Case Study Assessment – Heath Steele Tailings Area Miramichi, New Brunswick

MEND Report 9.2c

This work was done on behalf of MEND and sponsored by Environment Canada

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SNC·LAVALIN

Case Study Assessment - Heath Steele Tailings Area, Miramichi, New Brunswick

FINAL Report

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EXECUTIVE SUMMARY

The Heath Steele Mine site is located approximately 50 km northwest of the City of Miramichi, along Highway 430 in north central New Brunswick.

The tailings basin covers an area of about 215 hectares and is divided into three cells (the North, Upper and Lower Cells), all of which are hydraulically linked. The North Cell discharges through the North dam spillway into the Upper Cell, then to the Lower Cell through the internal dam spillway and finally to the environment via the main dam spillway. The Old Tailings Area is located in the northeast corner of the tailings basin. It contains oxidized tailings from the early operation of the mine (1957). This area is hydraulically connected with the Upper Cell. The old tailings deposit has been partly covered with high density sludge produced by the water treatment plant and partly by soil.

The mine and milling operations ended in 1999. During operations, tailings in the North Cell were deposited underwater, while in the Upper Cell, the deposition of tailings was sub-aerial. Providing a water cover, to form an oxygen barrier designed to prevent/reduce acid generation and metal leaching, was considered to be the preferable option for the tailings basin (Lower, Upper and North Cells). In order to meet one of the cover design criteria that calls for a water cover of no less than one meter over the tailings under normal operating conditions, tailings in the Upper and North Cell were dredged to lower elevations in 2000 and 2001. A large volume of potentially oxidized tailings of the Upper Cell was moved to the North Cell.

The water level in the Old Tailings Area was allowed to equilibrate with the water level in the Upper Cell by hydraulic connection created through a permeable sludge pond dam built on top of old tailings dam in 2001. The Closure Plan had anticipated that some AMD generation in the old tailings deposit was expected to occur in the long term and that the flushing of contaminant may affect the water cover quality of the North and/or Upper Cells.

Heath Steele Mine monitors the performance of the water cover in terms of surface water quality. It has observed a pH variation between the North and Upper Cells. The addition of lime at the internal dam is necessary to raise the pH in order to meet the final effluent requirement. Based on the water quality improvement observed downstream, the water cover had a positive impact on the environment. Only 2 years after the completion of the water cover, a reduction of the metal loadings to the environment was observed. In accordance with the Closure Plan, the tailings water cover is in the midst of a transition period in terms of water quality.

The case study for Heath Steele was completed in 2004. It was part of a series of case studies that were to be compiled and released on CD-ROM. Approval for publication was not obtained for some of the case studies, and in 2010 the MEND Steering Committee recommended posting the studies completed-to-date on the MEND web site.

As such, the data for this case study was collected up to 2003 from the Heath Steele mine site. Even though this case study is somewhat dated, it provides relevant and useful information on closure strategies for tailings, including management of an old tailings deposit.

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1.1 Site Location

The Heath Steele Mine site is located approximately 50 km northwest of the City of Miramichi, along Highway 430 in north central New Brunswick (Figure 1-1). The site is about 300 meters above sea level and vegetation communities are typical of the Acadian Forest Region.

The tailings basin is located on the west side of Highway 430, approximately 1 km south of the former mill site (Figure 1-2).

