Due Diligence, Sustainable Development & Environmental Mining for New and Existing Mines

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Abstract

Due Diligence and Sustainable Development – we have heard the terms and used the words; we know their definition and understand the real purpose behind them. But how far have we gone in integrating the concepts into our plans, our mine designs, and ultimately our day to day operations?

When environmental awareness and protection was first being promoted over two decades ago, the process was typically driven through a regulatory approach, which would be followed by discussions, arguments and a reluctant compliance. In some cases compliance came at the cost of premature abandonment of projects and the threat of closure. Certainly in some cases this process continues, but from a modern mining perspective there is more and more evidence of a fundamental change in the approach to mining and the environment.

This new approach to sustainable mining is often referred to as Environmental Mining and typically involves the following four major steps:

1. Characterization of the natural environment;
2. Identification of the potential environmental impacts and risk;
3. Ranking of risks and potential impacts and probing back through process operations and mine design to identify the significant issues; and
4. Integration of sustainable mine and process designs.

In this paper, the Environmental Mining concept is discussed and examples are given of both new and existing mining operations where the Environmental Mining process led to a significant change in the mining operations and resultant reduction in environmental degradation, environmental risk and related costs.

Introduction

It sometimes takes a long time for new, and what some may consider, controversial "ideas" to become accepted practice. Some argue that in the conservative mining industry, one of the oldest industries in human history, we should expect change to come even more slowly.

Sustainable Development is the, somewhat elusive, "holy grail" of industry today. It may ultimately also be the measuring stick by which society will value (or devalue) our industry. Mining, in particular, has struggled with the concept of sustainable development. As a primary resource extraction, mining, by definition, is both intrusive and finite.

Such efforts as *The Global Mining Initiative* underscore the enormous pressures being exerted by society on the mining industry, and correspondingly, the enormous effort by the industry to change the situation. From a modern mining perspective, there is more and more evidence of a fundamental change in the approach to sustainable development issues. This paper illustrates only a few examples of the types of advancements that have been made.

Sustainable / "Environmental" Mining

In the past, when it came to environmental matters, industry members typically acted in a reactive mode; we identified a problem and then tried to fix it. Water pollution was managed through treatment; large tailings or mine dumps by covering them (usually at the very end of the mine life). Experience has taught us that this may be neither efficient nor effective (from an environmental or cost perspective). As environmental considerations are now being treated as an integral component of new mine development and design, we can avoid or mitigate some of these historical problems through better site design and materials management. We also have the opportunity to change operations or plans at existing mines where the risks associated with inertia are often far greater than action. Though it takes thinking outside the box to truly get away from repeating our past mistakes, we are seeing a change in industry towards proactive rather than reactive environmental management.

The phrases "Environmental Mining" and "Sustainable Mining" are being used much more commonly by mineral extraction professionals in the context of modern mining. The references express a more proactive approach to incorporating the goals and objectives of sustainable development and incorporating due diligence in all aspects, for both new mine developments as well as operating mines. Moreover, sound environmental management is seen as an integral part of the business. Typically, the process includes four major steps:

1. The characterization of the natural environment prior to development (as a "greenfield project") i.e., *understand your starting point or baseline;*
2. Realistic, rigorous, and systematic identification of the potential environmental impacts and risk of the project or proposed changes to an existing operation (this should include stakeholder risk elements);
3. Ranking of the risks and potential impacts, then, using the knowledge gained to iteratively probe back through the project and mine design to identify the significant issues; and
4. Integration of sustainable mine and process designs based on risk reduction, practicality of implementation, and cost, i.e., *know where you are going.*

The first step includes an initial environmental baseline study or environmental assessment to characterize the existing background environment and susceptible receivers. Sensitive areas are identified and these are considered during the mine planning stage. This can be a crucial step in many cases, and should not be underestimated with regard to its importance to future mining activities.

The second step includes various predictive or forecasting methods aimed at determining and managing the potential environmental impact related to the various aspects of mining operations. Laboratory testing, including acid rock and mine neutral drainage predictive tests, detailed mineralogical examination and the use of computer and physical modelling, will typically play a large role in this stage. Recognizing there are limitations in both testing and modelling, we have learned not to rely on one single method or tool in providing predictive data but to accumulate and analyse information from a combination of these tools and methods.

In operating mines, the second step may include all of the above as well as impact assessments on specific receivers and other useful tools such as Environmental Effects Monitoring and Toxicity Reduction Evaluations. After completion of the second step we should have a better idea of what impacts we might expect, their source, and what effective measures may be taken to reduce or eliminate those impacts.

This takes us to the third step in the environmental mining process. At this stage we have to determine the risks associated with each potential or existing impact. Then we need to look back. By this we mean: look to the processing; look to the current mine plan; look to the materials management. Can any of these be changed to reduce / eliminate an impact or risk? In many ways this third step is an exercise in waste management.

