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Management of mine sites after closure

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Abstract

The ideal outcome for mine closure measures is a walk-away scenario, with all hazards and liabilities resolved and with the land returned to beneficial use. Unfortunately, in the majority of cases, this ideal is not practicably attainable. After a mining company makes large capital expenditures and completes its agreed closure measures, it may still have ongoing obligations, liabilities and risks. These could include: post-closure inspections and reporting, routine care and maintenance, and in some cases, ongoing treatment of effluent. In addition, there may also be residual hazards to the public, safety concerns related to, for example, unstable crown pillars or open pit slopes as well as a risk of failures due to long return period events, such as floods and earthquakes. Uncertainties will also remain regarding the performance of the long-term closure measures. There may also be unresolved liabilities requiring financial reporting and costs associated with ongoing beneficial use of the land. If, alternatively, the mining lease is returned to the government, there may be a requirement for a lump sum payment to cover future costs associated with the unresolved liabilities.

It is possible to estimate the aggregate cost of these unresolved post-closure liabilities using risk modelling. The risk cost could then form the basis for the following alternative approaches for managing mining properties after closure:

- *Retaining the property and establishing internal funding to pay for future costs and risks.*
- *Returning the mining lease to the government, with a payment to cover the future costs and residual risks.*
- *Transferring the ownership to a special purpose company and purchasing insurance against the residual liabilities on the property.*
- *Transferring some of the assets to a local community or government with some arrangement to cover costs of future maintenance and risks.*

1 Introduction

This paper gives examples of liabilities and costs that are associated with former mining properties even after the agreed closure measures have been completed. It also discusses using risk modelling to estimate future costs and discusses alternative approaches for management of mine sites after closure.

After a mining company completes its agreed closure measures, it may still have ongoing liabilities and risks such as:

- Long-term post-closure inspections and reporting.
- Routine care and maintenance.
- Ongoing treatment of effluent (in some cases).
- Hazards to public safety related to unstable crown pillars, open pit slopes, etc.
- Costs associated with the risk of failures due to long return period events, such as floods and earthquakes.

- Lump sum payments associated with returning the mining lease to the government.
- Unresolved liabilities requiring financial reporting.
- Costs associated with ongoing beneficial use of the land.

2 Post-closure liabilities

2.1 Definition of post-closure liabilities

In most jurisdictions, mines are now required to post some form of closure financial assurance with the government before going into operation. In addition, financial reporting rules require publicly traded mining companies to state in their annual reports the aggregate amount of their liabilities to close their operations (e.g. Asset Retirement Obligation, Canada or FAS 143, USA). Rules for estimating the financial assurance amounts and the asset retirement obligations vary from one jurisdiction to another. Nonetheless, both these amounts often comprise a defensible estimate of the costs to execute agreed closure measures. In this instance, agreed closure measures are the physical actions, e.g. demolition of buildings, site cleanup and revegetation, that are listed in a mine closure plan. Agreed closure measures would normally also include planned monitoring activities used to verify the effectiveness of the closure measures. The planned monitoring activities that are allowed for in closure plans are often relatively short-term in nature, typically in the range of five to ten years.

At the majority of mine sites, it will not be possible to achieve a walk-away closure. In other words, execution of the agreed closure measures is unlikely to resolve all the future liabilities associated with the closed mine site. There will be long-term costs or liabilities that are typically not funded by the financial assurance, nor allowed for in the calculation of the asset retirement obligation. For the purpose of this paper, post-closure liabilities are defined as long-term residual liabilities associated with a former mine site that remain after the agreed closure measures have been completed. These are discussed below.

Despite best efforts, uncertainty is inherent in mine closure. This uncertainty reflects limitations in our understanding of the issues to be resolved, such as acid mine drainage from waste rock piles and also with respect to the performance of measures chosen to mitigate those issues, such as covers. Unacceptable closure performance, such as acidic drainage from the toe of a waste rock dump, may not become apparent for many years. For this reason, governments are increasingly reluctant to accept ownership of closed mining facilities.

Experience has shown that changes in societal expectations over time can lead to increasingly stringent environmental standards as well as progressively more stringent design standards for containment structures. These changes can have significant cost implications with respect to the ongoing future management of the decommissioned facilities.

2.2 Examples of post-closure liabilities

Table 1 provides a list of common post-closure liabilities. It also indicates the disruptive agents (e.g. earthquake, flood, fire, etc.) that cause each liability.