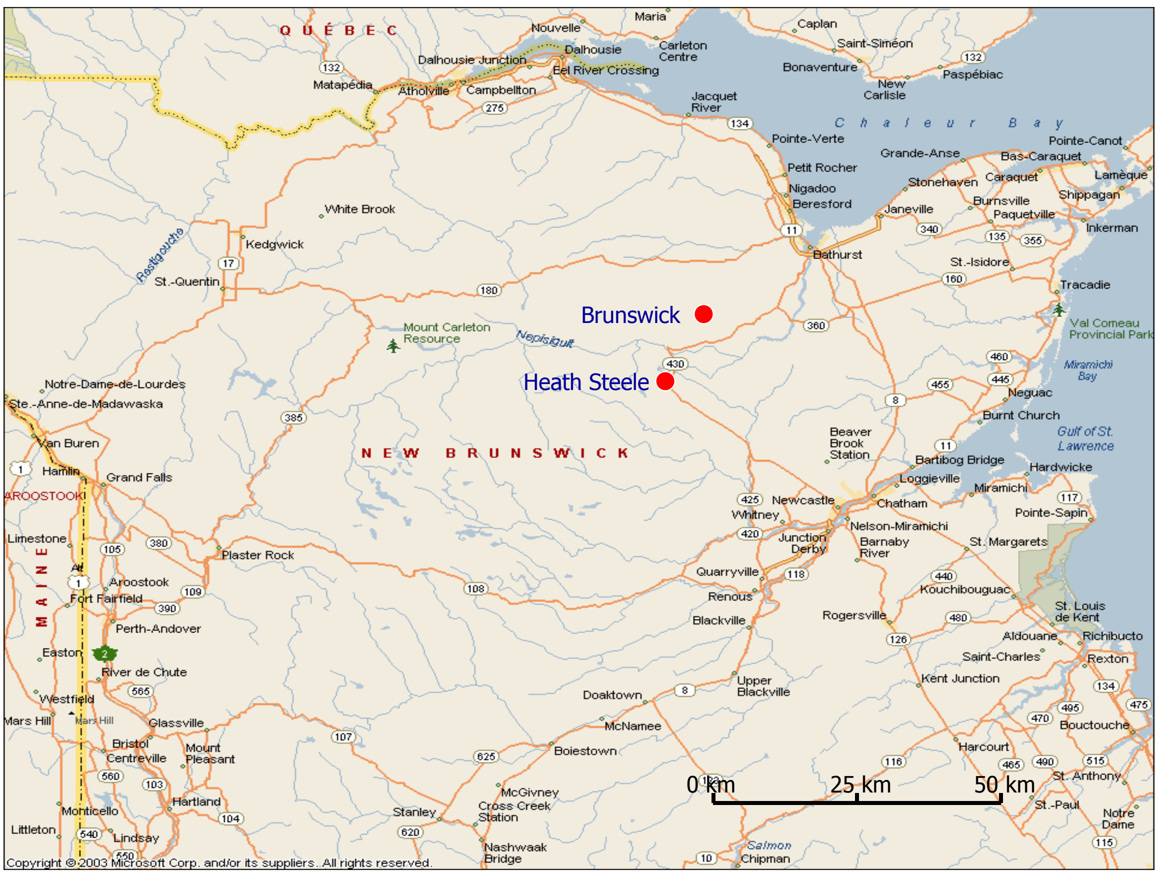


Figure 1-1 – Heath Steele Regional Setting

1.2 History

The Heath Steele Mine (HSM) property has a relatively long mining history, with mine and mill facilities first developed in 1955-1957 following the discovery of several local ore bodies containing massive metal sulphides from which zinc, lead, and copper/silver-rich concentrates were produced.

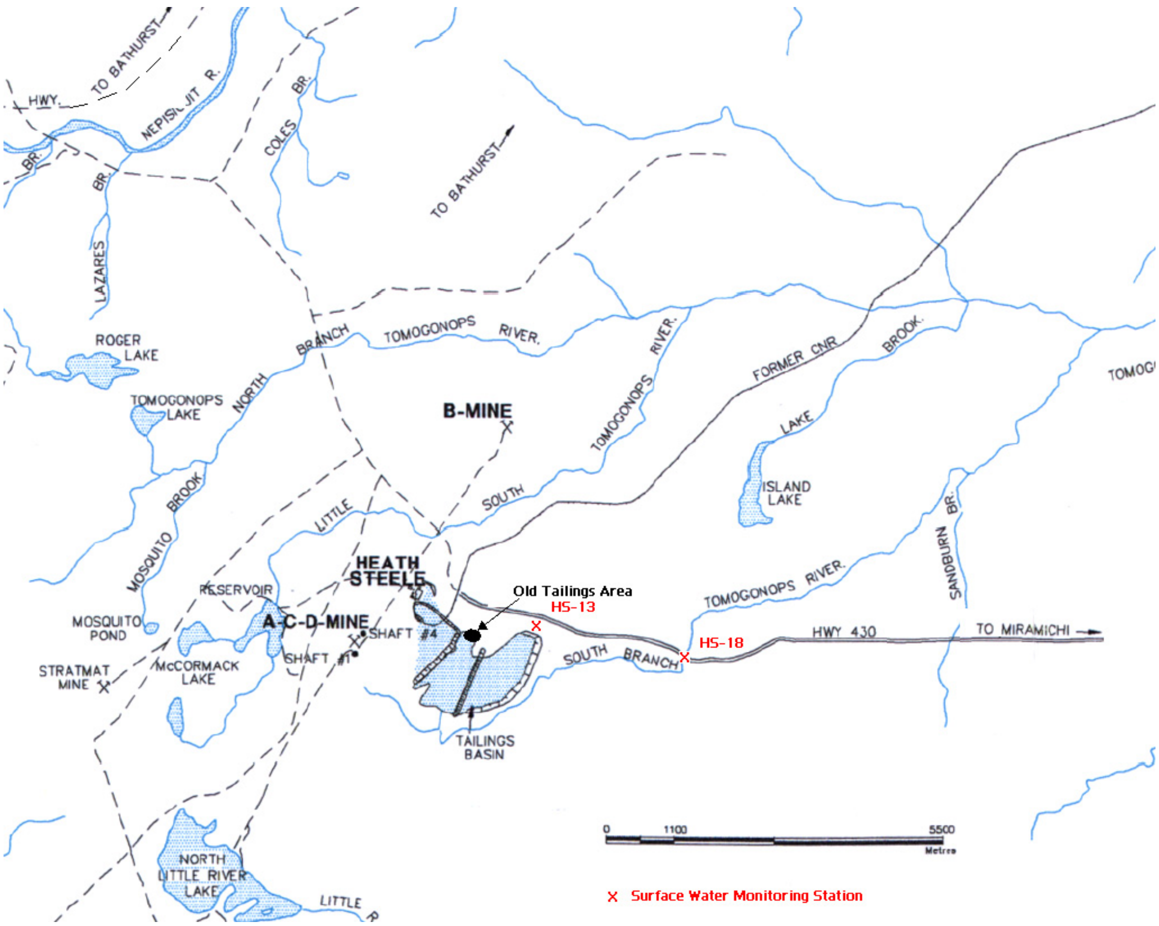


Figure 1-2 - Heath Steele General Arrangement

Mine development at the site has included both open pits and underground facilities. Mill production commenced at an initial rate of 720 tons/day in 1957. Tailings were initially deposited in the northeast area of the tailings basin (referred to as the "Old Tailings Area", Figure 1-2). At that time, a dam was constructed across a small stream to form an 11-hectare impoundment which now contains approximately 1.3 million tonnes of tailings.

After only a year of operation, the mine was shut down in 1958 because of low metal prices and the mine workings were intentionally allowed to flood. In 1961, metal prices had increased, at which time the mine was dewatered and production restarted. In 1963, the construction of the main dam was completed, and the tailings were deposited into the main tailings impoundment.

