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DESIGN FOR CLOSURE. DOES IT REALLY WORK?

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ABSTRACT

Since the 1980s mines have been designed and permitted with an objective of minimizing long-term liability. This concept has been called 'Designing for Closure'. Thus the permitting process regulates both the construction/operating impacts as well as the long-term, post-closure, impacts. This paper examines the success of the initial closure design, developed at the EIA/permitting stage, at predicting the final design configurations and identifies lessons for permitting new mines. The successes and shortcomings of the original mine design and conceptual closure plans at minimizing long-term liability will be discussed.

Examples are drawn from a mine which was permitted in the late 1980's through the early 1990s. This was a mine "designed for closure" operated in B.C., for which final closure designs have nearly been developed in preparation for immediate implementation. This paper examines the issues surrounding final closure and discusses the changes to final design which resulted from operational changes during the life of the mine.

Some of the unique technical issues from the property are discussed. These relate primarily to water management and the management of potentially acid generating materials. For example, it was decided to change the management plan for the PAG waste rock from a blended dump to a water cover. However, the tailings impoundment was not originally designed with this capacity.

INTRODUCTION

Since the 1980s mines in B.C. have been designed and permitted with an objective of minimizing long-term liability. This concept has been called 'Designing for Closure'. Thus the environmental impact assessment (EIA) and permitting process regulates both the construction/operating impacts as well as the long-term, post-closure, impacts. This paper examines the success of the initial closure design, developed as part of the EIA and at the permitting stage in the Reclamation Plan, at predicting the final mine configuration and identifies lessons for permitting new mines. The successes and shortcomings of the original mine design and conceptual closure plans at minimizing long-term liability will be discussed. The QR Mine is used by way of example.

QR Mine

The QR Mine is a combination open pit and underground mine, with an 1,100 tpd mill. It is located 60 km southeast of Quesnel. It was designed as a "zero discharge" facility, such that all process water would be stored in the tailings impoundment until closure. The tailings are treated using the Inco SO_2/Air process prior to discharge to the impoundment. The closure plan for the impoundment called for all the tailings to be submerged at closure under a 1 m minimum water cover, to prevent oxidation and acid generation.

The Stage 1 Environmental Assessment (Rescan 1989) was submitted in 1989 and Approval-in-Principle was granted in July, 1990. An amended Project Development Certificate was issued in February, 1994, incorporating changes made to the project since the original approval (Kinross 1994). Mill operation commenced in May, 1995.

THE DESIGN FOR CLOSURE CONCEPT

The concept of designing a mine to minimize its long-term liability (and residual environmental impact) was developed in the early 1970's with the burgeoning EIA process in the U.S. The philosophy of planning the development of the mine while considering its long term implications is widely accepted (Mining Environmental Management, 1998) by mining and engineering companies and incorporated into regulatory guideline documents such as the Ontario Ministry of Northern Development and Mines Guidelines for the Rehabilitation of Mines (1995).

AREAS WHERE MAJOR DEVIATIONS COULD OCCUR BETWEEN EIA AND CLOSURE

There are many aspects of a mine which could deviate from the original concept over the mine life. The following is a list of some of the more likely potential variations:

- change in requirements (legislative changes, discharge limits - think how much the rules have changed in the last 20 years!);

- reserves (affects tailings volumes, waste rock volumes, mine life);
- climatological changes (global warming) or natural variation (short period of record, lengthening over the mine life);
- flood flow estimates - site specific data on precipitation (site micro-climate not fully characterized for EIA), run-off characteristics (typically smaller drainage basin area than regional stations);
- waste characterization/classification (better estimates of metal leaching rates, identification of new (different) rock types); and
- socio-community considerations (mine attracts people/activity) and changes in land use (was remote hunting/fishing, now logging, higher level of recreational use).

SPECIFIC EXAMPLES

This section examines those which have affected the QR mine.

Waste Characterization/Classification

The initial tailings facility design for the QR Mine planned for storage of tailings and tailings supernatant only. The impoundment was designed to provide sufficient storage to maintain the operation as a "zero discharge" facility. However, changes in the QR waste management policy necessitated a redesign of the impoundment with ensuing economic and water management repercussions.

At the time of the tailings impoundment design by Klohn-Crippen in 1994, mineable reserves at the QR mine were estimated at 1.3 million tonnes from three ore zones. The Main Zone was mined by open pit mining methods, the Mid-West Zone was developed as underground workings, and the West Zone was developed as two open pits. An underground working in addition to the open pits was initially anticipated in the mine plan for the West Zone; however, weak gold prices precluded further development of the ore zone.

The pre-operational mine plan estimated that a total of 2.3 million tonnes of overburden and waste rock would also be removed.

Characterization of the acid generation potential of the waste rock and tailings was carried out as part of the permitting process in the late 1980s. Preliminary testwork indicated that the tailings and some of the waste rock may be potentially acid generating (PAG). Based on this work, a waste handling plan was developed.

PAG tailings would be contained in a permanently submerged state in the tailings impoundment, and PAG and non-acid generating (NAG) waste would be used to construct a layered dump to minimize the potential for acid rock drainage. Some of the acid-consuming waste rock would be used in tailings dam construction with the remainder used in the layered dump. The dump was designed to have an overall NPR of greater than 2. It was intended that PAG waste rock materials would be stockpiled while the intervening layers of NAG waste were prepared.

