

Use of an integrated source-to-receptor model to facilitate rapid assessment of water quality impacts during mine planning

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Abstract An integrated source-to-receptor model for assessing potential project-wide water impacts can save time and money by facilitating rapid evaluation of multiple design options. The proposed NorthMet Mine in northern Minnesota is presented as a case study for the benefit of using this approach. This modern mining operation will include a complex water management strategy designed to minimize potential impacts and make the mine more sustainable. An integrated source-to-receptor model was constructed for the mine site and used to evaluate various mine closure options during the mine planning process.

Keywords integrated mine water management, mine closure, water quality, predictions, Gold-Sim

Introduction

Mine water management is becoming more important as water quality regulations become increasingly stringent and water becomes increasingly scarce. Water plays an important role in most mining and extractive processes; it is used in mineral processing, for transportation of tailings or ore as slurry, for cooling, and for dust control (Nalecki and Gowan 2008). Water is also one of the primary mechanisms for transporting solutes from mine facilities to the environment. Defining and understanding how water is managed is critical during mine planning, operations, and reclamation.

In addition to the environmental aspects of water management, there are also economic incentives for mines to achieve a sustainable water balance. Operators need to insure that there is enough water for mineral processing throughout the year (including dry periods or times when water is frozen), yet having excess water can result in the need for additional treatment to minimize environmental impacts. Recycling water between various mine processes can minimize withdrawals and discharges, but complicate water management

requirements. The combination of environmental, economic, social and engineering factors have resulted in increasingly complex mine water management strategies.

It has long been recognized that life-of-mine water management strategies should be considered in the mine planning process. Advanced planning for integrated mine water management can prevent expensive reclamation solutions (Sawatsky *et al.* 1998), and the use of predictive models to assess mine closure options is consistent with guidance for developing environmentally sound management plans (Eary *et al.* 2008). However, during the mine planning process, the water management strategy is often in flux. The potential for unacceptable water quantity or water quality impacts can drive changes in the mine plan to reduce potential water quality impacts or provide water treatment. As a result, the prediction of potential water quality impacts during mine planning is typically iterative and designed to explore the costs and effectiveness of various mitigation or treatment options. Having an integrated source-to-receptor water model during the mine planning process allows for the rapid assessment of mine plan

changes to the project-wide water balance and potential impacts to the environment. In addition, use of an integrated model reduces the risk of continuity (water and mass balance) errors compared to the typical compartmentalized modeling completed for many projects.

Background

Water quality modeling conducted for the proposed NorthMet Project is presented to demonstrate use of an integrated model for rapid assessment of various design options during the ongoing mine planning and environmental review process. The NorthMet Project is a proposed copper, nickel and precious metals mine located in northeastern Minnesota's Duluth Complex (Fig. 1), one of the largest undeveloped deposits of copper, nickel and other precious metals in the world (Eckstrand and Hulbert 2007). The NorthMet Project is currently undergoing environmental review, so the Project design presented here may change during the review process. It should be noted that model inputs have been developed to meet environmental agencies' requirements for estimating potential impacts. As currently proposed, approximately 32,000 tons (29,000 t) of ore per day will be mined via open-pit methods from two mine pits. Waste rock with the lowest sulfur content will be placed in a permanent surface stockpile at the mine site. Remaining waste rock will be temporarily placed in lined surface stockpiles and will be backfilled into the first mine pit (at the completion of mining in this pit) for long-term subaqueous storage. During reclamation, the permanent stockpile will be covered, the back-filled mine pit will be capped with a wetland,

and the remaining mine pit will be allowed to flood.

Ore from the mine site will be transported approximately six miles (9.7 km) west to the plant site via rail, where it will go through crushing, grinding, flotation, and eventually hydrometallurgical processing. Tailings generated during the flotation process will be slurried to an existing, reclaimed taconite tailings basin for deposition. Reclamation of the tailings basin will include engineering controls designed to minimize oxygen and water penetration into the tailings as well as measures to collect and treat seepage emanating from the basin.

Evolution of the NorthMet Water Management Strategy and Modeling

The NorthMet Project is designed to re-use as much water as possible to minimize potential impacts to the environment, from both a water quantity and water quality standpoint. For example, during operations water generated at the Mine Site from pit dewatering and stockpile drainage will be treated and pumped to the Plant Site for use in processing. Then, during reclamation, water from the tailings basin will be treated and returned to the Mine Site to help expedite pit flooding, which will minimize the amount of time pit wall rock is exposed to the atmosphere and allowed to oxidize.