The Heath Steele Mine (HSM) production rate increased to 1,450 tons/day by August 1968 and to 2 720 tons/day by January 1970. Later that year, the No. 4 Shaft was commissioned and in June 1972, the No. 5 Shaft was sunk to the lower depths of the B zone. Production was increased, reaching a level of 3,630 tons/day and mill capacity rose to 4,000 tons/day in 1973.

In response to the observed detrimental effect of AMD discharges into the aquatic environment in the late 1960s, a program was initiated at HSM in 1968 to segregate, collect and treat the acidic drainage at the site. The control system, regarded as state-of-the-art at the time, consisted of extensive ditching to separate clean and contaminated drainages; a series of collection ponds for the contaminated water, and a system to pump the water to the new tailings pond where lime was added to control the pH level at 9.5 for the precipitation of metals. The resulting sludge settled within the tailings pond. The lime was added to the tailings in the mill and delivered to the tailings pond in that manner. The drainage system was periodically refined through the course of mine operation which gradually resulted in significant decrease of impacts on the receiving water system.

The North dam was constructed between 1975 and 1977 to contain the tailings to the north. The main dam was raised several times between 1966 and 2001.

The mill was closed in July 1983 to allow a modification for the processing of ore from the B-Pit but did not re-open until 1989 because of depressed metal prices. During that period, the mine water continued to be pumped and treated with lime in the tailings pond.

The nearby Stratmat mine was developed in 1988 as an open pit and underground operation. The HSM mill processed ore from Stratmat from 1989 to 1993. The internal dam was constructed across the tailings basin in stages between 1992 and 1996.

At HSM, both mining and milling operations were closed in July 1993 but reopened again in October 1994. From December 1996 until the final shutdown in 2000, the mill processed ore from the B mine and A-C-D mine at a combined rate of 2,700 tons/day.

1.3 Climate

The annual mean daily temperature at the site is 3.1^{o}C with the coldest mean daily temperature of –12.1^{o}C in January and the warmest mean daily temperature of 18.1^{o}C in July. The mean annual precipitation at the HSM site is 1,118 mm, of which about 68% falls as rain. The average snowfall totals approximately 350 cm per year. The average annual lake evaporation in the area is 485 mm. However, for the purpose of estimating the tailings pond water levels under dry year events, the annual evaporation rate was adjusted to 714 mm to account for an increase in evaporation that may occur under such conditions.

1.4 Hydrology

Three tributaries flow into the Tomogonops River: the North Branch Tomogonops River (NBTR), the South Branch Tomogonops River (SBTR) and the Little South Tomogonops River (LSTR) (Figure 1-2). The HSM mine and mill site are situated within the LSTR watershed, as are most of the mining facilities. A majority of the tailings basin site is located within the headwaters of the South Branch Tomogonops River (SBTR). The overall drainage pattern from the tailings basin site generally flows south and east to the SBTR. Only a small portion of the tailings basin runoff drains north from the Old Tailings Area towards Camp Brook Pond and the LSTR. The LSTR and SBTR, together with the North Branch Tomogonops River join to form the Tomogonops River, which flows into the Northwest Miramichi River approximately 10 km north of Wayerton. This system eventually flows into Miramichi Bay.

