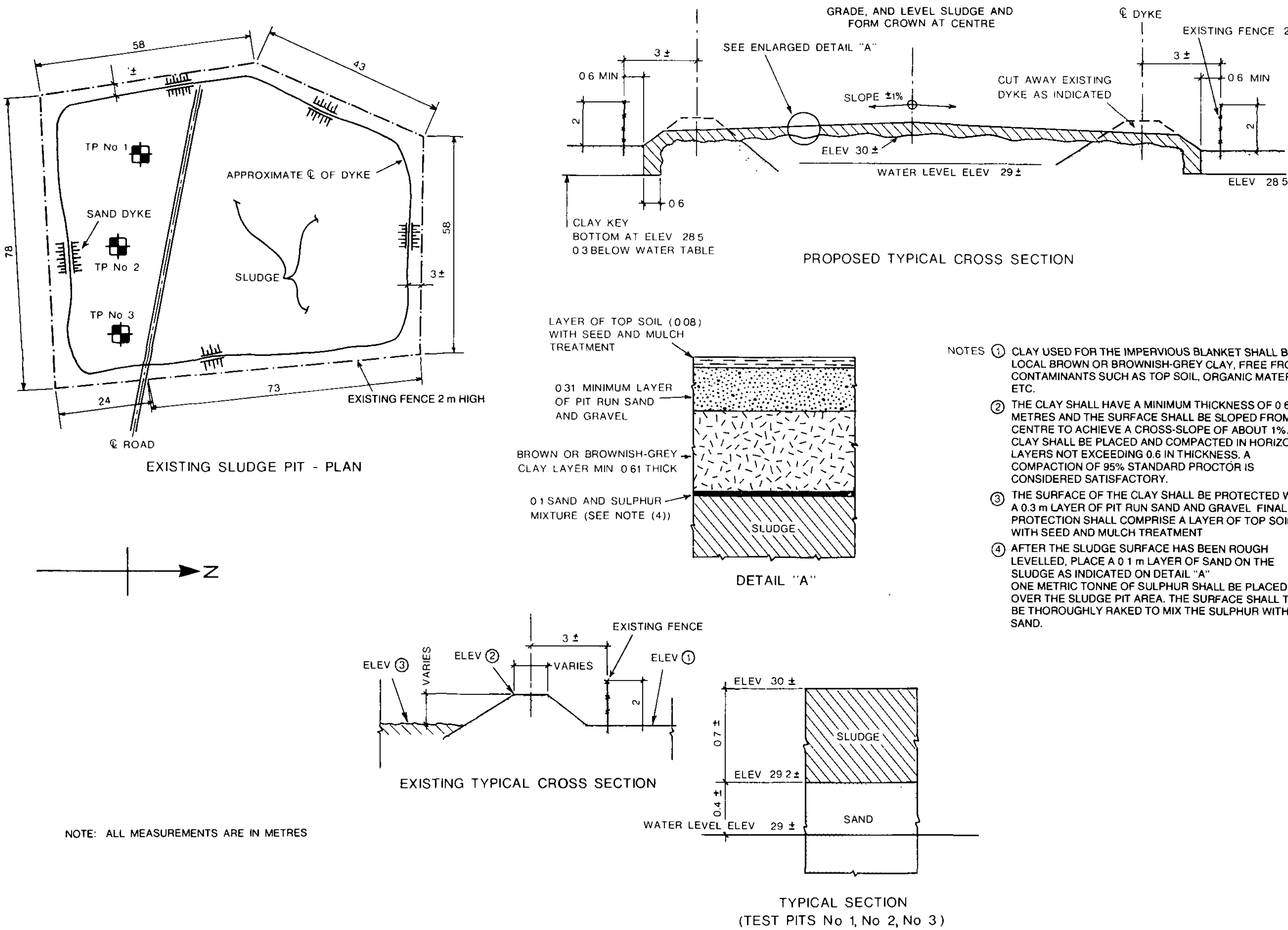


FIGURE B.2 DOMTAR'S MERCURY CONTROL MEASURES - ABANDONED SITE



NOTES
1. CLAY USED FOR THE IMPERVIOUS BLANKET SHALL BE LOCAL BROWN OR BROWNISH-GREY CLAY, FREE FROM CONTAMINANTS SUCH AS TOP SOIL, ORGANIC MATERIAL, ETC.
2. THE CLAY SHALL HAVE A MINIMUM THICKNESS OF 0 6 METRES AND THE SURFACE SHALL BE SLOPED FROM THE CENTRE TO ACHIEVE A CROSS-SLOPE OF ABOUT 1%. THE CLAY SHALL BE PLACED AND COMPACTED IN HORIZONTAL LAYERS NOT EXCEEDING 0.6 IN THICKNESS. A COMPACTION OF 95% STANDARD PROCTOR IS CONSIDERED SATISFACTORY.
3. THE SURFACE OF THE CLAY SHALL BE PROTECTED WITH A 0.3 m LAYER OF PIT RUN SAND AND GRAVEL FINAL PROTECTION SHALL COMPRISE A LAYER OF TOP SOIL WITH SEED AND MULCH TREATMENT
4. AFTER THE SLUDGE SURFACE HAS BEEN ROUGH LEVELLED, PLACE A 0 1 m LAYER OF SAND ON THE SLUDGE AS INDICATED ON DETAIL "A"
ONE METRIC TONNE OF SULPHUR SHALL BE PLACED OVER THE SLUDGE PIT AREA. THE SURFACE SHALL THEN BE THOROUGHLY RAKED TO MIX THE SULPHUR WITH THE SAND.

FIGURE B.3 DOMTAR'S MERCURY CONTROL MEASURES - EXISTING SITE removal, the area will be capped with an impermeable layer similar to that shown in Figure B.2.

The test wells surrounding the disposal area will be sampled and analyzed for mercury on a regular basis.

APPENDIX C DISPOSAL SITE AND PROCEDURES - ALUMINUM COMPANY OF CANADA LIMITED

The waste disposal area comprises two old red mud ponds formed in 1940-50 to dispose of residue resulting from the production of alumina from bauxite (see Figure C.1). The ponds contain over one million tonnes of red mud extending over an area of 14 hectares. About 85 percent of the red mud deposited in this area will pass a 325 mesh screen. When the mud was deposited in the ponds the coarser particles were deposited nearest the dykes, which were made out of clay, gravel and gypsum. The fine particles settled in the centre of the pond which is still in a semi-fluid state. The bottom of the pond is clay and rock.

Much of the sulphide-treated mercury deposited in these ponds between 1971 and 1976 was discharged near the inside dyke (the dyke between ponds 2 and 5); however, the sulphide-treated sludges and equipment from the dismantled plant were buried near the centre of the ponds.

As previously noted, studies were carried out to determine the absorption properties of mercury with red mud. The Company's and Couplan's studies indicated that the red mud has certain absorption and complexing properties. For these reasons the company believes that the mercury in the ponds is well stabilized.

Burial Procedure

After being dismantled, the equipment along with barrels of sludge was loaded onto trucks. These trucks were met at the plant gate by the local police. The police escorted the truck to the burial site and remained until all the equipment was embedded in the pond. This procedure was followed for all truck loads.

At the ponds a crane with a bucket and ball excavated holes about 13 m long, 7 m wide by 5 m deep. The equipment, if need be, was broken and smashed with the ball and then lowered into the hole. Any small pieces were pushed into the hole by a loader. At the end of the day another hole was excavated using the red mud removed to cover the buried material with a layer at least 1 m thick.

