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Evolution Mount Rawdon—an integrated closure planning case study

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Abstract

Mine waste needs to be carefully managed throughout the life of a mining operation to achieve closure goals and minimize adverse environmental impacts. From a mine planners' perspective, this means that waste dumps need to be designed to best achieve the final landform surface dictated by the site closure plan, inclusive of selective placement options. They then need to ensure that the material they're mining is selectively placed to achieve that design.

Unfortunately, a typical life of mine planning model will be built primarily to achieve ore or product tonnes, and would be limited to pits, haul road networks, ROM pads, and operational dumps without much consideration for closure. Integrating the mining and closure plans to include tailings storage facility embankments, waste rock storage facilities, sediment dams, bunds, and intermediate or final cover systems would provide visibility around whether the closure objectives can be achieved and improve the likelihood of achieving those closure objectives.

Without an integrated mine closure plan, competitive use of materials and material deficits is likely to occur. Material deficits may result in unachievable or undesirable closure outcomes, as well as unexpected costs relating to rehandling, mining and rehabilitating a new 'borrow' area to make up the material shortfall.

Evolution's Mount Rawdon Operation brought together traditionally siloed mine planning, tailings, and environmental teams to deliver a Whole of Mine integrated mining and closure model (WOM model). This allowed them to test and analyse the material balance and landform development sequence for their Progressive Rehabilitation and Closure Planning (PRCP) and evaluate potential closure options to improve the likelihood of meeting closure objectives.

The WOM model sequenced the remaining mining activities with the potential closure activities so they were shown in a single visualization. This became an effective tool to assess the viability of the selected closure option, quantify the overall rehabilitation material balance, and optimize material placement. The model quickly informed MRO that there would be a rehabilitation material deficit if they were to proceed with the closure option of covering the final landforms. Using this information, multiple scenarios were run to evaluate different borrow sources and cover placement options to achieve the potential closure option.

The 'final' mining surface (the state of the operation at the completion of mining and processing activities) was output from the WOM model and used in the construction of a probabilistic GoldSim water quantity and quality model for the entire site. This was used to provide a range of probable water quality outcomes for the post-closure landform design. The WOM model was then integrated with the water modelling to verify catchment areas that report to each node in the GoldSim model and enabled MRO to evaluate the impact of the selected material placement strategy on the water modelling.

The WOM model identified opportunities and risks for both mining operations and closure activities and is an outstanding example of designing for closure and implementing integrated planning.

1 Introduction

The ICMM Mine Closure Guideline (2019) states that early consideration of mine closure will make it easier and more cost effective to achieve final closure objectives and can improve the opportunities for relinquishment. Integrating closure planning into the traditional life-of-mine (LOM) plan to create a whole-of-mine (WOM) plan, and iteratively designing for closure to align with increasing site knowledge, significantly reduces the risk of suboptimal closure outcomes and costs.

This paper addresses aspects related to the development and maintenance of a WOM model to improve closure outcomes, including the Evolution Mount Rawdon case study, a site that is dealing with acid and metalliferous drainage (AMD).

2 The problem

As a preface to the Evolution Mount Rawdon case study, we will outline some common reasons why the mining sector may not achieve successful mine closure and rehabilitation outcomes, namely:

2.1 Inadequate closure planning

The site closure plan, such as an Environmental Impact Statement (EIS), can often lack the detail required for effective closure planning, and can easily become outdated with the constantly evolving LOM plan produced by Mining Engineers. The site closure plan should define the boundaries early in the mine planning process and be iteratively developed with every LOM plan. Changes in Environmental, social and governance (ESG) requirements throughout the mine's life may necessitate adjustments to closure plans, such as modifications to cover systems and buttressing on Tailings Storage Facilities (TSFs). Neglecting to address these changes in the LOM can lead to compromised closure outcomes because of material deficits (like not having enough non-acid forming material to cover the waste rock storage facilities at the end of mine life because the material was used to construct a TSF buttress) or equipment limitations (like hauling shorter, but outside of the detailed selective material design, to 'free up' haul trucks to haulage longer to the TSF buttress).