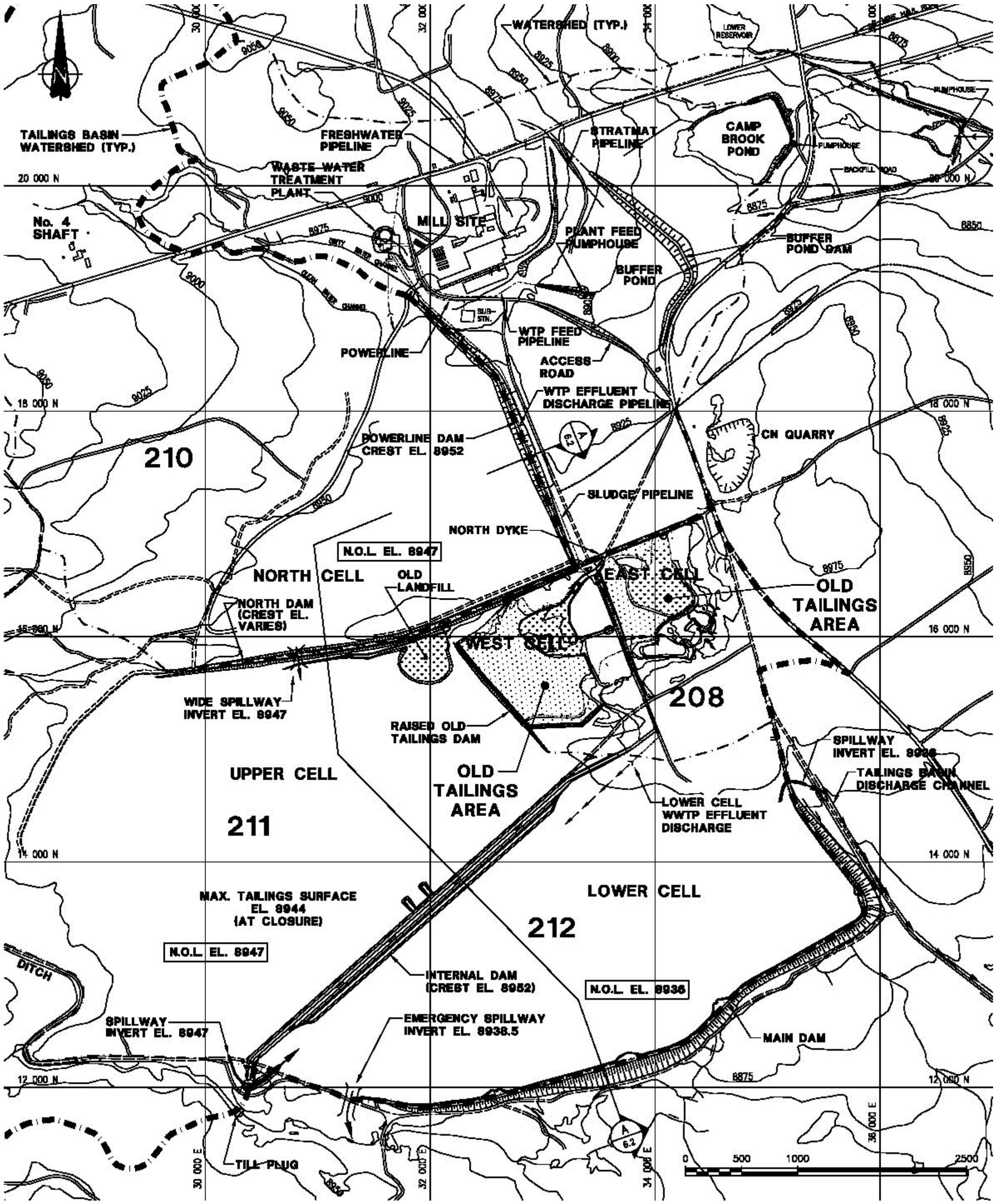


Figure 1-3 - Tailings Main Features

2. TAILINGS BASIN FEATURES

The tailings basin covers a total pond area of about 215 ha, and approximately 21.9 million metric tonnes of tailings have been deposited. Figure 2-1 shows the tailings main features. The HSM tailings basin contains four dam structures: the main dam, the internal dam, the North dam and the powerline dam, which form three cells (the North, Upper and Lower Cells). The largest of these structures is the main dam, a 2.1 km dam that confines the Lower Cell to the south and east.

The Upper and Lower Cells are separated by the internal dam constructed in 1992-96 to increase tailings storage capacity and to divide the tailings basin into the two (Upper and Lower) cells adequate for flooding of the tailings deposit upon closure. The North dam confines the Upper Cell to the north. The powerline dam is a low permeability structure constructed to increase tailing storage capacity. The North Cell is located between the powerline dam and the North dam.

High density sludge from the water treatment plant (WTP) is deposited over the "Old Tailings Area" located immediately east of the Upper Cell which contains oxidized tailings from the early days the mine was in operation. The old tailings dam was raised in order to accommodate sludge storage. Along the old tailings dam, the sludge (maximum elevation of 8945.5) is submerged (water cover elevation of 8947).

The tailings basin contains two landfills; one is located in the Old Tailings Area and the other in the Upper Cell. It is believed that both landfills contain some acid-generating waste rock. Soil and sludge cover were placed over these landfills in order to reduce infiltration by promoting runoff and evapotranspiration. During operation, a west diversion ditch was constructed to divert clean water around the tailings basin. In 1996 a till plug structure was built to re-divert the west watershed runoff into the Upper Cell to supplement the water cover. Figure 2-1 shows the watersheds (208, 209, 210, 211 and 212) reporting to the tailings basin. The potential of these watersheds was evaluated and found to be sufficient to maintain the water cover on the entire tailings during the 1:100 year low runoff event.

Downstream from the main dam (Lower Cell), there are two seepage collection facilities, which collect seepages and runoff and pump it back into the Lower Cell. When the water quality at these facilities meets the New Brunswick Department of Environment and Local Government (DOE&LG) requirements, they will be decommissioned.

3. CHARACTERIZATION STUDIES AND FIELD WORK

Many studies have been completed on aquatic environmental conditions downstream of Heath Steele since 1960. They have shown that elevated zinc and copper concentrations occurred in the Northwest Miramichi River downstream of Heath Steele in the 1960s and early 1970s, resulting in reduced salmon production and benthic community impairment. Conditions improved through the 1970s and 1980s, although conditions remained strongly impaired throughout the Tomogonops River during this period. In 1996, Beak performed an environmental assessment, which showed further improvements to water quality and biological conditions in the Tomogonops through the 1990s, including a return of Atlantic salmon to the river and dramatic recovery of benthic macroinvertabrate communities (Beak, 1997).

In the fall of 1995, a pilot scale implementation of a plant cover was initiated in the Lower Cell (St-Germain et al., 1997). The main objective of promoting a biologically supported water cover was to initiate the formation of an aquatic ecosystem. The plant cover would produce a layer of organic matter which would decompose through bacterial activity and create an oxygen barrier on top of the tailings. In addition to the covering of tailings with organic matter, the objective of this field trial was to reduce tailings resuspension. The planting technique involved sandwiching a 5-cm layer of plants between 2 layers of stucco wire. A total of 160 “sandwiches” covering an area of 1252 square meters were put in two different areas of the Lower Cell. The plants included pondweed and milfoil harvested from an alkaline lake situated 100 km from the Heath Steele Mine. The water in the Lower Cell was very alkaline with pH maintained between 9.5 and 10.5. Most of the sediment in this cell was settled lime sludge and the water depth was generally less than 2 m.

The pilot trial failed to establish plant growth, due to high alkaline conditions. Of the 160 “sandwiches”, only three showed limited growth. Poor plant growth and low phytoplankton: zooplankton ratios suggested inhibition to photosynthesis. Maintenance of a pH lower than 9.0 is preferable for the establishment of a plant cover with submerged aquatic plants.