After all the contaminated material was embedded in the ponds the total surface was gradually covered with one to three metres of coarse sand obtained by cyclone separation of the dredged red mud from neighboring pond 5. The surface was then levelled, clay and topsoil are being added and graded as shown in Figure C.2. Finally the area will be seeded with grass (1983-84). Drainage from the surface of the ponds is directed through stream B.

As a result of geotechnical studies by Geocon Ltée., a weakness in the north dyke of pond No. 2 was detected. This dyke was reinforced during 1982.

Twenty monitoring wells installed by Geocon to study losses of mercury via groundwater flows from ponds 2 and 3A are kept in good condition and are periodically sampled to detect any migration of mercury. Mercury in the groundwater from these wells averages around 0.3 micrograms per litre.

Samples of surface runoff and seepages are also sampled on a regular basis. Mercury concentrations in this runoff/seepage water averaged 1.4 µg/L for May, 5.0 µg/L for June, 2.4 µg/L for July, 6.4 µg/L for August, 3.4 µg/L for September and 0.8 µg/L for October 1981 for a total loss varying from 2 to 4 g per day. After the ponds are covered with sand, impermeable clay and topsoil, mercury evaporation from the pond surface should be reduced by a factor of 20.

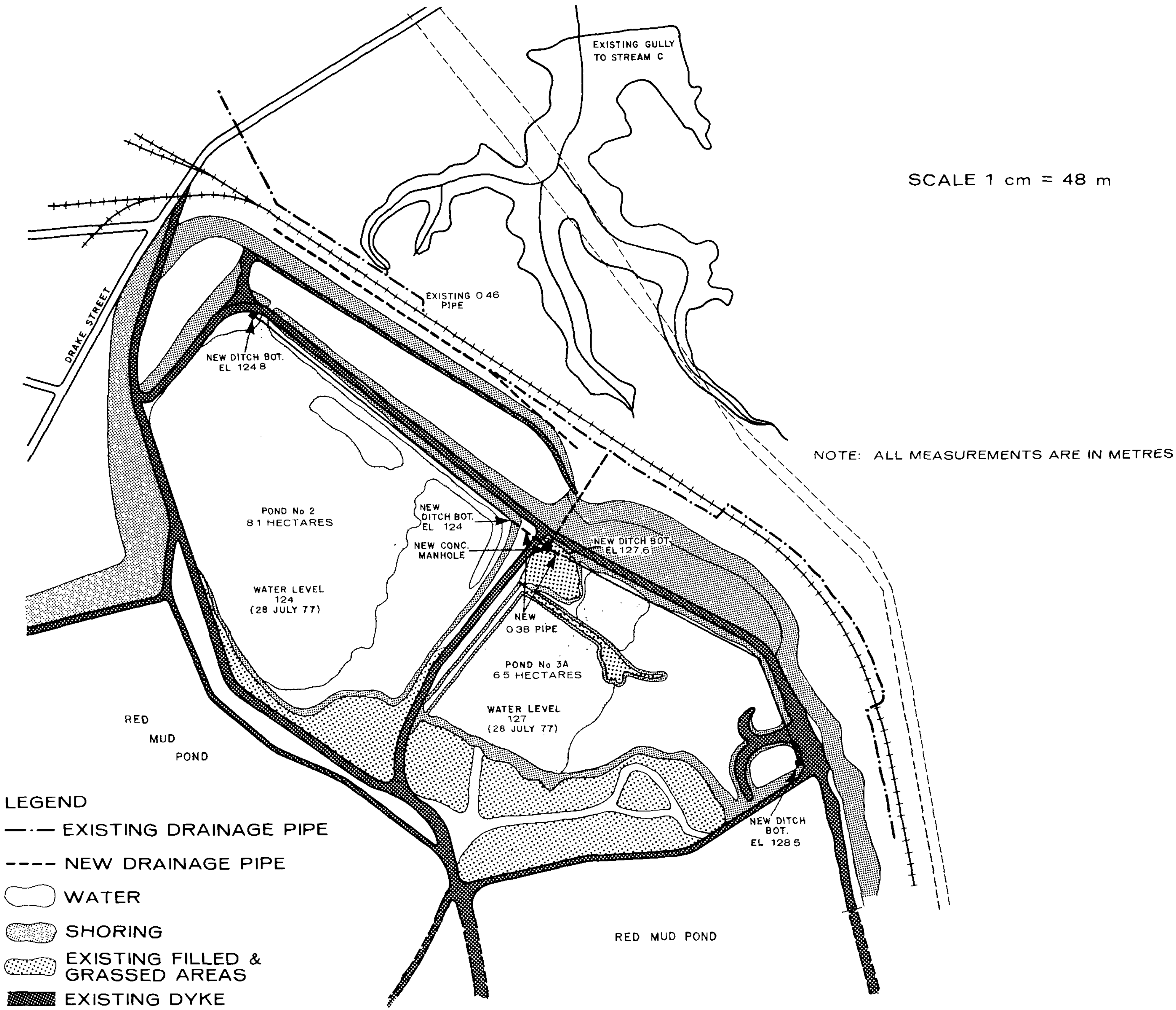


FIGURE C.1 RED MUD PONDS No. 2 AND 3A. ENVIRONMENTAL RESTORATION SEALING OF PONDS - PLAN VIEW, ALCAN LTD.