For every tonne of ore, there are often times multiple tonnes of material that have to be blasted, broken, processed through physical and chemical means, and then ultimately cast into a product, or disposed of in an engineered containment; in other words, managed. In some cases, the same material has to go through more than one handling loop. Two things should be obvious at this point: a fundamental aspect of the mining business is materials management and we have to get EVERYONE involved in this aspect of the operation. That includes the mining engineers, geologists and metallurgists. This is not "the other guy's or department's problem", because if neglected, it soon becomes *everyone's* problem. In looking at all materials in the process, some basic questions have to be asked: Do we really need the material? Are there better substitutes or a better use of the material? If we recycle water, change a chemical or part of the flotation process could this minimize or eliminate environmental problems or risks?

The ultimate goal of this third stage is to be proactive rather than reactive. We know treatment works, but with treatment also comes the acknowledgement of a long term cost, plus the treatment product to deal with. Treatment should be a last option.

The last step is the corrective action. Economics will play a large role in this stage especially where changes in operations are called for which may have significant economic impacts for the mine. Continuous improvement and a re-iterative step should also be included here to ensure the "corrective action" does not result in different but still significant risks.

This approach has been used by many of the world's mining companies both in initiating new projects and in operating existing mines. This paper briefly discusses the environmental mining process noted above and provides examples of both new and existing mining operations where the process led to a significant change in the mining operations and resultant reduction in environmental degradation, environmental risk and related costs.

Sustainable Mine Planning

The concept of Environmental Mining was applied at the initial mine planning stage of Barrick Gold Corporations' Bulyanhulu Gold Mine in Northern Tanzania. The site had several environmental constraints, including a limited supply of fresh water and potentially acid generating tailings. In response to these environmental issues the mine implemented a total paste solution for tailings management (Theriault, Frostiak & Welch, 2003).

Twenty-five percent of the tailings produced by the mill is blended with rock and used as backfill to provide stope support as the underground workings advance. The remaining tailings are deposited as paste at surface.

The use of paste tailings both below and above ground has resulted in the following environmental benefits at the Bulyanhulu mine:

1) **Reduced risk of high-consequence off-site impacts.** Typical conventional tailings facilities possess a fluid-retention dam and an elevated internal pond. In the event of dam instability, the pond acts as a driver for high-consequence off-site impacts. The Bulyanhulu paste tailings facility does not possess an elevated internal pond, nor does it impound tailings water; consequently, the risk of off-site impacts is greatly reduced.
2) **Less surface area is impacted.** Since the paste tailings are of higher density than conventional hydraulically placed tailings, the resultant footprint of the tailings facility is reduced.
3) **Less borrow material is consumed.** Since paste tailings require minimal physical containment, and since paste tailings are also being used for backfill material, there is a significant reduction in the quantities of borrow material consumed and, consequently, less surface area is impacted.
4) **Water conservation is realized through:** (a) recycling the filtered water in the process facility; (b) reduced runoff and seepage because of lower volumes of water being deposited with the tailings and the smaller

tailings facility catchment; and (c) reduced water treatment and water storage requirements.

5) **Paste tailings significantly increase the potential for concurrent reclamation.** Since a higher fraction of the tailings facility's surface is trafficable during operations, and since the paste tailings is near final density shortly after placement, a greater amount of concurrent reclamation is possible.

This approach to tailings and waste management can be considered key to the future of Environmental Mining.

Risk Management & Destroying Value

A critical area of materials management planning in mining operations is the management of what we typically call waste materials. Using an example of a pit with a stripping ratio of 3 : 1 (3 tonnes waste for every tonne of ore) at a mining rate of 1 million tonnes per year, means that 3 million tonnes of waste rock will be generated on an annual basis. Typically, an analysis would be performed on the waste materials (though geologic and analytical techniques) to determine its Acid Generation Potential. On the basis of this information, designated sites for the placement of the material will be chosen. Based on the given criteria, the ore grade, the cut off grades, the haul distance, etc., the economics of the ore body and the return on investment are then calculated and a mine plan developed.

Historically, during the mine design phase, key environmental controls such as: surface water management and diversion systems, water pumping and piping systems, and the labor to operate these systems, were underestimated. This results in the need for mine operations to handle excessive quantities of water in an ineffective manner, which is particularly evident during intemperate times such as winter and spring runoff.