A field study was undertaken at Heath Steele to evaluate the resuspension of tailings in the Lower Cell (Peacey et. al, 2002). The stored material in the cell consisted of unoxidized tailings with small amounts of sludge from the treatment plant. The 90 ha impoundment acted as a polishing pond, prior to the discharge of the final effluent. The pond was kept alkaline (pH of 9.5-10.5) in order to meet regulated discharge limits. Field measurements of suspended tailings were achieved by means of 16 sediment traps partly buried in the tailings bed. On some windy days when the Lower Cell experienced turbulent water conditions, the final effluent exceeded the suspended solids water quality standard of 25 mg/L. The dry mass of suspended sediment measured in 1999 ranged from 1.5 to 434 mg with relatively more material (> 100 mg) being suspended under shallow water cover (≤ 1 m). Both x-ray diffraction and scanning electron microscopy analyses indicated that the suspended material was mostly lime neutralization sludge and other material composed primarily of calcite and brucite and coatings of aluminum, iron, zinc and manganese hydroxides. It was noted that the sampling station located close to the treatment sludge deposition area collected larger amounts of suspended solids. Since the sludge was a loose fluffy low-density material, it would have required very little agitation of the water cover for it to be drawn into the water column. The results suggest that sludge and tailings resuspension and precipitation of solid phases in the water cover (≤ 1 m) likely combined to produce the observed, occasionally high total suspended solid concentration.

Another study on suspended mine tailings was undertaken at Heath Steele on the Upper cell (Catalan and Yanful, 2002). This area of the tailings pond was selected because no tailings or treatment sludge were deposited in this area after 1997. Sediment traps were used to perform the field measurement in the summer of 1998 and the fall of 1999. The study concluded that the amount of resuspension was related to the frequency of strong winds blowing in the direction of maximum fetch. The suspended tailings recovered in the sediment traps were more oxidized than bed tailings.

4. SELECTION OF THE REHABILITATION METHOD

Several potential closure options were identified in the original closure plan produced in 1989 for the tailings basin. Options included vegetation, engineered cover, underwater disposal and sludge cover. At that time, providing a water cover to form an oxygen limiting barrier was preferred over other options. The basic principle of the proposed Closure Plan was to prevent or very significantly reduce the tailings oxidation and hence generation of significant AMD.

In the final 1997 revision of the closure plan, restoration of the tailings basin site to its original land use was considered impractical. Therefore, the long-term water cover over the tailings basin was considered as the preferable option for the main tailings basin (Lower, Upper and North Cells). Where the tailings could not be flooded due to high tailings elevation (e.g., part of the Old Tailings Area) or if they were expected to be exposed during low flow periods, it was proposed that the high density sludge be used to form a dry cover.

The closure plan had identified concerns regarding the long-term water quality primarily related to acid mine drainage (AMD), long-term water levels in the various cells, existing contaminated porewater within the tailings mass and existing contaminated groundwater within the tailings basin.

4.1 Water Cover Design Requirements

The specific objectives of the tailings rehabilitation were to:

- Reduce the long-term oxidation rate of the tailings by providing an oxygen-limiting barrier (water cover) so that the rate of contaminant generation within the tailings deposit is low.
- Reduce the rate of tailings oxidation in the "Old Tailings Area" (highly oxidized tailings from the early operation) or, if not practically possible, reduce the rate of contaminant migration to an acceptable level.
- Collect and treat any contaminated seepage/runoff from areas where significant AMD flow cannot be prevented, where significant past contamination exists or where the removal of the AMD source is not feasible.

- Design a long-term monitoring program.

Besides dam stability and safety criteria, the water cover design had some specific criteria as follows:

- The minimum depth of water cover over the tailings deposit under the normal operating conditions is to be of 1 metre.
- A 1.5 m of freeboard for all major engineered structures.
- A minimum 0.3 m depth of water to be maintained over the tailings surface under the design dry year event (1:100 year low runoff event) to account for uncertainties inherent to hydrologic and seepage rate evaluations.

The Closure Plan was submitted to the New Brunswick Ministry of the Environment in 1997 and has not yet been approved.

5. CONSTRUCTION DETAILS

Consistent with the tailings basin closure strategy, some measures were put in place while the mine was still in operation, such as the construction of the internal dam, which divides the tailings deposit into the Upper and the Lower Cells (1992 and 1996) and the construction of powerline dam (1996) designed to form a new tailings disposal cell and the diversion of the northwest watershed (1996). Tailings in the North Cell were deposited underwater, while in the Upper Cell, the tailings were deposited sub-aerially during pre-water cover operation of the facility.

In 1998, the water cover depth progressively increased from zero at the tailings beach in the northern corner of the Upper Cell to more than 2 metres in the centre of the cell. In the summer of 2001, the Upper Cell was completely flooded.

In order to meet one of the cover design criteria of at least one metre water cover over the tailings under normal operating conditions, tailings were dredged in the Upper and North Cell, where the minimum water depth was not achievable. This work took place in 2000 and 2001. A large volume of partially oxidized tailings from the Upper Cell was moved to the North Cell.

The normal water cover operating level in the Lower Cell is at 8935 ft (relative elevation, local geodesic system). The main dam was raised in 2001 to achieve a crest elevation of 8940 ft to permit an operating water level.

The Old Tailings Area is hydraulically connected with the Upper Cell to minimize the potential for head differences and, therefore, tailings pore water seepage. The water level was raised slowly and evenly in both areas. The areas where the tailings elevation were above the final water cover elevation were covered partly with high-density sludge and partly with clean soil cover that was vegetated.