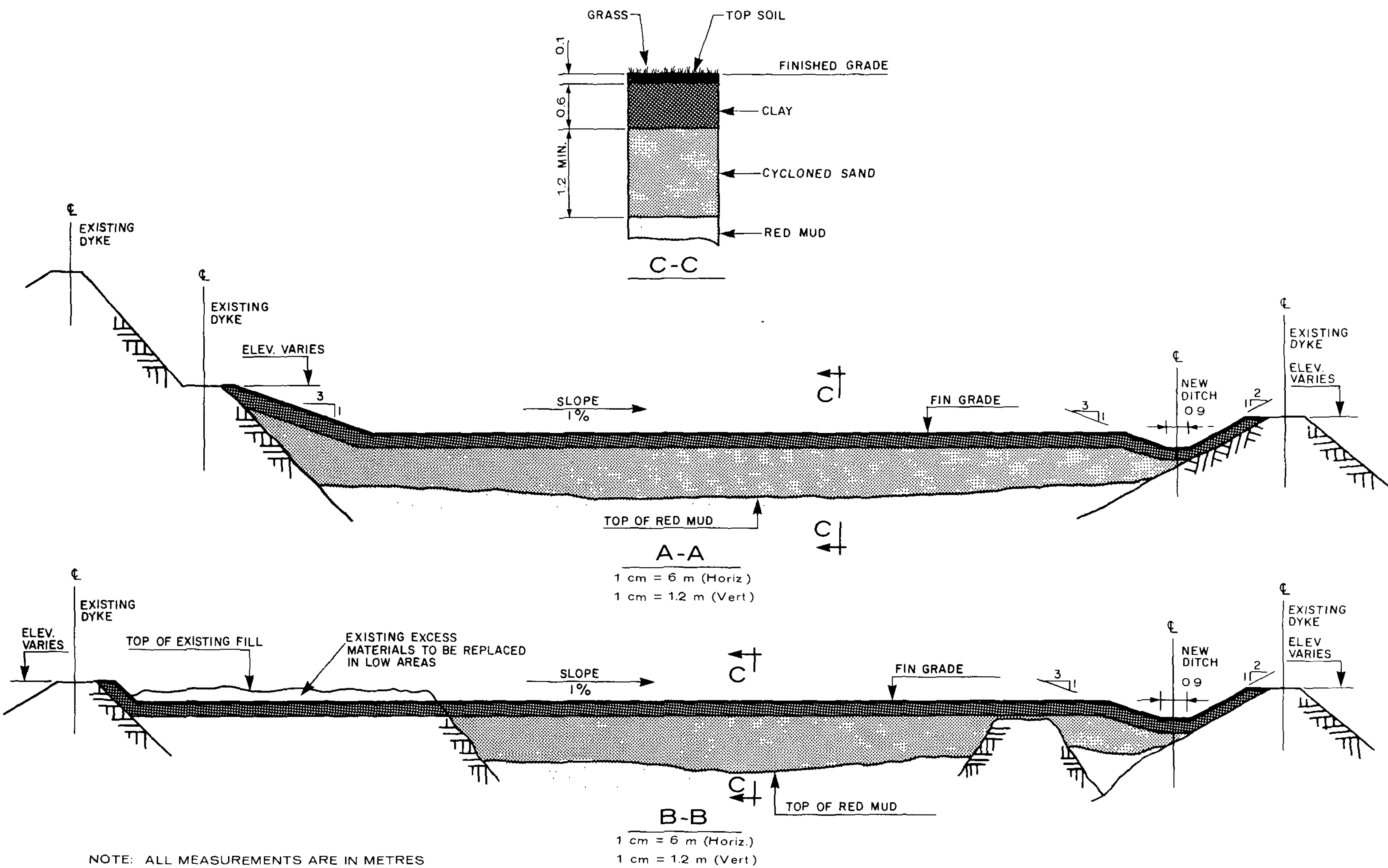


FIGURE C.2 RED MUD PONDS No. 2 AND 3A. ENVIRONMENTAL RESTORATION SEALING OF PONDS - ELEVATION VIEW, ALCAN LTD.

APPENDIX D DISPOSAL SITE AND PROCEDURES - GREAT LAKES FOREST PRODUCTS LIMITED

In 1970, when Dryden Chemicals Ltd. (the owners at that time) were instructed to reduce mercury losses to the environment, a suitable location for the disposal of mercury-contaminated material was needed. A suitable site was chosen where the earth formation has a relatively low permeability and high sorption capacity, and the water table is sufficiently below the bottom of the pits to allow some interaction between the sediments and any seepage that may occur. This site is in the township of Van Horne, District of Kenora and is on company property, which facilitates monitoring and ensures security.

The pits were excavated as shown in Figure D.2. A 5-mil polyethylene liner was installed, followed by the sludge. A polyethylene lining was then placed on top of the sludge, followed by a layer of compacted clay. If the mercury-contaminated material was placed in barrels or bags no polyethylene lining was placed in the pits; however, a 2-cm UNX plastic drain tubing was installed under each pit for monitoring purposes. Between January 1971 to June 1975 about 2 720 m^3 of material were buried in holes 1, 1A, 2, 2A, 2B and 3 as noted in Table D.1.

If sludge was being buried, it was stabilized by mixing it with cement and sand. One hundred and twenty kilograms of portland cement plus 235 kilograms of sand for each cubic metre of mixer capacity were first placed in a mixer. The mixer was then filled with sludge and the batch was mixed in transit and dumped into the plastic-lined pit at the site. If barrels were used, the cement, sand and sludge were mixed in the barrel and allowed to harden overnight before burial.

Prior to October/November, 1975, when the mercury cell plant was being dismantled and decontaminated, a pit 21 m x 6 m x 3.7 m was excavated. A plastic drain pipe was installed in the bottom followed by 30 cm of sand plus 20 cm of cement. Into this pit was placed all mercury cells, horizontal and vertical decomposers, vacuum degasifier, hydrogen cooler, scrubber, packing and header, mercury motors, caustic receiving tanks, cell lift frame, catwalk frames, caustic piping, other miscellaneous piping, etc. A total of 216 m^3 of concrete was then poured over the equipment (a 30 cm cap) followed by a plastic layer and a capping of compacted clay.

All other equipment from the plant, e.g., drums of sludge, mercury pumps, caustic filter, hydrogen vent stack, cell room floor, drying towers, water and gas headers, brine inlet and outlet headers, end boxes and seals, vent piping, weak and strong caustic headers, hydrogen piping, hydrogen coolers, decomposer covers, hydrogen scrubber, vacuum pot, mercury catch pots, miscellaneous pipes, etc., were placed in a 30 m x 6.7 m x 2.7 m pit which was plastic lined. A cement cap was poured over the equipment followed by a plastic layer and a capping of compacted clay. The total volume of material deposited in pits 3A and 4 was 1 000 m^3.

Subsequent to the plant closure, about 535 m^3 of sludge from the clarifier, river bottom, saturator dregs plus general plant clean-up along with 57 drums of sludge and a steel tank have been buried in pits 4A, 5, 5A, 6, 6A, 7 and 8. Pit 5A which contains clarifier and river bottom sludge was completely encased in a cement dome. Plastic liners were utilized in the other pits.

In 1981 all pits were covered over with clay and levelled. The location of all pits and of the six monitoring wells which were strategically located around the burial site, are shown in Figure D.1.

TABLE D.1 RECORD OF SLUDGE BURIAL AT DRYDEN

Cell No.	Date	Volume m^3	Elevations (m) Bottom of Sludge West	East	Top of Sludge West	East	Top of Fill West	East	Remarks
1	Jan. Apr. 71	283	370.03	369.72	371.40	371.39	373.38	373.29	Sludge mixed with cement and sand.
1A	Jul Aug. Nov. 71	446	369.42	369.11	371.25	371.24	373.01	372.72	67 barrels of sludge - 14 m anodes - 159 kg cement & 318 kg sand added per m^3 of sludge (this hardened overnight).
2	Oct. 72 Jan. June 73	637	369.87	369.57	372.47	372.47	373.38	373.53	170 barrels of anodes - 4 BBl of Quillon-C, 6 23-kg bags-Buson-881 - 115 m^3 of salt - 15 m^3 loose anodes.
2A	Oct. 73 Mar. May 74	553	369.87	369.72	372.74	372.58	373.78	373.44	50 barrels of anodes.
2B	Aug. Nov. 74	334	369.57	368.96	372.00	371.39	373.10	372.44	200 barrels of anodes, 107 m^3 of salt.
3	Dec. 74 June 75	467	369.87	369.72	372.47	372.46	373.33	373.50	Sludge mixed with cement and sand.
3A	Jul. 75 Mar. 76	669	369.72	369.57	372.31	372.31	373.35	373.10	250 barrels anodes, 17 truck loads scrap, 46 m^3 concrete, 69 m^3 gravel
4	Oct. 75 Nov. 75	333	Top of 20-cm slab 370.12	370.09	Top of 30-cm concrete cap 372.46	372.40	373.20	373.32	38 m^3 sand-bottom, 27 m^3 cement (20-cm slab), 20 HG cells 2 NaOH tanks, 1 degasifier system minor scrap piping 153 m^3 cement (30 cm cap).
4A	June 76 Apr. 77	430	369.57	369.57	362.46	372.44	374.00	374.00	580 m^3 of sludge with sand and concrete added.
5	Apr. 77 May 78	841	369.57	369.42	372.40	372.47	374.00	374.00	840 m^3 of sludge with sand and cement added.
5A	Sept. 77 May 78	363	369.42	369.27	372.62	372.74	374.00	374.00	(Reed Tech. Clarifier) 230 m^3 river bottom (30% bark, 40% rock, 30% sand) 133 m^3 concrete (30 cm concrete bottom, sides and cap).
6	May 78 May 79	646	369.27	369.27	372.62	372.62	374.00	374.00	646 m^3 of sludge with cement and sand added.
6A	May 80 May 81	505	369.27	369.27	372.62	372.62	374.00	374.00	430 m^3 of saturator dregs, 57 205-L drums of sludge.
7	May 79 May 80	672	369.11	369.11	372.16	372.16	374.00	374.00	107 m^3 of saturator dregs, 565 m^3 of sludge (with sand and concrete)
8	June 81 Dec. 81		368.96	368.96	372.00	374.00	372.00	374.00	7.3 m DIA x 3 m high empty steel tank filled with clay.