Table 1 Examples of post-closure liabilities

Potential Liability	Disruptive Agent	Post-closure Management
Erosion by runoff from site	Erosion, channel blockages	Regular maintenance of hydraulic structures
Unacceptable discharge water quality	Mine waste geochemistry	Ongoing treatment and monitoring
Unacceptable groundwater quality	Mine waste geochemistry	Ongoing interception and monitoring
Crown pillar collapse	Gravity, groundwater, collapse of supports	Establish safe setbacks and barriers or fencing, monitoring
Instability of open pit slopes	Gravity, weathering, erosion	Establish safe setbacks and barriers or fencing
Failure of shaft caps	Structural failure, corrosion	Inspection and repair
Dam failure – loss of containment	Extreme earthquakes/liquefaction	Repair dam and cleanup spilled tailings
Dam failure – overtopping	Extreme rainfall, plugging of spillways	Repair dam and cleanup spilled tailings
Dam failure – overtopping	Plugging of decants or spillways	Ongoing inspection and maintenance
Public safety hazards	Public access	Ongoing security, fence maintenance
Loss of vegetative cover	Drought, fire	Monitor and revegetate as required
Dry cover failure	Vegetation, ground movement, frost, erosion, intrusion by burrowing animals or humans	Surveillance and maintenance
Water cover depletion	Drought, seepage	Surveillance, seepage mitigation, water diversion
Dusting	Erosion, lack of vegetation	Maintenance of vegetation cover
Excessive seepage	Failure of liner, dry cover or dam	Surveillance and repair

The question arises, "Can these liabilities be eliminated by implementing appropriate closure measures, and indeed by designing the mining operation for closure?". Unfortunately, the answer is "no, not usually". Typical examples of unresolved liabilities include the following:

- *Site runoff:* There will always be some risk of runoff at all closed mine sites. In wet climates, runoff may be continuous. In dry climates, runoff may be a very infrequent phenomenon. Nevertheless, there may be increased risks associated with flash flooding. For this reason, agreed closure measures usually includes provision, i.e. hydraulic structures, channels, etc., to direct runoff safely off the site. Unfortunately, hydraulic structures and channels are never maintenance free. They can be seriously eroded when flows occur that exceed the design basis flow for the channel. Serious flooding and damage can also result if hydraulic structures become blocked by debris or vegetation or by the actions of animals. For example, in parts of Canada, the requirement for the frequent clearing of beaver dams often presents the single largest demand for maintenance on closed mine sites.

- *Crown pillar collapse:* Around the world there are many historic mining areas that have been seriously affected by the post-closure collapse of crown pillars where underground mine workings approach the ground surface. Carter and Miller (1995) list and assess unstable crown pillars at multiple sites in Ontario, Canada. Aside from property damage and the direct risk to public safety, unstable crown pillars have effectively sterilised large areas against future development. There is no question that rock mechanics and the application of modern mining methods have greatly reduced the risk of crown pillar collapses above modern mines. Also, agreed closure measures sometimes include stabilisation of crown pillars by structural spanning, backfilling, or blasting. Nonetheless, it is not usually possible to completely eliminate the risk of collapse or subsidence.
- *Dam failure:* At many mine sites, one or more dams will be left on-site after closure to contain water and/or tailings in perpetuity. Currently, these dams are designed to remain stable under seismic (earthquake) loading, and this design normally also takes into account the possibility of seismically induced liquefaction of the tailings, of the dam itself and also of the foundation of the dam. The intensity of the seismic loading used for design purposes is selected by taking into account the seismicity of the area, the failure consequence category of the dam and the design life of the facility. As an example, it is not unusual to design a closed tailings dam to resist seismic loadings associated with an earthquake with a return period of 1,000 years. While this is a reasonable engineering approach, it does leave some residual risk. Firstly, there is uncertainty in predicting the seismic loading and also in predicting how the dam and its foundation will respond to the loading. Secondly, there is a chance, albeit small, that a seismic event will occur that exceeds the selected return period.
- *Cover failure:* Dry covers are now commonly used to rehabilitate tailings and rock dumps, especially in arid and semi-arid environments. Where acid rock drainage is an issue, dry covers are designed to limit the ingress of water and/or air to inhibit oxidation of the sulphide minerals. Covers on coal wastes aim to reduce oxygen flux in order to prevent spontaneous combustion and the resulting danger to the public. The integrity of the dry cover can be affected by climatic conditions (such as frost or drought), by erosion, and also by damage by vegetation roots. Ground movement has been especially problematic for dry covers on rock dumps. If the cover makes use of geosynthetics such as geomembranes or geotextiles, the finite longevity of geosynthetics will be a concern because the design life of closure works is effectively in perpetuity. It may be necessary to allow for the periodic replacement of geosynthetics over the long-term.