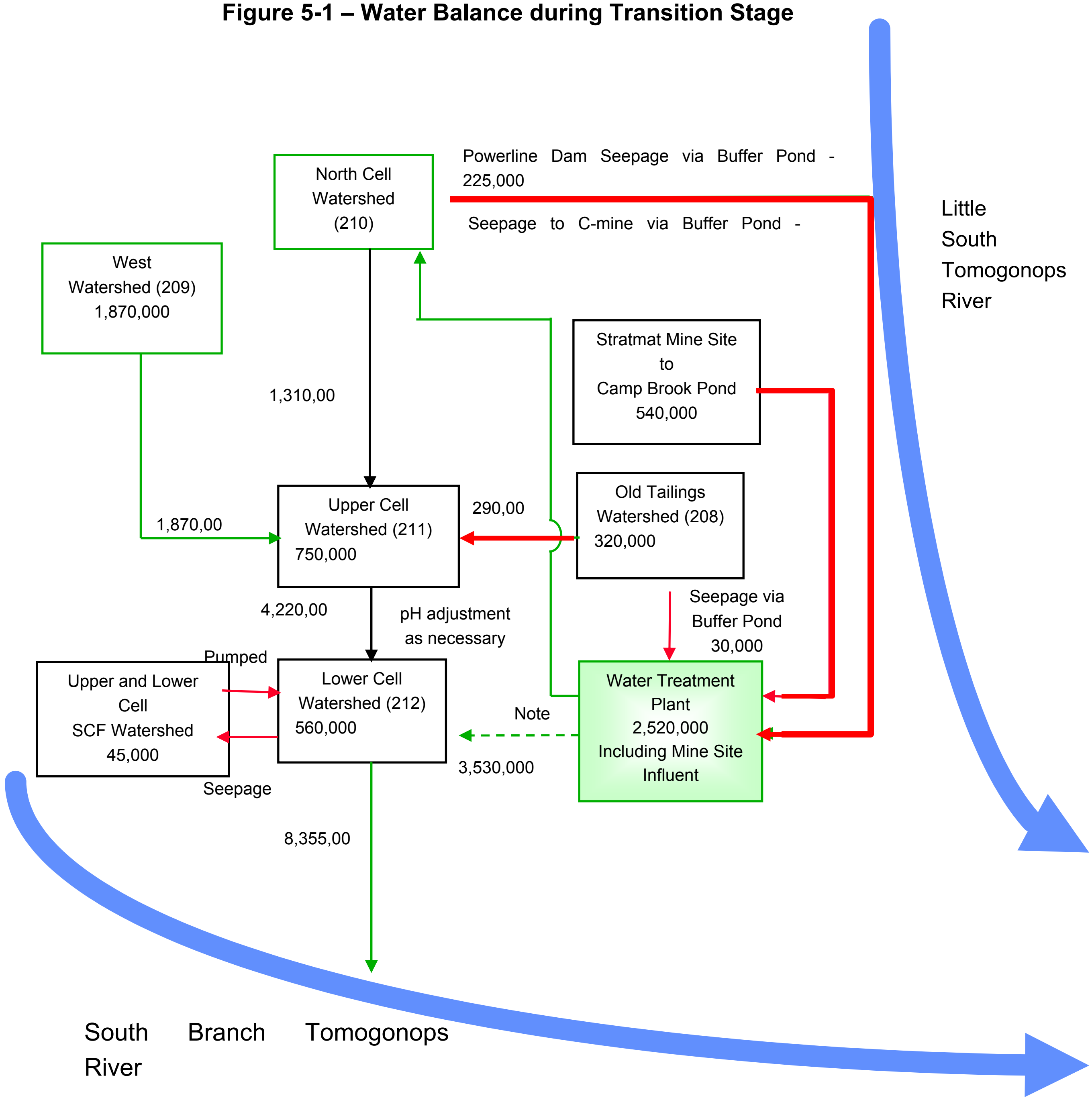
5.1 Water Management

Figure 5-1 illustrates the closure plan tailings water balance during the transition stage after closure.

The inflows to the tailings basin are the water treatment effluent in the North Cell and the runoff of the watershed 210, which includes No. 1 and No. 4 Shaft sites. The water treatment plant is treating contaminated waters from Stratmat and A-B-C-D mine water and tailings impoundment seepage. The No. 1 and No. 4 Shafts are areas which contained AMD waste rock. The No. 1 Shaft area has been cleaned, but the No. 4 shaft cleanup remains to be completed in the coming years.

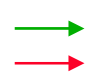
The North Cell discharges through the North dam spillway into the Upper Cell. The Upper Cell receives the runoff of the Old Tailings Area watershed (208) and the runoff of the western watershed (209). The water is then discharged to the Lower Cell by the internal dam spillway and finally to the environment via the main dam spillway.

Figure 5-1 – Water Balance during Transition Stage



Note:

- Only flows relevant to the tailings basin are illustrated. Other flows to the water treatment plant and the Little South Tomogonops River are not illustrated.
- All units are m^3/a



6. MONITORING PROGRAM AND PERFORMANCE TO DATE

HSM monitors on a regular basis the water quality of the inflows to the tailings basin (watershed 209, 210 and WTP effluent), the cover water quality at various locations (North Cell at North dam, Upper Cell at internal dam and Lower Cell) and the tailings final effluent (HS-13). A sampling station (HS-18) located downstream of the tailings basin at the mine road and South Tomogonops River is also monitored. Zinc is the most significant metal detected downstream as it is relatively mobile (i.e., it represents a good tracer of the site contamination).