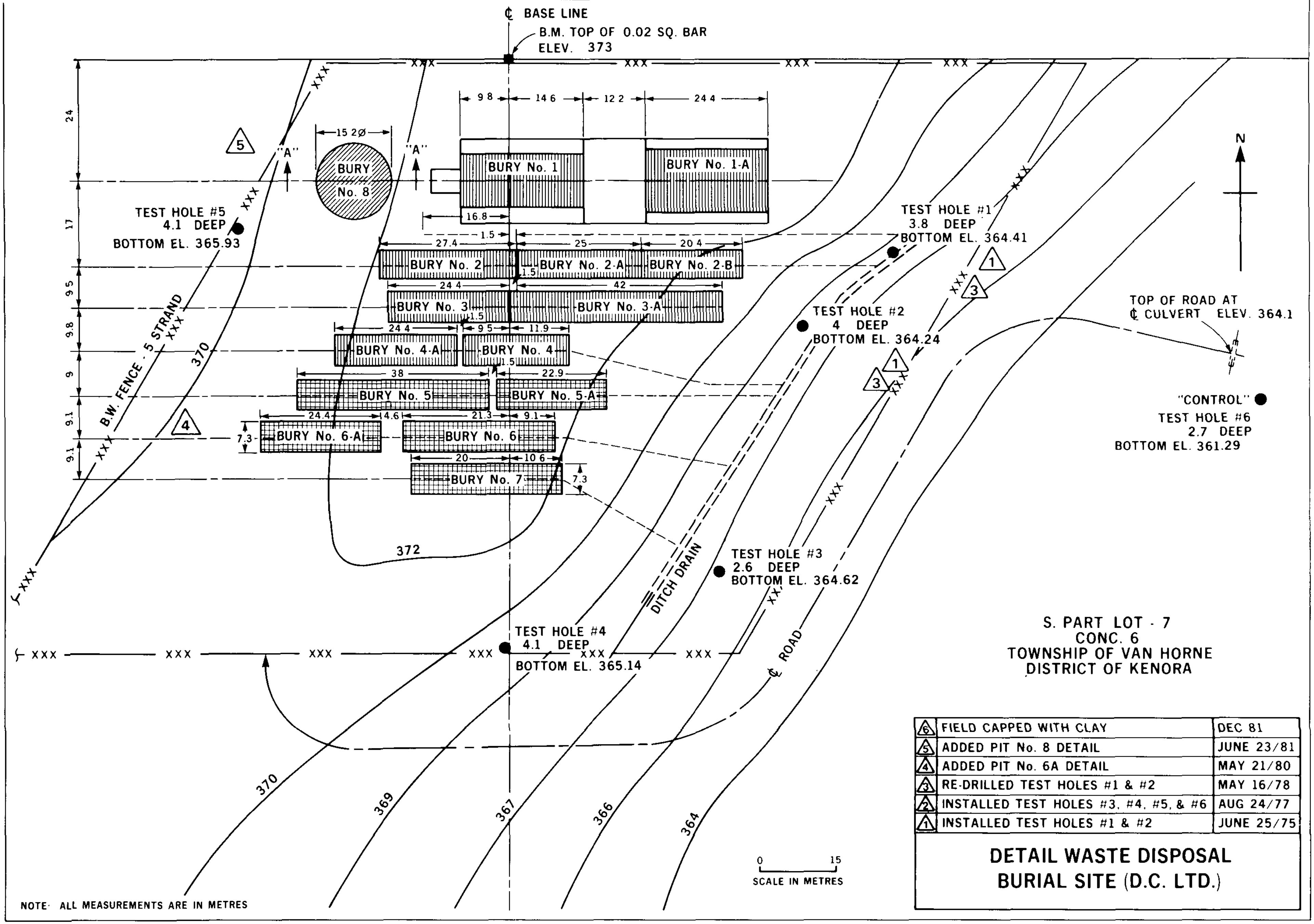


FIGURE D.1 DETAIL WASTE DISPOSAL BURIAL SITE - GREAT LAKE FOREST PRODUCTS LTD., DRYDEN

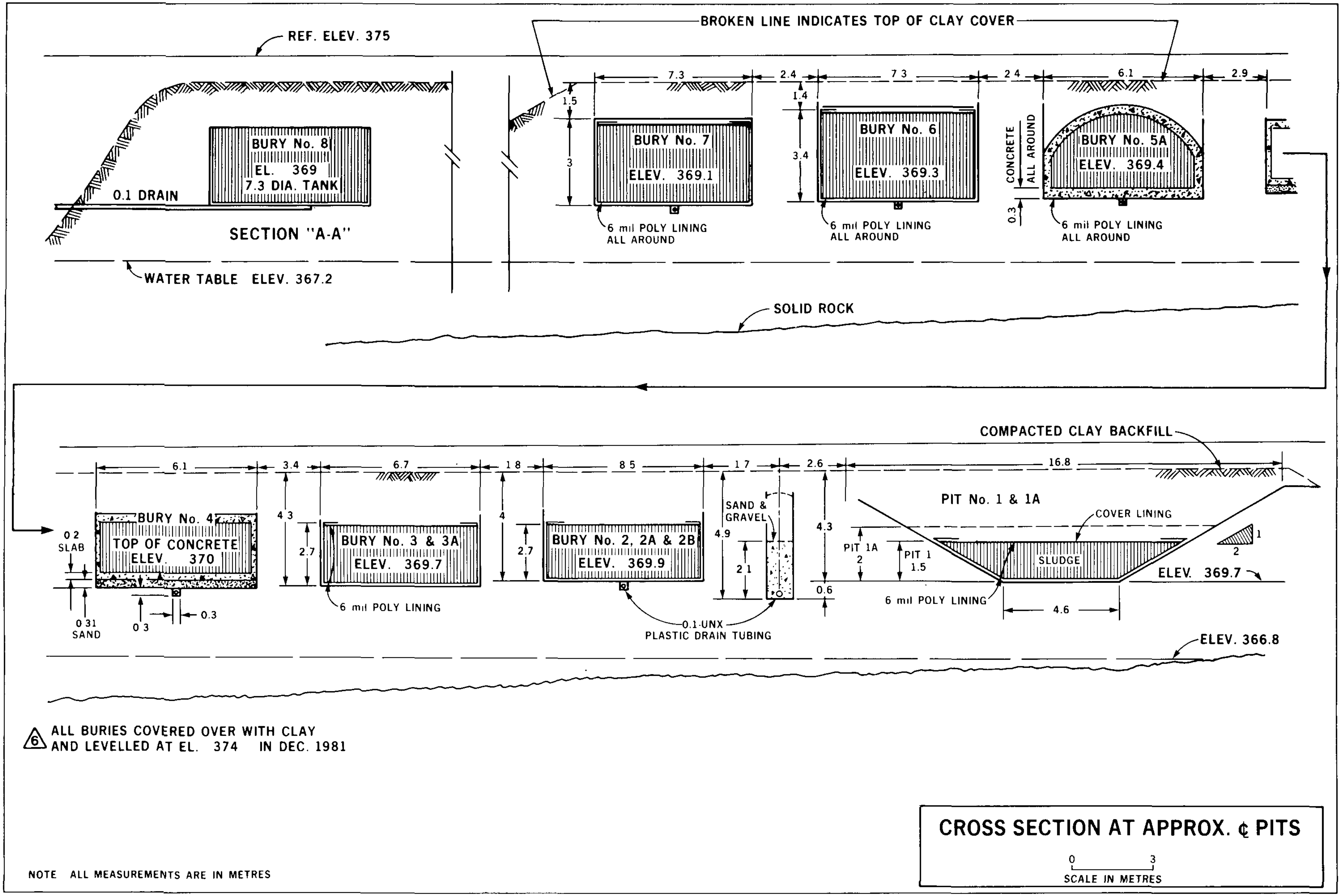


FIGURE D.2 CROSS-SECTIONAL DETAIL OF BURIAL PITS - GREAT LAKE FOREST PRODUCTS LTD., DRYDEN

APPENDIX E DISPOSAL SITE AND PROCEDURES - AMERICAN CAN OF CANADA LIMITED

Reed Ltd. Technical Group (now Great Lakes Forest Products Ltd.) was engaged as consultants by American Can of Canada Limited, based on their experience in the dismantling of the Reed Ltd. chlor-alkali plant in Dryden, Ontario. They designed the disposal pit and the procedures that were followed during the dismantling of the plant.

American Can engaged the services of Warnock-Hersey, Professional Services Ltd., to locate a suitable site for the burial of the contaminated equipment. An ideal site would have been in a clay area remote from any water supplies; however, since no clay area is accessible in this area a site 100 m by 200 m was chosen adjacent to the burial site used since 1971. This area is leased by American Can of Canada Ltd. from the Crown through the Ministry of Natural Resources for Ontario.

Three test wells were installed by the company on three sides of the vault as shown in Figure E.1. The area has a very low water table as wells No. 6 and 7 are 23 m deep and well No. 5 is 25 m deep. There is never more than about 0.7 m of water in any well even during the spring runoff and on most occasions wells No. 6 and 7 are dry. The results of mercury analysis from the test wells ranges from trace levels up to 4 μg per litre mercury.

The details of the construction of the disposal pit are shown in Figure E.2. The floors and walls of the pit are 30 cm thick reinforced concrete of 210 kgf/cm^2 strength. After all the cells, mercury pumps, end boxes, decomposers, seals, brine inlet and outlet headers, end box drain header, soft water header and piping, weak and strong caustic header, mercury catch pots, hydrogen cooling tower, hydrogen header, piping and other scrap was carefully positioned in the cement pit, extra room was available since the vault was made extra large to accommodate any unforseen equipment. This space was filled with 240 205-L drums of sludge, taken from the mercury treatment tanks, to minimize the volume of concrete needed to cement the contents of the pit together. The small void remaining was filled with 50 m^3 of sand from around the pit that was possibly contaminated with mercury. The pit area was first lined with 200 m^3 of 140-kgf/cm^2 free-flowing concrete before the sand was put in place so that the sand was isolated in a pocket of cement. Fifty cubic metres of 210-kgf/cm^2 concrete was then used to cap the pit.

The cap was slightly domed being approximately 20 cm thick in the center and 15 cm thick at the walls with a 15 cm overhang at the edge of the pit. This will cause any water that seeps onto the roof to run off and around the pit. After the concrete set, the entire area was covered with 1.5 m of soil from the pit excavation.

The pit was over-designed to withstand any possible local disturbances such as earth tremors, faulting, etc. The pit was buried below the frost line to prevent any heaving. In the event that the pit fractures, only the material along the faces of the fracture should be available for leaching of mercury by groundwater. Rapidly rising mercury levels in the groundwater will indicate that the pit is fractured and that some action must be taken to correct the situation.

From 1971 to 1977 mercury-contaminated sludges, used anodes, etc., were placed in steel drums which were buried in pits at the disposal sites. The location and structure of these pits are shown in Figure E.1.

During the burial of the plant equipment a fence with a locked gate was installed around the burial pit to prevent unauthorized personnel from entering this area. A permanent fence with a gate prevents access from the road entrance.