Problems with the waste handling plan became apparent early on. First of all, it was evident that the practice of stockpiling and rehandling the PAG waste was very costly. In addition, it became clear that while waste rock materials had been characterized well, the quantities of each type had not been projected. There were insufficient volumes of basic, or non-acid generating, waste to construct a layered dump. An ARD Prediction and Prevention Plan was developed to prevent acid generation and metal leaching as well as to develop research plans relevant to the new waste handling plan. A key feature of this new plan was the decision to place all potentially acid generating waste in the tailings pond and the mined-out Main Zone pit for permanent underwater storage. These revisions to the waste handling plan contributed to the need to raise the ultimate crest of the tailings dam higher than the original design.

In this example, the initial design for closure did not work as expected in that the volumes of waste encountered dictated a new waste disposal method. However, the concept of designing for closure was adhered to in the development of the new waste disposal method. As a result, QR is implementing safe and cost-effective techniques to minimize the risk of ARD after closure.

Mine Size

During the permitting process the QR ore reserves were estimated at 1.3 million tonnes. Over the life of the mine the ore reserve estimates doubled. The increased reserves required higher dam raises than were originally projected, to accommodate the increased tailings volume. The lesson that can be learned from the experience at QR is that reserve estimates tend to increase, which should be considered during the tailings impoundment site selection process.

The weak gold price also affected the tailings pond design at the QR Mine. Over the course of the mine life, low low-grade ore (LLGO) had been stockpiled for future milling in the event of rising prices. However, the falling gold price meant that the LLGO was economically infeasible to mill. Rather than being an asset, the LLGO was simply potentially acid-generating waste rock and, as such, had to be placed for submergence in the tailings pond and Main Zone pit for ARD abatement. This contributed to re-design of the final tailings impoundment dams to accommodate the volumes of waste rock that would be placed within the tailings impoundment and to maintain adequate water cover over PAG tailings and waste rock.

Placement of the LLGO for submergence in both the pit and tailings impoundment also led to a re-evaluation of the water balance and water management plans for closure. The water management plan for closure involves routing all water for the catchment areas of the tailings pond and Main Zone pit through the pit, with a discharge to the Quesnel River via a small naturally occurring creek. Approximately 300 000 tonnes of waste rock is currently being deposited in the Main Zone pit, resulting in reduced storage capacity for water. The water balance was re-visited to determine when a discharge from the Main Zone pit can be expected.

Table 1 summarizes the increases in tailings pond storage requirements throughout the project life to date. The combination of tailings and waste rock to be stored in the impoundment has increased storage requirements by 225% (on a tonnage basis). This has lead to a closure design 15 m higher than the initial design effectively doubling the height of the dam.

Table 1 - Storage Requirements for Tailings Impoundment

Year	Ore (Mt) (Tailings)	PAG Waste Rock (Mt)	Total (Mt)
1994	1.3	0	1.3
1998	2.84	1.18	3.02

Precipitation Prediction/Flood Flow Estimates

While precipitation estimates for Barkerville (with 100 years of record) have not shown any significant changes in estimates of long return period events (100 year, 200 year and Probable Maximum Precipitation), correlation of site date with regional data indicate that site conditions at QR, including peak precipitation events, lie between that of high elevation, wet, Barkerville and low elevation, dry, Quesnel. However, for the initial design and conceptual closure planning, the PMP estimate used was that for Quesnel of 175 mm. Preliminary closure planning now considers the more conservative 287 mm PMP estimate for Barkerville, instead. Final design for closure will need to be based on a multi-station evaluation, a cost typically avoided at the feasibility engineering stage (i.e., EIA).

Similarly, regional analysis of run-off indicated annual site run-off could be on the order of 25% of total precipitation. However, 3 years of monitoring of the operational water balance for the tailings pond indicated a run-off coefficient of 40% is more indicative of site conditions (Klohn-Crippen, 1998). This represents an increase of over 50% in annual flows. So although site precipitation estimates have not changed significantly since the EIA stage, water management has become even more significant. As a consequence, pit filling will occur more quickly than previously calculated.

Pit Wall Failure

A pit wall failure in the Main Zone pit was another factor affecting the closure design of the tailings impoundment. As per the initial design, the tailings impoundment is situated in a valley north of the mill site. The tailings impoundment is formed by the Cross-Dyke at the southern end of the valley (at the divide) and the Tailings Dam across the valley to the north. The Cross-Dyke at the north end and the Freshwater Dam at the south form the freshwater pond. In the original design, the Freshwater Dam rather than the Cross-Dyke was intended as the permanent dam for closure. The Cross-Dyke was to be inundated by rising water levels.

A movement of Wally's Fault, trending north-south, in the Main Zone pit occurred in July 1997. Because the Main Zone pit is located just downstream of the Freshwater Dam, concerns arose regarding the effects of the pit wall movements on the long-term stability of the Freshwater Dam. Consequently, Kinross decided that the Cross-Dyke would be used as the final closure dam for the south end of the tailings impoundment. Raising the Cross-Dyke as a final closure structure required a re-design of the

Cross-Dyke to ensure stability of the dam in the long term. Had it occurred following closure, changes to the dam design would have been far more costly and difficult to implement.

This example illustrates even further that the initial design for closure did not successfully predict final design configurations. However, it serves to underline that while designing for closure is not always successful, it is a concept that must guide the decision-making process during mining as well as through closure. With the designing for closure concept in mind, QR Mine has been able to adapt to changing conditions encountered during operations and successfully plan to minimize long-term liability.

CONCLUSIONS

It is evident that designing for closure has not been entirely successful at predicting final design configurations at the QR Mine as situations arose which led to significant changes in the initial design. The experience at the QR Mine underlines the importance of accurate characterization of types and quantities of wastes generated, as well as the importance of good site selection for tailings and other mine waste storage facilities. The key issue for QR in terms of minimizing potential liability is a good waste management plan. The problems and solutions that developed at QR with respect to waste handling reinforce that designing for closure must be an integral part of mine operation.

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