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A closure case study: the multidisciplinary and interconnected opportunities and challenges at a mine in northern Ontario, Canada

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Abstract

This paper explores the challenges and opportunities of a mine's closure plan amendment (CPA) in northern Ontario, Canada, which supports expanding the mine plan and extending the mine life. The future mine plan includes going underground, consolidating two neighbouring open pits, shifting and expanding a mine rock stockpile, and adding a fourth tailings facility.

The scope of this closure plan is extensive and interconnected. There is the multidisciplinary nature of including all aspects of mine planning throughout its operational life, ultimate configurations and anticipating the needs to run a large mine, while also planning for reclamation and closure for what will be.

There are over 15 technical studies that support the CPA. These studies are interconnected and result from one cascade into the next. Of the 15 studies, more than half are related to water, water balance, water quality, interaction of surface and groundwater, bioremediation, water management infrastructure, and impacts of water on land cover. More than six consultants support this work and all the mine's departments came together to find alignment for two difficult challenges: more potentially acid generating waste than in the original mine plan and more water than previously modelled. The paper will walk through understanding how these scopes intertwine and the importance of working the interconnectivity and multidisciplinary nature of closure planning together to create a CPA.

Keywords: *case study, closure amendment, multidiscipline*

1 Introduction

This paper introduces a case study of the conceptual closure for a mine site in northern Ontario, Canada. Mine operations are expected to continue for at least another 20 years, thus the closure plan is still multiple iterations away from a complete and detailed design. Though the mine is still in conceptual stages of closure, this is the fourth major closure plan amendment (CPA) to date. Each amendment captures the ever evolving and changing mine plan, understanding of conditions on site, and socioeconomics.

There are sections on the background of the mine, the closure plan concept, the material changes to the mine plan, and closure plan milestones. The closure plan milestones provide helpful lessons learned through the experiences of preparing an extensive CPA with a focus on the challenges and opportunities. The milestones include freezing the project description, geology data review, water, infrastructure, financial assurance, data management, and communicating technical information.

Fifteen technical studies support the CPA that required a multidisciplinary team across the mine site and from consultant support. Water is the link between these studies and results from one study cascade into

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the next. It takes several integrated technical studies to build the roots of a strong and comprehensive closure plan to achieve the anticipated outcome of a stable environment, as depicted by Figure 1.

The current operation is within the traditional territory of several Indigenous Nations, and though not covered within the scope of this paper, it is very important to consider their inputs when developing a closure plan. This paper focuses on the technical side of closure planning and though equally important, does not touch on the aspect of social closure.

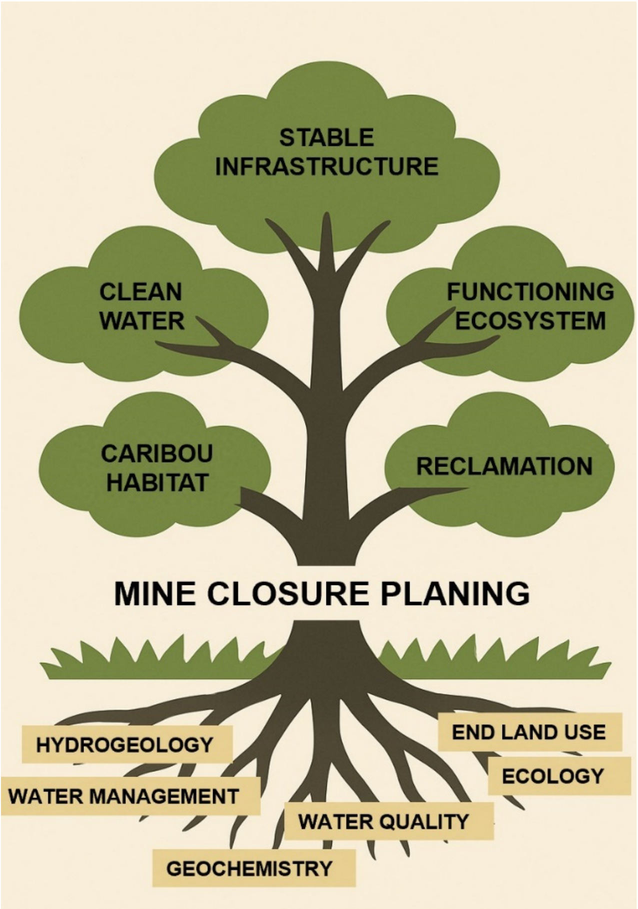

Figure 1 Image representing the interconnected nature of closure planning

2 Background on mine

This paper covers the closure planning of a brownfield open pit and underground gold mine that operated from 1983 to 1999, then entered closure and remediated the full site, with construction recommencing in 2010 when purchased by another mining company.