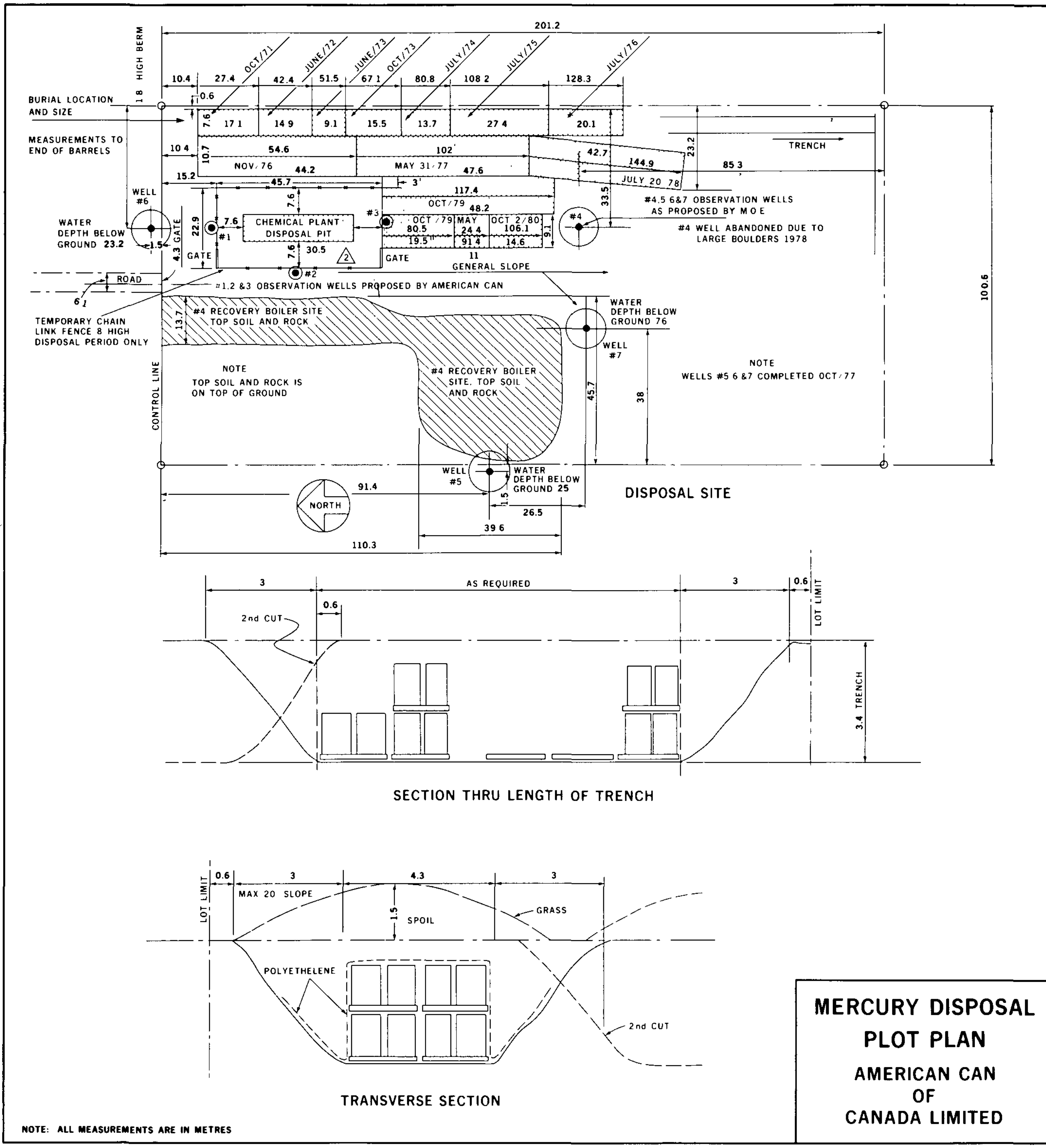


FIGURE E.1 MERCURY DISPOSAL PLOT PLAN - AMERICAN CAN OF CANADA LIMITED

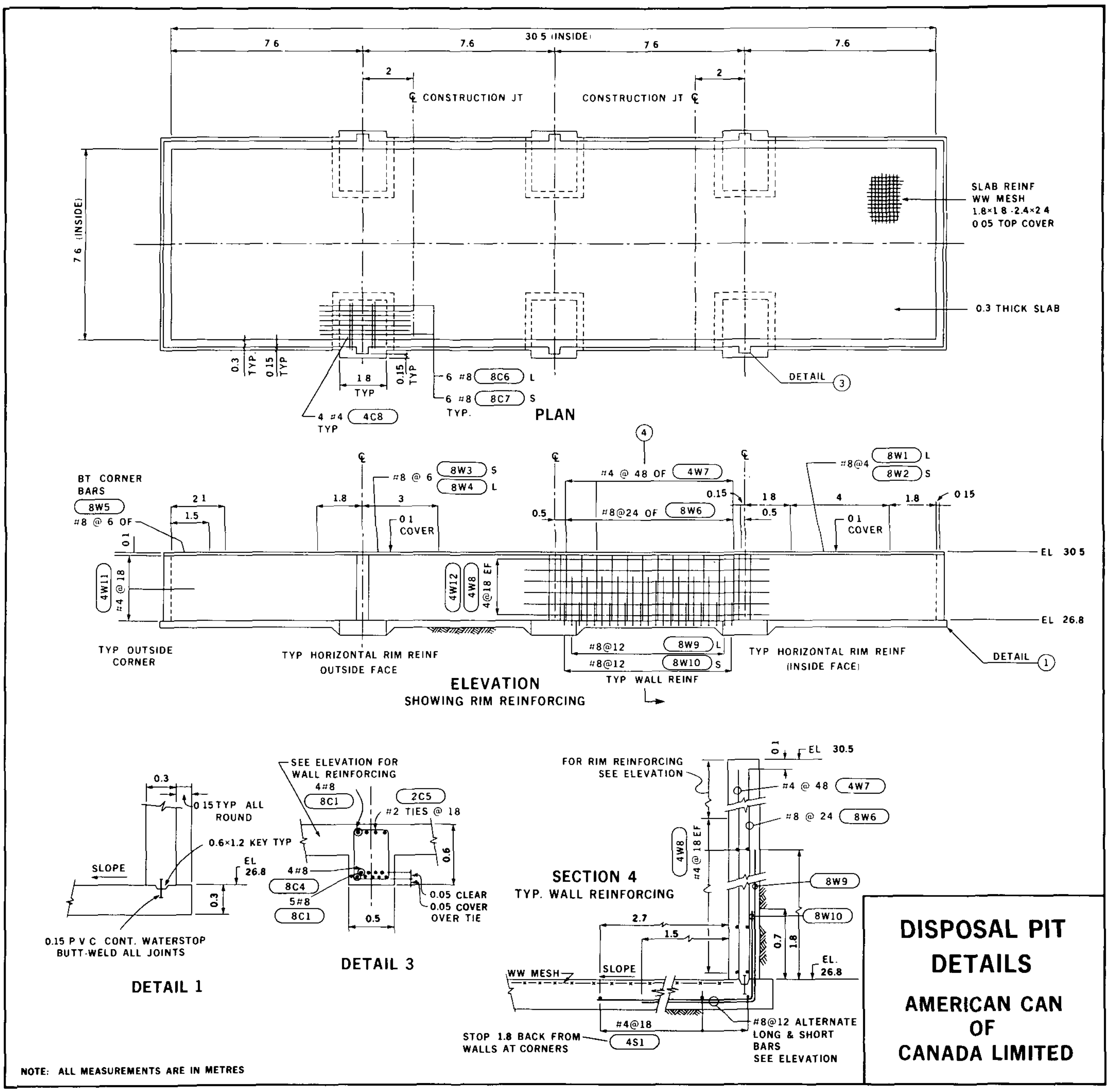


FIGURE E.2 DISPOSAL PIT DETAILS - AMERICAN CAN OF CANADA LIMITED

APPENDIX F DISPOSAL SITE AND PROCEDURES - CANADIAN INDUSTRIES LIMITED

A number of studies to determine the arrangement of the strata and the geotechnical properties of the soil in and around the St. Boniface burial site were carried out by Geocon Ltée. in 1975, 1977, 1978 and 1981 and by Laboratory Choisy Ltd. in 1981.

The burial site chosen is situated about 5 km west of the plant. It is bounded on the west by a ravine, on the south by a railway, and several hundred metres to the north by an auto route. The land is flat and covered by vegetation. The ravine is about 12 to 14 m deep with a slope varying between 18 to 30 degrees. Most of this slope is wooded.

The stratigraphy of the site consists of about 15 cm of topsoil over a bed of silty brown clay about 2 m deep followed by a firm grey silty clay. A rocky base was encountered in drillhole F3 (see Figure F.1) at a depth of 7.6 m; however, at drillhole F4 which is only 14 m away, clay was encountered up to a depth of 16 m, where the drilling was stopped.

"Resistance to shearing" tests carried out on an intact layer of brown silty clay varied from 10 250 to 13 200 kg/m^2, indicating a clay that is very stiff in consistency. The resistance to shearing tests, which terminated in the grey silty clay at a depth of 14 m, varied from 3 700 to 13 400 kg/m^2, indicating a clay with an average to very firm consistency. Several resistance to shearing tests were carried out on the altered clay found on the surface of the ravine. The values obtained varied between 440 to 2 800 kg/m^2, indicating a very soft clay subject to change (see Figures F.2 and F.3 for stratigraphy of the soil).