2.2 Lost critical technical aspects

Critical technical aspects, such different material classes that address AMD or other contaminates that need to be managed, can be misunderstood, or oversimplified by mining operations teams, and glossed over during the development of the LOM plan. A lack of granularity, context and understanding of the material classes can cause significant environmental issues and compromise the success of rehabilitation. Additionally, simplified, and generic terms like "topsoil" may not accurately reflect the composition of rehabilitation materials, which can affect the success of landform restoration and material balance.

2.3 Lack of integration among work teams

The complex nature of mining often results in work teams operating in isolation, leading to a fragmented understanding of the overall closure objectives. Spatial models and mine plans that typically focus on ore or product tonnes do not communicate the Whole of Mine story of mining through to closure.

3 Potential solutions

3.1 Develop an integrated whole-of-mine (WOM) approach to planning

Existing mine planning software packages can be used by mine planning teams to create an integrated WOM model to encompass both the spatial and temporal progression of mining operations and closure-related activities, extending until full site rehabilitation. Creating and maintaining a WOM model enables proactive identification and resolution of potential issues that could affect the achievement of closure objectives.

The WOM model should include detailed spatial designs for all mine domains, including key components of the mine site that are typically overlooked due to the segregated nature of technical division, such as TSF embankments and decants, Waste Rock Storage Facilities (WRSF), sediment dams, bunds, and intermediate or final cover systems. Neglecting these key components in the mine plan can result in competitive material usage and significant material deficits later in the mine's lifespan, which in turn can lead to undesirable closure outcomes and unexpected costs to rehandle or mine 'borrow' areas to make up the shortfall.

Creating and maintaining an integrated WOM model also provides a clear visual representation of the overall mining and closure sequence for better communication, transparency, and to create a shared focus of what successful closure outcomes look like for the site.

3.2 Iteratively design and schedule for mine closure

Orebody and deposit knowledge continuously improves as a mine progresses. The WOM model should also continually evolve with the new orebody and deposit knowledge to ensure any changes in material classifications, quantities, and timing of material extraction from the pit is accounted for in the landform development sequence and overall material balance. Both operational and final CML designs may need to change to align with the added information to ensure the material balance is managed throughout the mine life, while still achieving the desired closure outcomes. This iterative process often presents the challenge of balancing or negotiating priorities.

An example of this might be:

- An operational CML design may be modified to accommodate evolving material inventories or types.
- The updated CML design might necessitate a new cover system due to changes in surface area.
- The revised cover system design may require more coarse non-acid forming (NAF) rock than the previous design.
- The selective material placement within the operational CML design might need to change to ensure there is sufficient coarse NAF available for the cover system at the end of the mine's life.

Although the iterative process can be complex, it delivers tangible value to the asset and closure outcomes, even when the designs and schedule updates are at a high level. The WOM plan should capture each iteration of designs and sequences for both for mining and closure activities. Documenting each updated scenario in a separate visualization can highlight potential risks to the mine plan, the closure plan, and the overall asset value early on, enabling the implementation of strategies to enhance the asset's value.

3.3 Ongoing monitoring and review of the WOM plan across the siloes

Regular monitoring and review of the WOM plan is essential to maintain a clear strategy and foster a common goal among traditionally siloed planning departments.

Reviewing the WOM model works towards developing strategies to improve closure outcomes and reduce overall costs. This is particularly true for closure planning, as net present value (NPV) analysis often defers critical decisions until the end of the mine's lifespan.

4 Case study—Mount Rawdon operations (MRO) WOM model

4.1 Background

Evolution's MRO operation is located in Queensland, Australia, and mines gold using conventional open pit mining methods. At the time of this project, mining operations were scheduled for completion in FY24, and long-term ore stockpiles would be processed until the end of FY27.

MRO geological block model classes expit waste as NAF and potentially acid forming (PAF) with low, medium, or high capacity. The site has one active WRSF (North Waste Rock Dump, or NWRD) with an operational design that includes PAF ‘cells’ encapsulated with NAF to mitigate the potential for AMD. There is also a legacy WRSF (West Waste Rock Dump, or WWRD) that is believed to be constructed from predominantly NAF waste. The WWRD is treated as a NAF stockpile that is reclaimed to supplement expit NAF for the construction of the TSF embankments during operations.