The current mine started with a single open pit, and was expanded to include two additional pits, five mine rock stockpiles (MRS) and three tailings cells, and this latest iteration to the closure plan includes pit consolidation and going underground.

During operations, over the past 10 years, reclamation trials have been progressing, investigating geotechnical, ecological and hydrological performance of various closure cover options on the success of remediation.

3 Closure plan concept

The high-level closure plan has four closure phases: active, passive, final, and post closure, as seen in Figure 2. The closure plan focuses on reclamation and demolition, land cover and revegetation, water management, and site management and monitoring. The current end land use plan is to establish mainly upland conifer and mixed wood forest with the goal of creating a physically and chemically stable, healthy habitat for woodland caribou (*Rangifer tarandus*).

At closure, all mine facilities will be removed, landscape features will be covered and revegetated, and the open pits will be allowed to naturally flood. The main pit will also act as a water management facility, with all seepage collection diverted and managed there until the respective facilities have achieved suitable water quality for direct release to the environment.

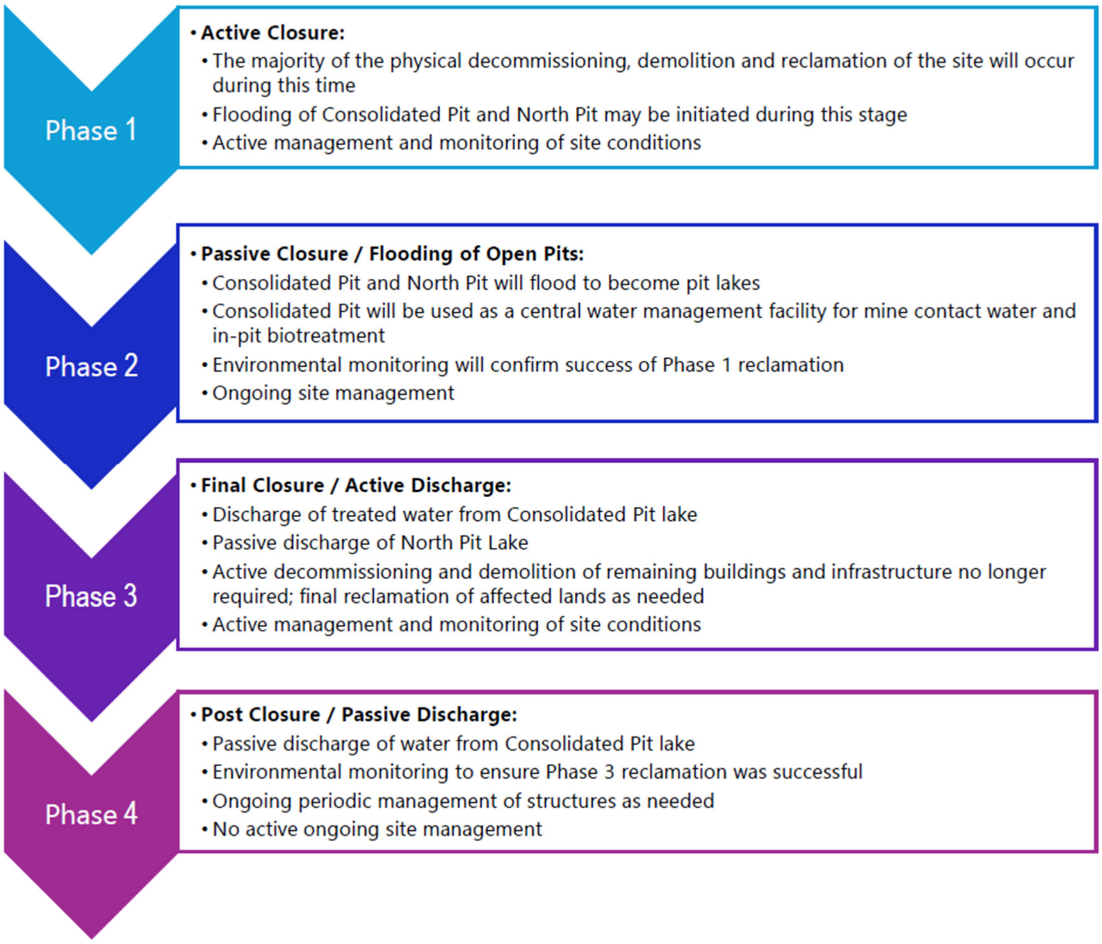

Figure 2 The four phases of closure and concurrent water management stages

4 Material changes to the mine plan

To align with the regulations in Ontario (Government of Ontario 2024), a CPA was drafted based on the proposed changes at the mine site. These changes included the consolidation of two pits, the shift and expansion of an MRS with potentially acid generating (PAG) rock, underground mining, and an additional tailings storage facility. These changes were substantial enough to trigger a full CPA.

As the mine plan has changed and new areas are being mined, many technical studies needed to be updated from previous amendments or investigated for the first time. The technical studies in support of the closure plan include the following, noting that some updates were not considered independent studies but are being updated while working on the CPA:

- Acid base accounting block model update.
- Source term update.
- Geochemistry update.
- Water balance and water quality model update.

- Pit lake model update.
- Deep pit injection and water management modelling update.
- Integrated surface and groundwater modelling.
- Water treatment concept update.
- Geotechnical pit stability.
- Underground and crown pillar stability.
- End land use plan update.
- Demolition update.
- Post-closure energy update.
- Pit lake spillways update.
- Waste rock management plan update.

5 Closure plan milestones' lessons learned

The following subsections include the lessons learned highlighting the challenges and opportunities of some of the key milestones while working through the CPA.

5.1 Freezing the project description