Since two of the burial pits were located only about 13 to 30 m from the edge of the ravine, Geocon was commissioned to study the long-term stability of the natural slope. They concluded that: 1) there was no visual evidence of slippage or movement along the slope in the past; 2) at the location which is considered representative of the slope the results indicated that under the piezometric conditions observed and considered normal, the security factor is acceptable; 3) under the condition that no external phenomena cause a change in the conditions of the soil at the top or bottom or sides of the slope, or that no artificial process causes an erosion or cut at the base of the slope, or that no discharge of clay is executed, and above all that the drainage at the top and bottom of the slope is not prevented by the spreading of clay in that area, the probability of an unstable slope is extremely unlikely; and 4) no work can cause vibrations in the proximity of the slope, and no modifications to the actual conditions can be attempted without a preliminary study.

Burial of the Sludge, Waste Material and Plant Equipment

1) Six holes up to approximately 13 m deep varying in size as shown on Figure F.1 were progressively opened.

2) Mercury-contaminated mud and equipment that had previously been buried alongside the sedimentation/treatment pond was removed and buried in hole No. 1 during the summer of 1978.

3) Approximately 18 500 m^3 of brine purification muds, containing an average mercury concentration of 210 g/kkg for a total of 6 790 kg mercury were removed from the sedimentation/treatment pond. In addition, about 15 300 m^3 of sand and silt, containing an average mercury concentration of 45 g/kkg for a total of 1 105 kg mercury were also removed from the pond. These contaminated solids were buried in holes 2 and 3 at the waste disposal site at St. Boniface.