The proposed design of the NorthMet Project has changed several times throughout the mine planning and environmental review processes. Changes were made for both economic reasons (for example, changes in mine pit dimensions as additional information on

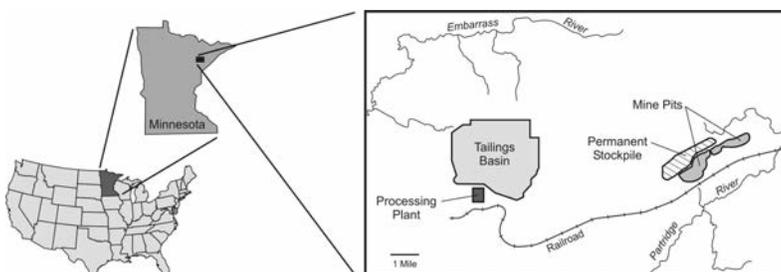


Fig. 1 Location of the NorthMet Project

the ore deposit became available) and environmental reasons (for example, changing the design of the tailings basin seepage capture system to increase effectiveness). In addition, the environmental review process requires the consideration of Project alternatives. This process resulted in the need for many iterations of water quality impact modeling. Each time the design of a feature changed, modeling was conducted to assess if the design change would potentially affect water quantity and quality. If the potential for impacts increased to an unacceptable level, additional engineering controls were added to the Project and the water impact modeling repeated.

Because of the interconnections between the various mine features, the change in the design of one feature had the potential to affect the water quality and quantity impacts associated with other mine features. For example, changing the type of cover used to reclaim a stockpile had the potential to affect:

- size of the wastewater treatment plant,
- flooding rate of the mine pit,
- potential water quality down gradient of both the stockpile and the mine pit,
- amount of tailings basin water that can be sent to the mine pit to expedite pit flooding, and as a result,
- potential water quality and quantity impacts associated with the tailings basin.

Initial water quality modeling conducted for the Project was performed using a series of stand-alone models, which required manual transfer of data between models. Separate models were constructed for the tailings basin pond, the tailings basin, mine pits, stockpiles, groundwater, surface water, and the wastewater treatment facilities. The manual transferring of data between models represented a high risk for error. To evaluate a change in the design of a mine feature, the various models needed to be re-run by multiple different modelers, which would often take days or weeks to complete. Having stand-alone models also

made it difficult to assess whether mass was being conserved throughout the process and allowed for the possible double-counting of water as modelers attempted to make conservative assumptions with respect to various competing impacts.

Knowing that the mine plan was still changing and numerous options would need to be evaluated, the decision was made part-way through the environmental review process to integrate the stand-alone models into source-to-receptor models for the Mine Site and the Plant Site. New models were constructed using the GoldSim modeling platform. The integrated GoldSim models can more rapidly assess potential water quality impacts, and have alleviated the concerns associated with data transfer among multiple models.

Following the conversion of the modeling to GoldSim, several different options were considered for operation, reclamation and long-term closure of the Project. For each option considered, the GoldSim model was run and the potential impacts to groundwater and surface water were assessed. Unlike previous modeling iterations conducted using the series of stand-alone models, these various options were quickly assessed in a matter of days using the integrated model.

Comparison of Reclamation Scenarios

At one point in time, the proposed Project design resulted in increasing concentrations in the mine pit lake following reclamation. This design, presented here as the base model, included natural pit flooding, active treatment of the pit water during flooding, an engineered soil cover on the permanent stockpile, and a partial seepage containment system around the permanent stockpile. Knowing that increasing pit lake concentrations following reclamation may not be acceptable to the regulators or the public, three mine site reclamation scenarios were modeled to evaluate their effect on pit lake concentrations. Note that none of the scenarios presented here and ex-

amined in this intermediate modeling exercise are identical to the final design of the proposed NorthMet Project.

The three scenarios evaluated are as follows:

- Expedited Pit Flooding (Scenario 1) – Expedited pit flooding in closure is a common strategy for mitigating loading from pit walls. However, expedited pit flooding results in less time available for active treatment of the pit water before discharge to the environment would occur. Several different options for pit flooding were considered for the NorthMet Project, including changing watershed areas via dike removal to direct more runoff to the pit and sending water from the tailings basin to the pit. This scenario looks at the option of routing up to 3,300 gpm (0.21 m³/sec) from the tailings basin to the pit to expedite the time it takes to flood the pit.
- Geomembrane Stockpile Cover (Scenario 2) – Engineered covers on waste rock stockpiles help to minimize the amount of infiltration that can contact the waste rock and mobilize solutes. The only permanent waste rock stockpile for the NorthMet Project was modeled with both an engineered soil cover (base model) and a geomembrane cover. The infiltration through the stockpile primarily influences the water quality of the downstream pit lake. This scenario includes the expedited flooding from Scenario 1.
- Stockpile Containment and Treatment (Scenario 3) – The base model includes a seepage containment system (cutoff wall with drain tile) constructed around three sides of the permanent stockpile in order to prevent seepage from flowing off-site. Water collected in the containment system is treated and discharged into the mine pit during flooding. The containment system was not originally planned to fully surround the stockpile, allowing

for stockpile seepage in the area without the containment system to flow into the mine pit. The option of extending this system around the entire stockpile was assessed to see how it would affect the treatment needs for the Project. This scenario includes the expedited pit flooding from Scenario 1 and a geomembrane cover on the permanent stockpile from Scenario 2.