Like all operating mines, and life, everything is always changing. It was important to freeze the mine plan to streamline data collection to support the technical studies and create alignment across them. Freezing the mine plan was the key to creating consistency and prevent revisiting work. A life of mine plan (LOM) was selected for the CPA including the material takeoffs (MTOs), mine site configuration and sequencing. With such a large mine plan update, the site's multidisciplinary team was involved in this decision and with providing the necessary inputs. These inputs include large quantities of data that supported multiple technical studies many of which feed their results into one another.

5.1.1 Challenges

There were three LOM changes following the freezing of the CPA project description, a general mine plan update, an update to a MRS's size and configuration, and the sequencing of two of the tailings cells. Though these changes are not difficult technically, they are difficult to implement with time and resource constraints.

The general LOM was updated relatively early in the process. Nevertheless, the change resulted in revisiting the MTOs, double checking that each study and associated consultants had been properly updated and timelines matched.

The MRS size and configuration were updated part way through the study due to the geology data review, discussed in the next section. This change was unexpected and resulted in schedule delays as mine planners had to redesign the facility and come up with alternative configuration options.

The tailings cell sequencing was updated after most technical studies were already in draft, impacting study completions and delaying the CPA schedule as the impacts of the change was fully appreciated and implemented.

5.1.2 Opportunities

By updating the LOM, the CPA more accurately represents the current understanding of the mine plan. This ensures that the technical studies, and therefore the mine's financial assurance, properly account for the mine footprint, planned infrastructure, and closure remediation activities.

The change in the MRS opportunity is described in Section 5.2.2.

By changing the tailings cell sequencing, the timeline for permitting could be advanced on one of the cells and more information could be gathered to support locating the next tailings cell creating more certainty and reducing risk to the mine plan. Also, by changing the sequencing, it resulted in needing to revisit some modelling results, which highlighted some opportunities for refinement.

Sensitivity analysis or risk rewards help to determine the impact of mine plan changes. Sometimes the change is insignificant to the results of the technical studies, within the standard deviation or tolerable limits. Other times there is material change and impacts can be positive or negative.

5.1.3 Lesson learned

Build flexibility in your closure plan. Model inputs are easily updated, results are communicated quickly to impacted teams, and redundancy is built into the schedule.