2.3 Post-closure management of liabilities

Table 1 lists possible management approaches that can be taken in dealing with particular residual liabilities and disruptive events that can occur after closure. These approaches generally fall into three categories:

- *Routine inspection and maintenance:* Routine inspection and maintenance is necessary for water control and conveyance facilities, as well as for maintenance of vegetation. Where active effluent treatment is provided after closure, planned maintenance can include equipment replacement/upgrades, dredging and disposal of water treatment sludge, and similar activities. In many closed mining facilities, some degree of environmental monitoring may be required in the medium- and long-term. Because the actions in this category are by definition routine, it is relatively straightforward to predict the ongoing effort, cost and schedule associated with them.
- *Keeping the public away from unresolved hazards:* Where it is not practicable to remove public safety hazards, the next best thing is to keep the public away from those hazards. For example, rock mechanics studies can be completed to establish safe setbacks around open pit slopes or potentially unstable crown pillar areas. These areas can then be securely fenced off. Fences and other barriers need to be inspected, maintained and periodically replaced in perpetuity. It is relatively straightforward to predict the costs and schedule associated with such maintenance. Hazardous lands are likely to be unavailable for future productive use after closure. At the very least, their future land use may be restricted, and these restrictions may be registered on the land title.
- *Repairs as necessary:* The disruptive events that can bring about the need for repairs to closed facilities are stochastic in nature. Engineering facilities such as dams and spillways are necessarily designed for certain deterministic limits, such as maximum earthquake accelerations or flood flows

of a particular return period. There will always be a residual risk that a disruptive event will occur which will exceed the design limit and such long return period events may cause serious damage. The most realistic way of dealing with this residual risk of unplanned disruptive events is to have contingency plans in place to repair the damage. For example, if a tailings dam fails because a long return period seismic event or flood occurs, then the dam needs to be repaired and any tailings that have escaped need to be cleaned up and put back into containment. It is not possible to predict in advance the magnitude and timing of future disruptive events, they can only be dealt with as a probability function. As a result, the cost and timing of repairs must be dealt with as a probabilistic risk.

3 Risk modelling of post-closure liabilities

3.1 Limitations with deterministic approaches

Procedures for estimating costs associated with mine closure (as distinct from the post-closure liabilities that are the topic of this paper) are now fairly well established, particularly for the determination of financial assurance amounts or asset retirement obligations. These closure costs are usually expressed as a single lump sum cost, which is calculated deterministically. This deterministic approach can be justified for closure costing for several reasons:

- The agreed closure measures are well defined and are agreed upon between the mining company and the regulator.
- The majority of closure costs usually comprise capital costs incurred within one or two years of the date of mine closure, so the timing of these costs is predictable.
- Closure measures are normally engineered using design standards that incorporate defined return periods for disruptive events. The probabilistic liabilities associated with longer return period events are ignored.
- Closure plans often include a commitment to carry out certain actions after closure, such as inspections, periodic water quality sampling and even water treatment. However, the commitment is often for a relatively short period such as five or ten years. These costs are usually reduced to a net present cost (NPC) using an agreed discount rate.

Some authors, mining companies and regulators have recognised the value of risk modelling for closure costs, but the use of such modelling is still fairly limited.

The use of deterministic estimates is not adequate for the calculation of post-closure liabilities, for several reasons:

- The design period for post-closure is effectively in perpetuity, so it is difficult to justify ignoring the residual liabilities associated with disruptive events that have a return period greater than the return period that was used for the deterministic design of the facilities.
- The timing of repairs as necessary actions is completely unknown and thus the NPC of these actions can only be assessed using risk modelling.
- It is not realistic to represent, as a single deterministic cost figure, the sum of the liabilities from low probability events of uncertain timing over a design life of forever. The output from risk modelling is a cost versus probability curve which represents the liabilities in a more realistic manner.

3.2 Application of risk modelling approaches

Within the Canadian regulatory framework, the costs to mitigate unplanned, long return period events are typically excluded from the financial assurance for closure. However, in special circumstances, the proponent has been required to adapt a probabilistic approach to estimate the post-closure liabilities. During the closure of the federally regulated Quirke uranium tailings management area in Ontario, Canada, a probabilistic performance assessment was carried out for the decommissioned facility (Welch et al., 1997). The assessment considered long-term performance and made provisions for extreme disruptive events that may occur over a long period of time. A Monte Carlo stochastic model was run repeatedly for time periods ranging from 200 to 1,000 years. The results were expressed in cumulative probability curves for damages (or lack of performance) and cost. Interestingly, the results indicated that the overall liabilities for the repair of damage from extreme events, such as seismically induced dam failure, are generally small compared to the costs for routine surveillance and maintenance.