The results of the water quality estimates for the base model and the three reclamation scenarios are shown in Figs. 2 and 3, which compare the modeled concentration of sulfate and nickel in the pit lake. Expedited pit flooding (Scenario 1) decreases the pit flooding time by approximately 30 years, from Year 95 under the base model to Year 65, and increases the modeled concentrations for sulfate and nickel in the pit lake at the end of flooding when pit water is expected to discharge to a local stream either naturally or, if necessary, via treatment. The modeled increase in concentrations is due to there being less time available for active treatment of the pit water prior to complete flooding. The long-term water quality approaches a similar steady state regardless of the pit flooding scenario. Stockpile reclamation with a geomembrane cover (Scenario 2) decreases the modeled concentrations in the pit lake at the end of flooding (Year 65) and more significantly in the long-term steady state condition. For these solutes there is very little difference in the modeled pit concentration with and without the extended containment system (Scenario 3), although pit concentrations are lower under this scenario.

The combination of expedited pit flooding and a geomembrane cover on the permanent stockpile results in pit lake concentrations that trend downward following reclamation, which was the desired outcome for the evaluation. Both of these options have been included in the revised mine plan for the Project. While extending the stockpile containment system is not predicted to significantly reduce pit lake concentrations of sulfate and

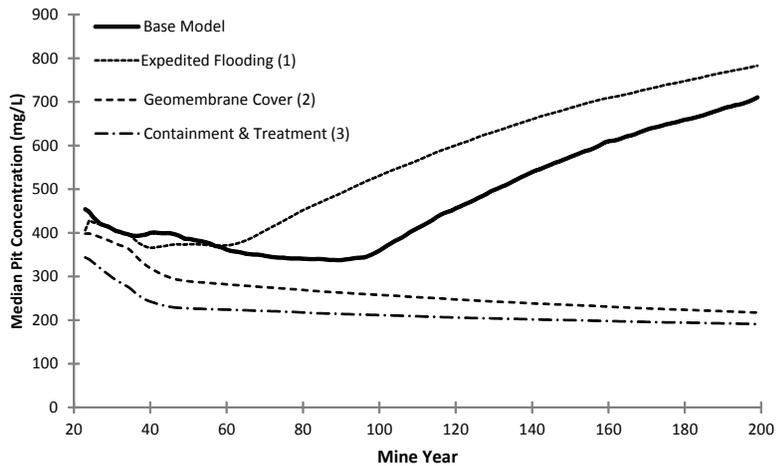


Fig. 2 Comparison of modeled pit sulfate concentrations for the base model and the three reclamation scenarios evaluated. Note that each modeled scenario assumes the inclusion of all previous scenarios.

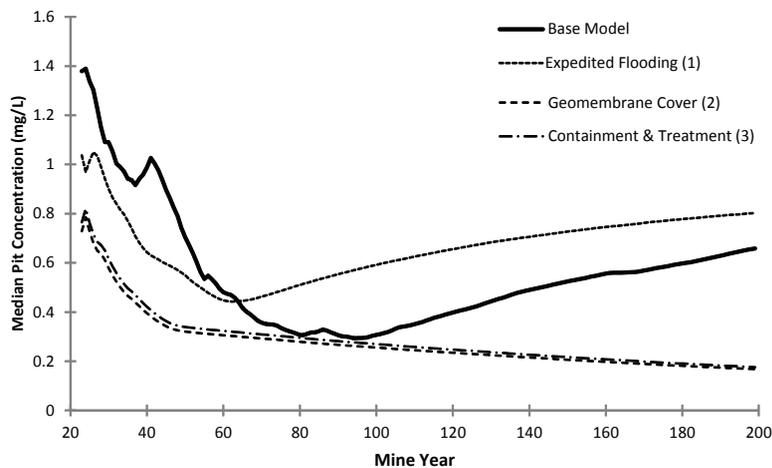


Fig. 3 Comparison of modeled pit nickel concentrations for the base model and the three reclamation scenarios evaluated. Note that each modeled scenario assumes the inclusion of all previous scenarios.

nickel, this option has also been integrated into the revised mine plan because it should aid in the eventual transition of the Project from active to passive treatment, the discussion of which is beyond the scope of the evaluation presented here.

Summary and Conclusions

As regulatory pressure increases and water sources become scarcer, mine water management is becoming more critical. This often results in complex mine water management plans, which can be difficult and time consuming to assess. Developing an integrated source-to-receptor water impact model early in the mine planning process can help facilitate rapid assessment of potential water quality and quantity impacts during mine planning. This

approach was taken on the NorthMet Project, a proposed copper-nickel mine currently undergoing environmental review. The use of an integrated model allowed for rapid assessment of various options for mine site reclamation. In addition, having a single model, as opposed to separate models for mine features, groundwater and surface water, helped to insure mass conservation and prevented the double counting of water.

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