The MRO site footprint is relatively small, and as a result, long-term ore stockpiles are built both adjacent to and on top of the active North Waste Rock Dump and will remain there until pit operations have ceased. There are complex and frequent spatial interactions between the ore stockpiles and the North Waste Rock Dump, and the operational designs of both the NWRD and ore stockpiles continuously evolve with increased orebody knowledge and changing commodity prices.

The site also has a single TSF. The TSF embankments need to be built progressively while the operation is processing ore. At MRO, the TSF embankments are strategically designed and have capacity for both NAF and PAF material.

4.2 Project objectives

MRO was planned to be closed after the completion of ore processing in FY27. The closure plan assumed cover systems could be constructed over the NWRD and TSF to create safe and stable landforms. The closure plan also assumed that there would be sufficient, suitable material available to construct the cover systems, but the material balance had not been quantified. The final profiles of the WRSF and TSF were also unknown, and the final landform surface (the position of the site at completion of mining operations and ore processing) had not yet been modelled.

During the development of the Progressive Rehabilitation and Closure Plan (PRCP), the MRO closure team recognised that the rehabilitation planning had been conducted on a domain basis instead of encompassing the Whole of Mine requirements and were aware that there was high potential for competing demands for topsoil, subsoil, regolith strata, and competent NAF rock for their cover system closure option.

As well as this, site water balance and water quality models had not been developed for this closure option.

The key project objectives were to determine whether there would be sufficient material available to complete the closure designs, model the final landform surface, then create site water balance and water quality model for the cover system closure option.

4.3 Project process

RGS Environmental Consultants (RGS) and Deswik developed the MRO WOM model by building upon the existing operational Deswik Landform and Haulage model (LHS model).

An LHS model will generate haulage scheduling and landform modelling based on the following inputs:

- Mining blocks that have been generated during the mine planning pit reserving process, and scheduled based on available equipment, production rates, and target tonnes.
- A haul road network that should represent current and future haulage routes. Haul road availability can be controlled via rules for time-based mining and physical constraints.
- Truck files for the truck fleets on site will contain parameters such as max speed, rolling resistance, fuel burn, payload, etc. These factors will be applied to the truck scheduling to ensure that both the landforms results, and the estimated truck hours reflects the site's operational capabilities
- Dumping blocks can represent interim landform designs, or closure landforms.
- Dump Dependency rules will ensure that dump blocks are filled from the bottom up, and will incorporate any other scheduling dependencies, such as a wait on a pit or strip being mined before backfilling can occur.

The MRO mine planning team had developed internally the LOM LHS model, which was primarily used to:

- schedule the pit mining operations to achieve the required ore tonnes using the available mining equipment,
- visualise and communicate the mining sequence to key stakeholders, and

- quantify the trucks hours required to achieve the mine plan.

Despite the detailed planning built into the LOM LHS model, the end position of the model did not represent the final landform at the completion of mining operations.

The WOM model built upon the LOM LHS model to incorporate:

- Modified NWRD designs that aligned with the scheduled quantities of each waste material class and the LOM mining sequence,
- Modified low-grade ore stockpile designs and sequences,
- Updated TSF embankment and decant designs,
- Construction sequences of the TSF embankments using expit NAF supplemented by NAF rehandle form the WWRD,
- Conceptual WRSF and TSF cover systems,
- Final drop structures for the TSF and WRSF, and
- Topsoil stockpiles.