There are approximately 10 sampling stations located within the watersheds 209 and 210 reporting to the tailings North and Upper Cells. In year 2002, the pH varied between 3.7 and 6.3, while the zinc concentrations ranged from 0.02 to 10.7 mg/L. The most acidic waters were recorded along the Clean Water Channel (CWC) originating from the C-Zone (Shaft No 4), where waste rock is deposited. This area still has to be cleaned. The flows of the CWC are diluted in the North Cell with the remaining watershed and the WTP effluent.

Although the flooding of the tailings started in the early 1990s, the water cover project was completed in 2001, after the dredged tailings were transferred from the Upper Cell to the North Cell. Figure 6-1 illustrates the pH trend, while Figure 6-2 shows the zinc concentrations trend in the various ponds since 2002.

In compliance with their Certificate of Approval (C. of A.), the pH at the tailings final effluent (HS-13) must be maintained within 7.5 and 9.5, so that the pH at the sampling station HS-18 located at the South Tomogonops River remains higher than 6.5. The maximum permissible zinc concentration of the final effluent is 0.3 mg/L.

In order to maintain adequate water cover quality, lime is added to the WTP discharge (North Cell) and the pH is maintained at 9.5. Hydrated lime is also added on a regular basis at the internal dam spillway, by emptying a truck load at the internal dam spillway. The lime is regularly added each time the pH drops below 8.5 at the internal dam spillway. This approach has been developed in order to meet the pH requirement of the final effluent (minimum pH of 7.5). In 2002, a total of 573 tonnes of hydrated lime was added to the internal dam spillway, while in 2003 the lime addition decreased to 401 tonnes.