Risk assessment is increasingly being used as a tool to evaluate residual liabilities for closed mining facilities. There are usually difficulties related to the lack of precedent data. For example, it is generally unreliable to extrapolate a 10,000 rainfall event from 50 years of precipitation records. For this reason, the risk assessment is usually conducted by an expert panel and includes three steps: hazard identification (failure modes); risk analysis (severity and likelihood of failure); and risk evaluation (risk acceptance and mitigation). Expert judgement is commonly used to provide input into the model with respect to the following: the consequences of extreme events, the threshold at which damage first occurs and the likelihood of its occurrence. The risk evaluation matrix considers environmental, safety, regulatory and financial impacts of the failure and forms a basis for actions to mitigate the risk.

Closure risk assessment can also be used to consider changing societal expectations over time as reflected in regulations and public perceptions of mining development. This has led some mining companies to focus more resources on community communication and to alter their strategy for effluent treatment. An example for the latter case is the use of as low as reasonably practicable (ALARP) as a criterion for treated effluent water quality.

Post-closure liabilities are ultimately integrated in a computer model and they are expressed in terms of cost. While it is still commonplace to calculate a single value of expected post-closure cost, there is a growing recognition that the cost estimate itself is inherently variable. A probabilistic-based cost estimate can provide a more robust answer. The results are expressed as an ‘S-shaped’ curve of cost versus the probability of exceedance. Figure 1 shows typical probabilistic cost predictions.

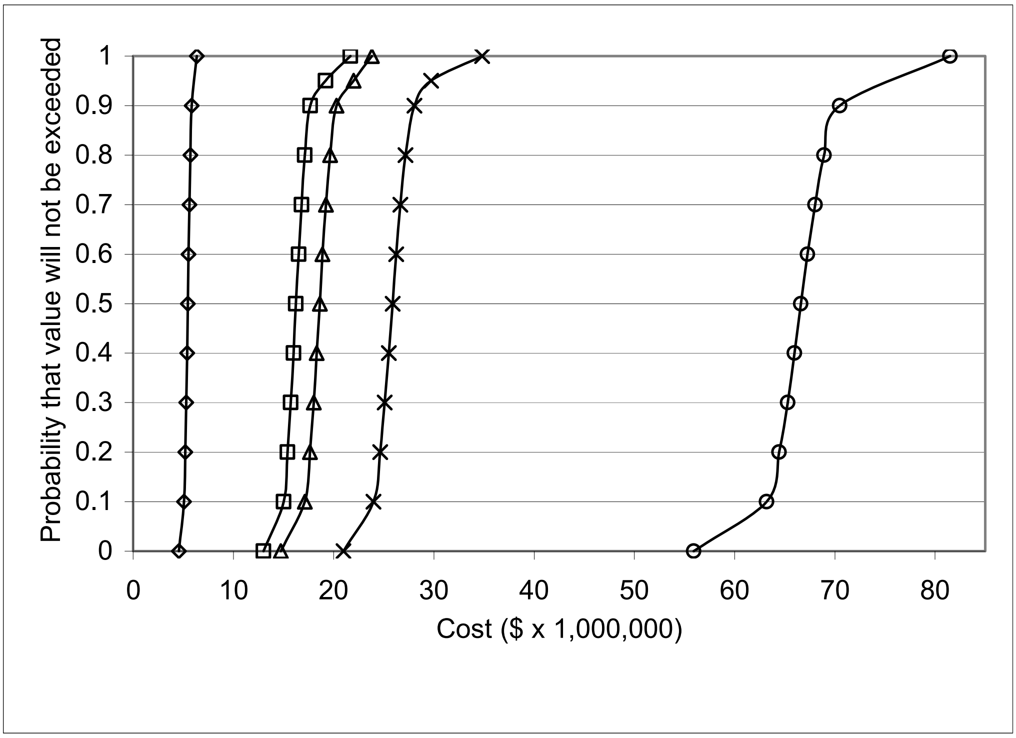

Figure 1 Typical stochastic prediction of care and maintenance costs for five tailings areas

Based on stochastic simulation with cost parameters that have predetermined probabilistic distribution functions, the cost model can answer questions such as “How much money does a mining company need to put aside to satisfy the outstanding liabilities 50% of the time?”. The process of computing the likely range of overall costs and also the distribution of each individual cost component can be very instructive. It can indicate cost-effective actions that can reduce the liability. For example, the construction of a back-up 'dry spillway' in an impoundment can reduce the consequences of plugging of the main service spillway. In short, risk modelling can serve as an invaluable tool to help manage the outstanding liabilities.