One way to build in flexibility is to build models so that inputs can be updated relatively easily (swapping out inputs) and letting the model run. Another is collaborating with consultants at the same time and workshopping how changes impact each consultant and figuring out what changes or assumptions are worth pursuing as a group. Open and early communication between all teams working on the project, while having an experienced site team, all helped make these changes manageable.

5.2 Geology data review

The site has a lot of geology data which feeds into ore segregation, mill processing, and waste management. The CPA required an update to integrate the new areas to be mined.

5.2.1 Challenges

Earlier stage projects have a tendency to focus on understanding, sampling, and testing for ore qualities in their geologic samples. With the disconnect that typically exists between operations and exploration, this means environmental and geochemical testing important for closure is often a lower priority. As the CPA was being prepared, a gap analysis identified the need to further investigate the acid-based accounting (ABA) modelling of the new areas to be mined between the open pits and the proposed underground. Conservatism and additional time were required to add this update to the CPA.

The ABA modelling with additional conservatism built in indicated that there was more PAG rock than originally forecasted which resulted in requiring an update to part of the mine plan, increasing the size of one of the MRSs to accommodate the additional storage. The update had to take into consideration the following, as well as additional inputs; existing water bodies, planned water management infrastructure, other mine infrastructure, including the new underground crown pillar, reclamation objectives, traditional land uses and corporate standards for critical infrastructure. Taking into consideration all these variables made it exceptionally difficult to finalise the new MRS footprint.

5.2.2 Opportunities

Because of the increase of PAG waste, the multidisciplinary site team were pulled together to determine the best location and design of the MRS. Through multiple sessions, the team brought their expertise and respective interests to the meetings and an updated configuration was agreed upon by all site teams. The updated design meets each team’s requirements and fulfills the needs from the ABA update.

5.2.3 Lesson learned

Start gap analyses early and keep data updated. By waiting, the schedule may be compromised and the preferred team may not have availability to support the required updates. This challenge also highlighted the benefit of having a multidisciplinary team working together to achieve an outcome that will work for all functions.

5.3 Water

Water is one of the main considerations for closure planning and is often the aspect that has the ability to leave a long legacy. Water is also one of the most culturally significant items when it comes to mining and closure planning. As such, water is the interconnecting feature in the CPA so understanding how it interacts with the geology, the surface, the underground, and ecology all require investigating the amount, quality, and interactions. There are four main technical studies with their primary focus as water: the water balance and water quality model, deep pit injection and post-closure water management, the pit lake model, and the integrated surface and groundwater model. Secondary water studies include the land cover and ecology, post-closure energy (it is necessary to know how much energy is required to manage water on site after active closure), pit lake spillway designs, and potential water treatment requirements.

5.3.1 Challenges

With many technical studies' primary and secondary focus being on water, studies often run in parallel, with the critical path on the overall schedule being the sharing of results from one study to the next. Keeping everyone abreast of the priorities, data updates and changes, and the interconnectivity of each study was challenging. An additional layer to the challenge was that each respective technical study was managed by a different consultant, each being a subject matter expert in their field.

5.3.2 Opportunities

Early on as the first few technical studies' preliminary results became available and consultants were diving into their work, a water workshop brought together the consultants and site teams working on water scopes. Through short (5–7 minute) presentations, each technical study's scope, initial results or impressions, and any identified gaps were summarised. Though challenging to stick to such short timelines, it helped to focus on the top priorities of each study and tease out the most important gaps or challenges, especially with how one studies' results fed into another. With these shorter summaries, the team was able to focus on solutions to the gaps and challenges as a group to improve the CPA with experts bringing their respective expertise and experience to the table. Instead of only meeting with one consultant at a time, collaborating with many of them on specific challenges improved the supporting information for the CPA while also improving efficiency and removing miscommunication. Many of the consultants and internal site teams needed each other's results and needed to understand the background behind modelling decisions and assumptions, so creating an open communication system and regular collaborative sessions supported pulling together the CPA.

5.3.3 Lessons learned

Collaborating internally and externally, early and throughout the CPA, was critical to creating an efficient and better product.