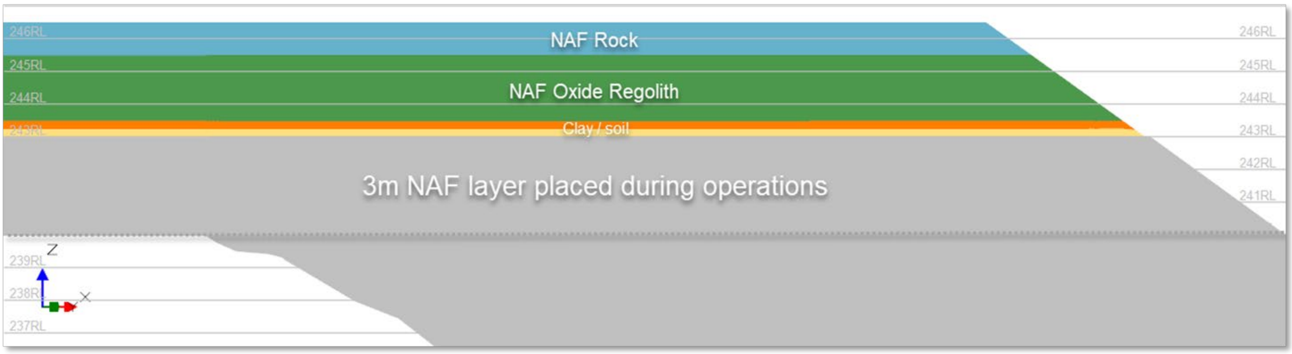

Figure 1 - North Dump conceptual cover system design

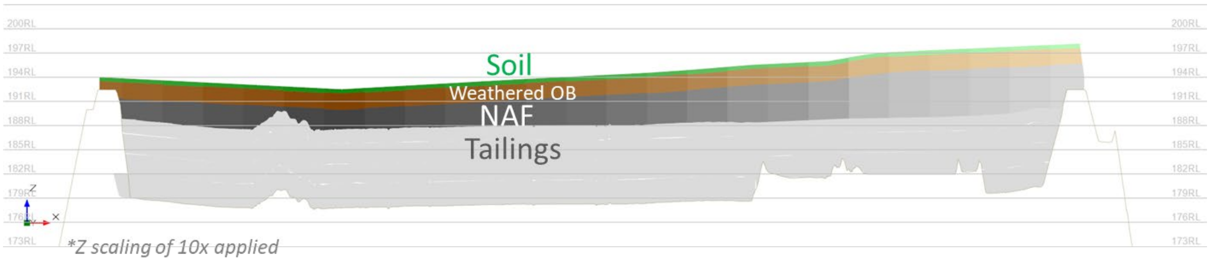

Figure 2 - TSF cover system design

4.4 Project outcomes

Initial analyses of the WOM model revealed that the remaining NAF broken stocks would not be enough to complete the NWRD and TSF conceptual cover designs, and that there was a material deficit of competent NAF at the site.

While locations had already been identified for borrow pits to source clay and weathered overburden, preliminary material characterisations completed by RGS implied that it was unlikely that the mining depth of these borrow pits would expose the competent NAF required to complete the cover systems.

This information was presented to the MRO mine planning team, and they identified another potential 'borrow area' on the crest of the MRO pit as a source for competent NAF. The current geological block model indicates that this material was not acid forming, but it was noted that additional drilling and sampling would be required to confirm the geophysical and chemical, and its suitability for use in the cover systems.

The competent NAF borrow source was added to the WOM model and provided sufficient NAF to complete the cover systems for both the TSF and the NWRD.

The WOM model sequence was further analysed and used to identify opportunities and risks for mining operations and closure activities. Initial observations included the need to rehandle PAF rock on the NWRD to accommodate low-grade ore stockpiles, and opportunity to place ex-pit PAF rock within the TSF footprint to reduce rehandle and environmental risks. These opportunities were added to the WOM model.

RGS integrated the completed WOM model with a probabilistic GoldSim water quantity and quality model. This integrated approach allowed for the evaluation of a range of probable outcomes for the post-closure landform design, including the final void. The WOM model also facilitated the verification of catchment areas within the GoldSim model and enabled the assessment of the material placement strategy's impact on water modelling.

This case study exemplifies outstanding design and integrated planning for closure. The work brought together the open pit mine planners, WRSF, and TSF technical teams to integrate their work into a WOM strategy.

5 Conclusions

The development, maintenance, and execution of a WOM model and plan come with inevitable challenges that need to be overcome. These challenges include:

- Overcoming the barriers of working across technical silos to gather and consolidate information for developing a WOM model.
- Continuously updating factors and the WOM model to incorporate feedback, address previously overlooked factors, and ensure the relevance of the WOM plan.
- Establishing standardized usage of the WOM model as a communication tool to effectively convey closure objectives and assumptions.
- Closing the feedback loop and implementing checks and balances to ensure alignment and collaboration among stakeholders towards achievable and effective closure goals
- Considering the broader perspective of the ICMM closure planning funnel across the entire asset to mitigate siloed planning within corporate teams and planning horizons.

By addressing these obstacles and integrating mine planning and design for closure, we promote transparency, knowledge sharing, and a collective, iterative journey toward achieving the desired successful outcome outlined by the ICMM and sought by society.

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