4 Approaches for management of mining properties after closure

There are several options available to mining companies for the management or disposition of mining properties after they have completed the agreed closure measures. Four such options are discussed below.

4.1 Retaining mining properties

By default, most closed out mining properties remain in the hands of mining companies. This is not a desirable outcome for the companies because it leaves them with unresolved liabilities with respect to properties that may have little or no remaining commercial value. They will likely incur costs on an ongoing basis for the inspection and routine maintenance of the property at the very least. They are also at some risk of facing large expenditures should low probability events occur, such as a tailings dam failure due to a large seismic event. Depending on accounting rules in the jurisdiction where their stock is listed, they may also have to report some of these unresolved liabilities as ongoing asset retirement obligations on their books. Risk modelling provides a means of estimating an appropriate level of internal funding to cover the future management of retained closed properties.

4.2 Returning mining properties to the government

Many jurisdictions have provisions in the law governing mining which theoretically allows mining companies to return closed out mining properties back to the government. If such a return takes place, the mining company will cease to be responsible for future environmental liabilities associated with the property, and these responsibilities will become the responsibility of the public through government. Out of the public interest, the government will place strict conditions on such a transaction.

Regulations and guidelines in this area are still being developed. However, it is expected that the conditions that will apply to returning closed mining properties to the government will include the following provisions:

- A final environmental audit must be carried out that demonstrates that the property has been closed out as per the filed closure plan.
- Items that will require long-term or perpetual care must be identified and a risk assessment must be performed regarding those items.
- An estimate must be prepared of the long-term or perpetual care costs to maintain identified items.
- The mining company would then have to make provisions to fund the costs of future care of the property.

While the potential to return mining properties to the government is recognised in a number of jurisdictions, the authors are aware of only one site on four continents where a closed mine has actually been returned. Some simple exploration properties, which did not have milling facilities or tailings areas, have been returned recently, but only one mine per se. Also, several mines were returned prior to the advent of closure planning in the 1990s. For that reason, little or no precedent has yet been set with respect to the terms, conditions and financial payments for such a property return. Risk modelling is likely to be a key component of reaching agreement on a financial payment upon return of future properties.

4.3 Transferring ownership and using insurance to manage post-closure risks

A mining company could achieve a responsible exit from a closed mine through an environmental liability transfer programme that would insure the residual environmental liabilities in an arms-length special purpose company (SPC) that provides a complete indemnity and financial assurance to the regulator. The SPC would assume the management responsibility for all aspects of the post-closure liabilities, retaining contractors and professional advisory services, as appropriate.

The cornerstone of this programme is an environmental insurance and risk financing structure underwritten by a highly-rated insurer and financial institution. In this instance, the insurer will use risk modelling to establish the insurance premiums. The funds required to implement an environmental liability transfer programme would be treated as an insurance premium expense for tax purposes and the closure liabilities may be removed from the financial statements of the mining company (Fitzgerald, 2006).

4.4 Transferring assets to local communities

Development of new mines involves expenditures amounting to hundreds of millions of dollars, and such development often creates significant capital assets. These assets could include: town sites, access roads, power lines, electrical substations, port facilities, air strips, water supplies, and the like, which could potentially have enduring value to local communities even after the mine closes. Transferring valuable assets to a local community or to government can meet sustainability objectives. It can also reduce closure costs by eliminating the need to dismantle, demolish and dispose of the assets. At the same time, there are likely to be unresolved liabilities associated with the transferred assets. Infrastructure requires regular maintenance and can be damaged by extreme events. As a result, the assets may not be fiscally self-sustaining for the community, or the government may be unwilling to take on the perceived liabilities. It may be necessary to set up funding to cover future maintenance and risks. Once again, risk modelling can help evaluate these options.

5 Conclusion

Mine closure planning has advanced significantly over the past two decades. As mining properties complete their agreed closure measures, the realisation is growing that most properties will continue to have residual liabilities post-closure. It is necessary to use risk modelling techniques to realistically evaluate the value of these post-closure liabilities. Such a valuation will be required regardless of how the property is managed after closure: by retaining ownership, by transferring the property to the government, by transferring the property to an SPC using insurance, or by transferring assets to a local community.

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