5.4 Infrastructure

There is a lot of infrastructure on site and with a site that has a changing mine plan, including expansion plans, tracking all the changes is difficult. The inventory is regularly updated, and specifications gathered to support permitting and audits. The additional tailings storage facility and mine water pond added in this CPA are substantial structures on site with substantial supporting infrastructure, which requires multiple stages to design.

5.4.1 Challenges

Challenges exist with inventory and specifications of new buildings, often with ongoing changes and projects at the mine site, not all the details are passed along for inclusion in the closure plan, additionally some plans are in the conceptual phase during closure planning but need to be constructed within a specified period that doesn't always align with the closure plan approval timelines. There are time consuming ways of updating registrars by comparing previous iterations to new satellite imagery, but not everything is captured and the specifications can be missed. A potential greater challenge exists with planning for critical infrastructure, such as tailings facilities and water management infrastructure. Due to long lead times, permitting, including closure planning, needs to be started years before construction is able to commence on the facilities, and this means that closure planning is usually conducted using conceptual designs given the lack of information available in advance of the permitting phase. This lack of information is typically driven by the hesitation to invest resources into an area when the permitting guarantees or timelines are unknown. Due to this, as closure planning advances, more information becomes available and sometimes footprints or designs need to be adjusted to accommodate this new information. With this comes the cascading changes to other technical studies that are dependent on these footprints or specific design details.

5.4.2 Opportunities

By being fully integrated onsite and being a part of the operational team, changes are integrated early and captured within the CPA with relative ease. Building conservatism into the closure plan can also help absorb some changes that might be met while advancing closure planning.

5.4.3 Lessons learned

Be one with site. It is important to remain integrated with the site and operations teams, or have someone who is part of the detailed closure planning that has a strong site presence with the day-to-day. This helps forecast any changes that might be required to the closure plan early on in the planning process.

5.5 Financial assurance

It is common practice across most jurisdictions that prior to developing a mine or an advanced exploration project that financial assurance be put forth in the event the operator is not able to complete closure activities and then this duty falls to the Crown. Financial assurance can be in the form of a bond, letter of credit, or other depending on the regulatory body. Financial assurance calculations are meant to estimate how much money it will cost to close the respective mine facilities, if it were to close tomorrow. Here we explore the challenges and opportunities of estimating financial assurance for the sole purpose of providing financial assurance to regulators along with the closure plan and not estimates specifically for LOM budgeting or asset retirement obligation calculations, which may vary slightly.

5.5.1 Challenges

As outlined in the previous section, one of the main challenges with estimating financial assurance is first having an inventory of all site infrastructure that will need to be removed during closure of the operation, which in this case study is a large footprint. Challenges arise when deciding on unit rates for estimating costs, being several decades from closure the closure costs are still subject to inflationary pressures, with every amendment the costs go up. Another challenge is costing out the closure with existing assumptions built in, at this phase in the operation some aspects of the closure plan are still in the conceptual phase or unstudied so costing is based on a set of assumptions that will need to be adjusted as new information is obtained. Lastly, there is no clear guidelines on estimating financial assurance supplied by the local regulator in this jurisdiction, so it is open to interpretation and requires a lot of dialogue with the regulator to ensure the calculations and final amount are agreed upon.

5.5.2 Opportunities

Maintaining an active log that tracks new minor infrastructure and specifications that are built between major closure amendments will make updating costing easier. Also building a cost model early on allows for easier updates and the ability to run sensitivity to different unit rates to best manage and forecast financial assurance.

5.5.3 Lessons learned

Be sure to have supporting documentation and justification for all costs, as you will be audited.

5.6 Data management

There is a lot of data required to support compiling a CPA and the associated technical studies.

5.6.1 Challenges

The quantity of data is hard to manage for a CPA and the associated studies even if the exact information is known. Initially, the requests for information seemed reasonable but with iterations and multiple data sources, keeping up to date was challenging. Some of the challenges included the source of data, the version of the data, the relevance of the data, and the results from these different data sources or versions. This challenge also included the flow of information to and between consultants. The decision-making process and change management meant archiving older files or tracking the change.

5.6.2 Opportunities

There is room for improvement for the next CPA. Through this process, learning what worked well and what could be implemented for better management will make the next version better. As previous sections mentioned, the communication with consultants was frequent and often included many of them which helped insure they had the most up to date information and data required for their work.