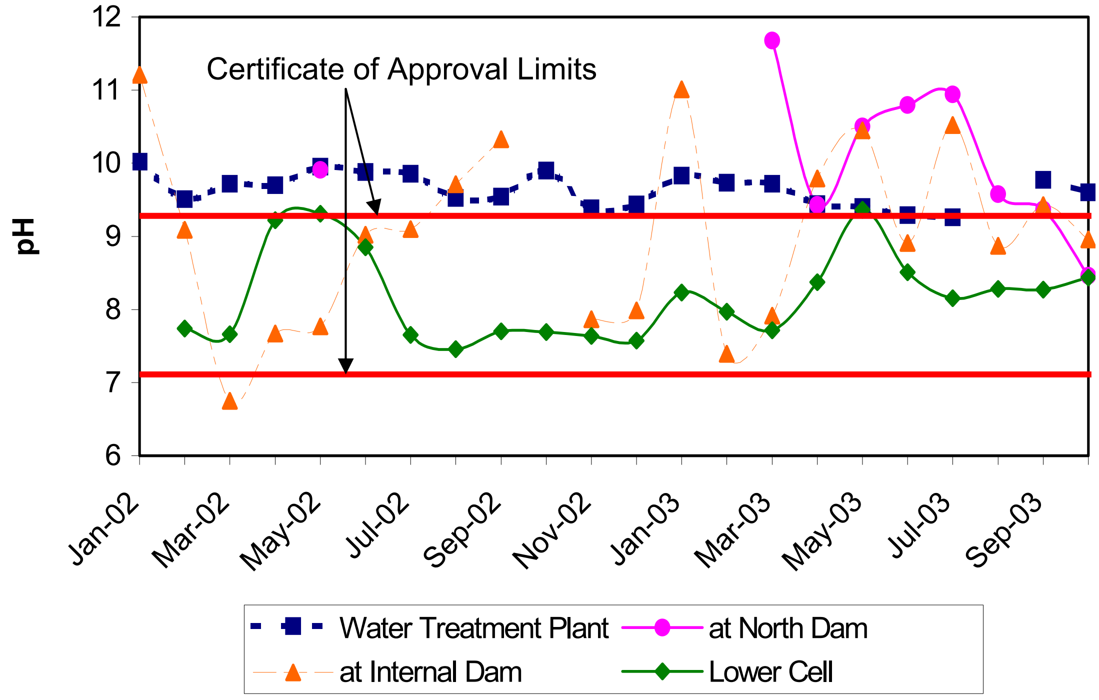


Figure 6-1 – pH at Different Locations in the Tailings Basin

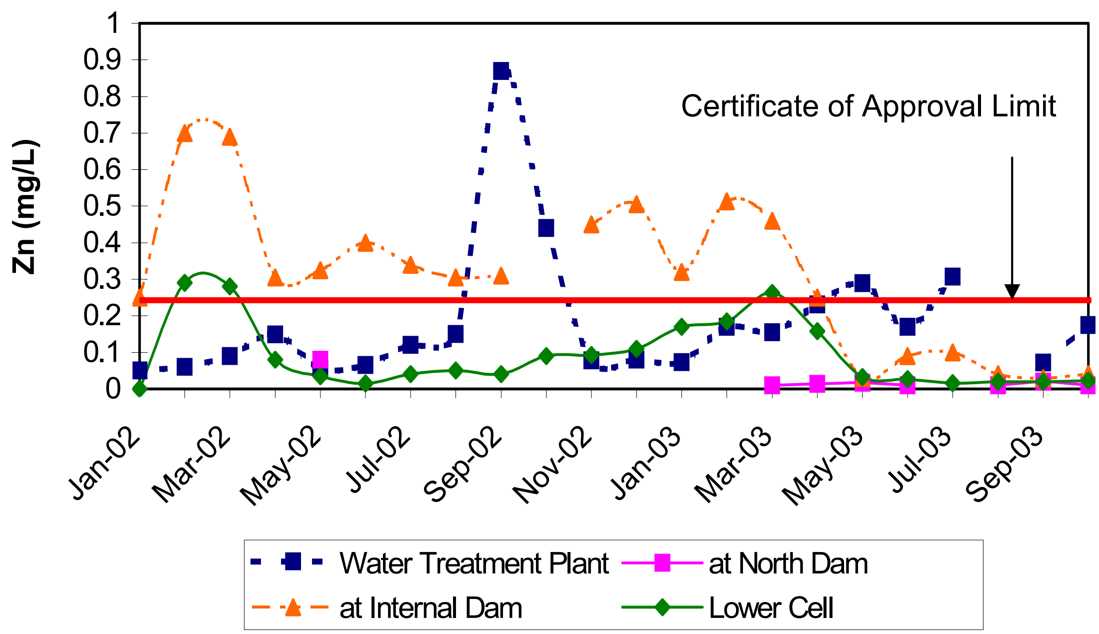


Figure 6-2 – Zinc Concentrations in the Tailings Pond Area

Based on the monitoring data available, the pH in the North Cell is controlled by the WTP effluent. At times, the pH is higher in this cell as lime was added by the truck load to the Upper Cell (internal dam). The North and Upper Cells are hydraulically linked. Therefore, the acidic water flowing from the watershed (C-Zone) does not appear to affect water cover quality significantly. One must keep in mind, however, that the tailings in the North Cell were deposited underwater and are not oxidized.

The Upper Cell is the area in which there is the greatest pH variation. As mentioned above, lime is added on a regular basis at the internal dam to maintain pH. During winter months immediately prior to spring runoff, the pH in the Upper Cell drops drastically, in comparison with the other cells. Zinc concentrations are also generally higher in the Upper Cell. The water quality degradation could be explained by the absence of runoff during this period. Since the tailings are oxidized, porewater contained in the tailings releases zinc and acidity to the tailings water cover, which is impacted more during winter months as no dilution occurs.

The Lower Cell acts as a polishing pond, and on some occasions, lime is added to the central decant (now decommissioned). When the pH is higher than the discharge limit, carbon dioxide is added.

Since the completion of the water cover in 2001, the water quality at the final effluent (HS-13) and further downstream (monitoring station HS-18) has been in compliance with the C. of A. requirements. In 1997, the average final effluent zinc concentration was 0.12 mg/L, compared to 0.09 mg/L in 2003. At the sampling station HS-18, which receives the tailings discharge and seepage from the main dam, the average zinc concentration was 0.19 mg/L in 1997 and 0.07 mg/L in 2003. There has been a significant reduction in contaminant loadings of the effluent discharged.

In order to comply with regulatory discharge criteria, lime will have to be added to the internal dam spillway as long as required to control the pH level. Note that a pH discharge of 7.5 appears difficult to sustain over the long term, without lime addition as the rain water pH is slightly acidic in the area, due to acid rain.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Lessons Learned

Several factors affecting the water cover quality are as follows:

- The sub-aerial deposition of tailings, dredging and subsequent flooding of the tailings beaches in the Upper Cell have resulted in contaminants flushed out of the exposed tailings beach.
- Seasonal changes in the quality of the supernatant, as a result of contaminant sources from the northwest watershed and/or the Old Tailings Area which drain toward the Upper Cell.
- Flushing of contamination from the Old Tailings Area. The Upper layer of the old tailings deposit is heavily oxidized. Flooding of tailings has resulted in an increase in the contaminant concentrations, mainly by diffusion of contaminants from the tailings porewater to the water cover.
- Some contaminants stored in the tailings beach upstream of the internal dam are flushing into the Lower Cell upon flooding.

Over time, it was observed that areas located within the tailings watershed contain acid generating waste rock. There are still active sources of contaminants which enter the tailings area watershed.

Operations-wise, the pH control at the internal dam spillway is not an easy task by addition of lime at the spillway, especially, when the tailings final effluent pH from the Lower Cell must be kept higher than 7.5. At present, HSM adds lime to maintain a pH of 8.5 in the Upper Cell, but in some occasions, carbon dioxide must be added at the discharge to lower the pH. Continued monitoring and experimental testing will allow the optimum pH to be maintained in the Upper Cell in order to meet compliance levels with respect to the final effluent.

Based on the water quality improvement observed downstream, the water cover has had a positive impact on the environment. Only 2 years after the completion of the water cover, it was noted that lower metal loadings were released into the environment. More time will be needed for the water cover quality to stabilize and for the contaminants stored in the tailings pore water to be flushed out.

7.2 Recommendations for Further Studies

A further field assessment study is recommended at Heath Steele Mine to verify some of the issues that have been brought up in the closure plan, such as:

- Assessment of contaminated seepage water from the Old Tailings Area into the Upper and North Cells or even towards the Lower South Tomogonops River (CN Quarry).

- Evaluation of the flushing of contaminants from the Old Tailings Area to the flooded cells.

- Evaluation of the flushing of contaminants from the Upper Cell to the Lower Cell from beneath the internal dam.

The field study should include a surface water and porewater sampling program, which would also incorporate installation of peepers at different locations in the North, Upper and Lower Cells. The interstitial water analysis will provide valuable information on the metal fluxes to the tailings surface and porewater.

8. ACKNOWLEDGEMENTS

Thanks to Dr. Nand Davé, Natural Resources Canada, Mr. Gilles Tremblay, MEND Secretariat, and Mr. Denis Kemp for their comprehensive review of this report.

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