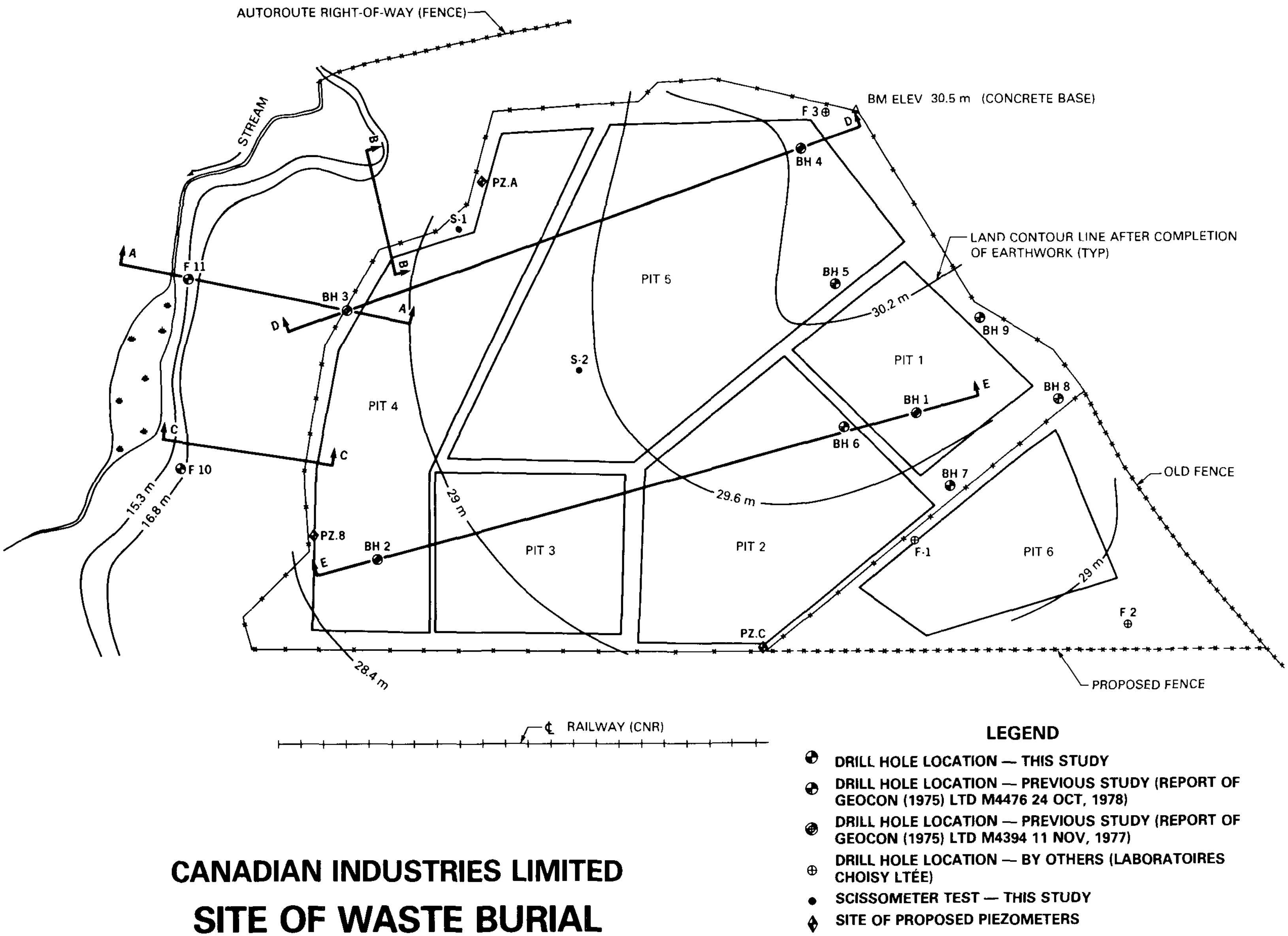


FIGURE F.1 BURIAL SITE FOR MERCURY RESIDUES - CANADIAN INDUSTRIES LIMITED

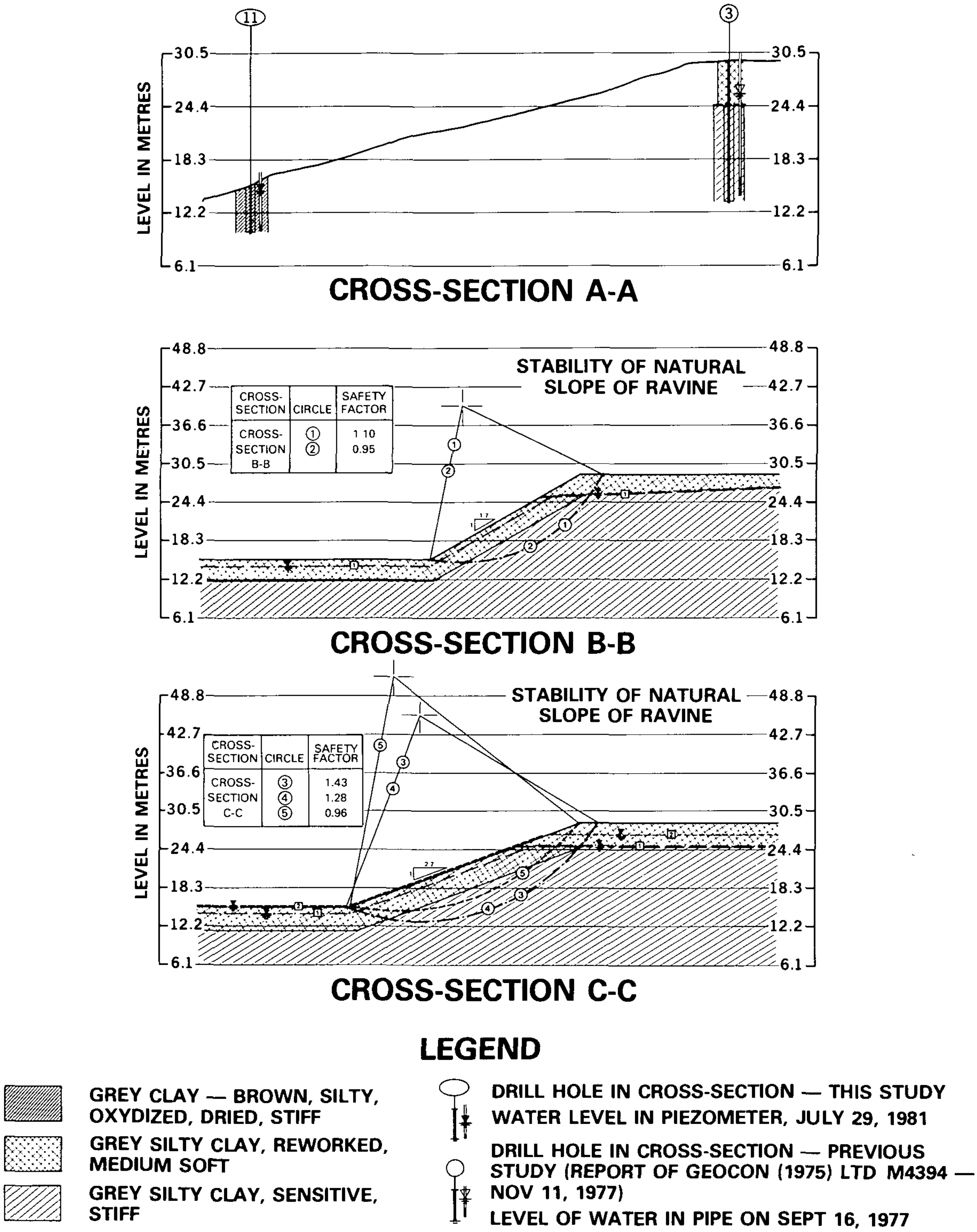


FIGURE F.2 STRATIGRAPHY OF THE SOIL AT BURIAL PITS - CANADIAN INDUSTRIES LIMITED

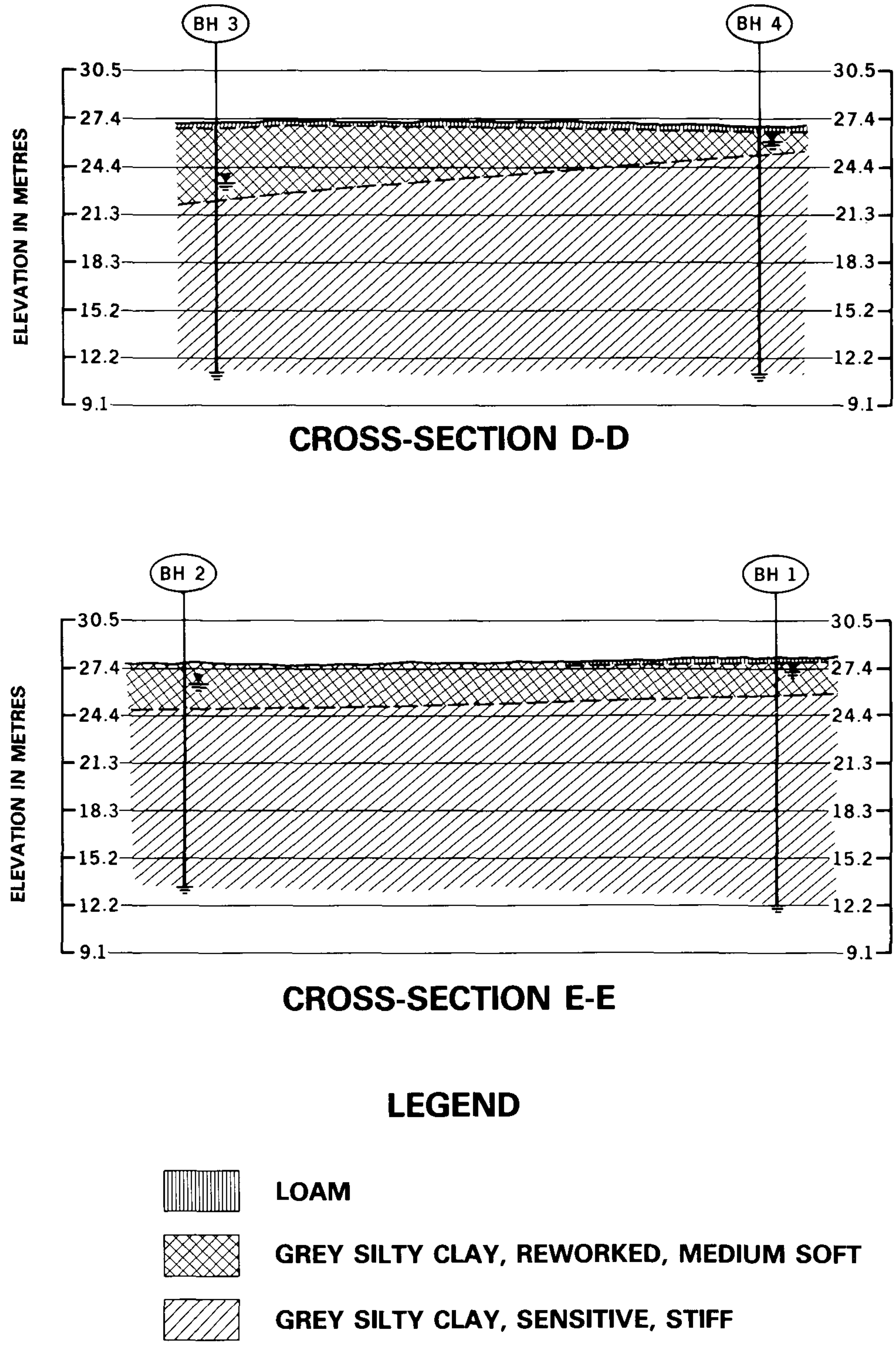


FIGURE F.2 STRATIGRAPHY OF THE SOIL AT BURIAL PITS - CANADIAN INDUSTRIES LIMITED (Cont'd)

4) Approximately 61 200 m^3 of brine treatment solids, used electrodes, sand, clay, broken cement, etc., were removed from the ravine. This material contained an average mercury concentration of 82 g/kkg for a total of 8 500 kg of mercury. This material was buried in holes 2 and 3 at the burial site.

5) All the equipment from the brine area, cell room, hydrogen section, caustic section, and chlorine section plus the buildings housing this equipment including the contaminated soil under and around these buildings was removed and buried in holes 3, 4, 5 and 6. The cells, anodes, bricks, steel, wood, cement floors and pillars, etc. contained an estimated 3 000 kg of mercury. The 30 600 m^3 of sand and clay removed from under the cell room and surrounding area contained an average of 75 g/kg mercury for a total of 3 675 kg of mercury.

6) A total of close to 142 000 m^3 of material containing around 23 000 kg of mercury were buried in the six holes.

7) After each hole was filled it was capped with 0.75 to 1 m of dense clay (removed from the holes) levelled and covered with 15-20 cm of topsoil and then seeded.

8) A record of all the material deposited in the six holes was made.

9) The site has been fenced to prevent access by unauthorized persons.

10) Monitoring wells are strategically located around the site. Samples will be taken periodically to determine if there is any migration of mercury. If there is any environmental concern, the company must take corrective measures.