5.6.3 Lessons learned

Don’t give up on data management; something is better than nothing. Figure out what structure works best and add all communication with dates. The main organisation system and having a consistent CPA team focused on compiling the CPA helped manage the data.

5.7 Communicating technical information

Though typically conceptual in the early phases, a closure plan is highly complex with many technical studies that are written by experts in their respective field. With so many technical studies and reports that are very long and data heavy, determining how to share the information with local Nations, communities, and site staff was very important. Additionally, when commencing consultation, it was imperative that none of the information in these studies or in the CPA was new to the Nations when they received the CPA draft document. Relationships with local Nations is precious and requires building trust that a site is open, transparent, fair, and most importantly willing to listen to concerns and incorporate them into the closure planning process.

5.7.1 Challenges

With the 15 technical studies and a CPA document far exceeding 100 pages, there is a lot of information and it is highly technical. Most people do not have the background or expertise to review these types of documents, but it is extremely important to share the findings and receive feedback to help improve the CPA.

5.7.2 Opportunities

There are opportunities to engage early and often, starting years prior to a CPA being shared with external participants. There are also many different ways to share the information that support a broader audience. Some of the ideas that have been used in prior CPAs and are being proposed for this CPA include plain language summaries of the technical studies, an open house and forum to present the CPA with consultant support at stations and posters summarising the work, using videos to help show the mine at its ultimate configuration, and immersive scenes to show what the site will look like at closure. It was important to ask the Nations how they wanted to see the CPA, so these requests could be integrated into how the CPA was communicated, as each specific Nation or community may have a different way they would like to be engaged.

5.7.3 Lessons learned

There are many different ways to communicate technical work, so it is important to use different ways to help with engagement and to ensure that they feel comfortable providing feedback that will be integrated into the site's CPA. Early engagement is key and appreciated.

6 Conclusion

Closure plans are difficult. There are many interconnected scopes that require understanding the bigger picture and collaborating across multidisciplinary teams internally and externally. There is no 'one size fits all' but there are ways to create efficiency and more accurate CPAs.

The lessons learned from this case study are:

- Build flexibility in your closure.
- Start gap analyses early.
- Collaborate internally and externally, early and often.
- Be one with site.
- Be constantly tracking changes between closure amendments.
- Don't give up on data management.
- Make technical work less technical by using different mediums such as open houses, forums, videos, and posters.

From our experience, don't look at the task as simply a closure plan or technical report, but rather as a project that needs to be managed. Therefore, major steps would include:

1. Build a multidisciplinary project team that includes mine site knowledge (for the mine you are drafting the closure plan for) and closure experience. Assign a project manager (recommended to be an internal employee).
2. Schedule a kick-off meeting to outline objectives and timelines of the project.
3. As a project team, build a design basis for the closure plan that includes the mine plan to be followed and any major assumptions. This team should also explore the various alternatives for the design basis and closure concepts.
4. Outline all required studies to support closure planning including relevant regulatory, environmental, social, governance and financial requirements.
5. Utilise existing subject matter experts (SMEs) (internal and external) working on operational studies to expand their scopes to include closure, or obtain any missing SMEs for relevant support.
6. Host a workshop with all SMEs to review interconnectivity and cascading impacts of their respective scopes/studies.
7. Ensure the project has a well detailed schedule to monitor timelines and communicate any project delays.
8. Determine consistent generalist reviewers and assign internal SME reviewers as required.
9. Develop a strong consultation plan, in collaboration with partner Nations, recognising that consultation should be ongoing throughout the whole listed process.

10. Work with partner Nations and regulatory bodies to incorporate any recommendations for updates to the closure plan.
11. Once finalised, debrief and prepare for the next amendment because if the plan is developed for an operating mine a future update will be required.

Acknowledgement

We would like to acknowledge the several Nations who are sharing their land with us and adding valuable insights in our closure planning. We would also like to acknowledge the extensive efforts of many members of the mine site staff and external consultants that supported us while we navigated these challenges and took advantage of every opportunity to make our closure plan a better, more holistic document.

References

Government of Ontario 2024, *Ontario Regulation 35/24: Rehabilitation of Lands*, under the Mining Act R.S.O. 1990.