A factor that is often overlooked is the aspect of neutral drainage. Typically there is a sense of relief that your waste will not, according to the tests, cause acid mine drainage. But that can be only part of the story. For example, neutral or alkaline mine drainage (NAMD), though non-acidic as its name implies, can still have elevated concentrations of sulphate, iron and manganese. If the possibility of NAMD was not determined, there suddenly may be a 3 million tonne pile that now has to be considered leachable and requiring control. Since the staging area was originally designed for a "benign" material you are now forced to recondition this area with proper drainage, water collection and treatment. Moreover, as this may be located a significant distance away from the pit, a substantial element has been added to the watershed management issues.

Taking into account the new reality, 3 million tonnes of materials, which were originally budgeted for $1 a tonne, will now cost say, $3 dollars a tonne (additional reclamation costs), a net increase of $6 million dollars ***per year*** to the mining costs. Additionally, you must add increased pumping, piping, collection, power and labor to your annual operating costs while the reclamation plans are being revised. It is easy to see how a new cost structure can evolve if proper environmental risk management measures are not put into place. There can also be a substantial credibility cost associated with past mistakes and subsequent delays in acquiring regulatory permits.

At Falconbridge's Raglan mine, work beyond the initial baseline study was continued to better understand the long-term behaviour of the waste rock. Although the potential to generate acid mine drainage was very low, there was potential for neutral drainage. Even though very little literature was available for comparative value, it was determined that there was sufficient risk to consider alternative plans. In one particular planned pit, the original mine plan was changed, stripping ratios were reduced dramatically and the work to begin an underground operation was commenced two years ahead of the original mine plan (and budget of course). The net result was that, to date, over 10 million tonnes of potentially problematic waste was eliminated from being exposed at surface. In addition, the mine plan was modified to incorporate new, more stringent, waste handling protocols for all surface mining activities. These protocols are amongst the most stringent known in the industry. Other ore bodies for future development have since been re-examined and designed to meet the criteria.

More Materials Management (Water, water everywhere……)

One area that is becoming a prime focus is the tremendous "water intensity" associated with the mining industry. There can be no question that water consumption is an issue with the industry. At Falconbridge's Raglan mine in Northern Quebec, although the effluent from the milling operations met all other criteria of the government guidelines, it could not meet the toxicity requirement, primarily due to its concentration of "salts" (the test is done with fresh water species). Typically, all efforts would be focussed on treating or diluting the problem to eliminate the effect. In other words, look at the end of the process (the treatment side) for solutions.

In this case, a different type of solution was proposed and it was proposed on the basis of the following question: why have an effluent at all?

It was clear in this situation, that there were no easy solutions, so the longer-term solution was sought. Over an almost two-year period, tests were conducted, processes reviewed and a water balance performed to seek opportunities to convert to a "zero discharge operation". At the end of these investigations it was found to be technically achievable, yet there remained some mineralogical questions. After a thorough review and the appropriate level of engineering and tests, an underground recycle reservoir was constructed (into permafrost) and what is believed to be the first of its kind (at least in this environment) 100% recycle project for mill process water was initiated.

Over the two-year construction period, the fresh water consumption had fallen by almost 25%, while milling production was up almost 20%. Also, the discharge of mill treated effluent will be decreased by almost 200 million liters per year (reducing with it the associated loadings). It is anticipated that these benefits will be retained over the rest of the mine life. Although still in commissioning, the prospects are tremendous. The implications are clear: the mining industry can demonstrate that better ways of doing things are possible.

One crucial point to the success of this project was that ALL departments and a variety of people were involved, including the mine, the mill, engineering and the environmental department. This cooperative effort had a huge positive impact on the project!

Fundamentally, it must be kept in mind that every gallon that goes into our processes must leave somewhere. It will leave after we have added heat, energy, reagents, and of course the associated capital structures to handle large volumes (which may not have been necessary in the first place). The science of metallurgy has advanced tremendously, and will continue to advance, taking into account these new challenges, but alternatives will only come available if we continue to look for them. Paraphrasing Samuel Taylor Coleridge in *The Rhyme of the Ancient Mariner*: "Water, water everywhere, but not a drop to drink". Perhaps in the modern world we can add: "at least not for free."

Fixing an Existing Problem

The concentrator facility at the Falconbridge Sudbury Operations Strathcona Mill produces two separate tailings streams:

1. a low sulphur tailings (typically 0.6 to 0.7% total sulphur) that is produced as a tailings from the scavenger flotation circuits and is further processed by cyclones into a coarse fraction used for backfill purposes by the mines and a discarded fine fraction; and

2. pyrrhotite tailings containing approximately 30% sulphur that originates as a reject from the pyrrhotite flotation circuit.

Prior to 1994, the two types of tailings were discharged into the Strathcona tailings basin from a common point. As a result, the tailings mass was a blend of the two streams and contained an average of about 15% sulphur. The Strathcona Mill tailings currently cover an area of approximately 110 hectares with a maximum depth of tailings in the basin of greater than 20 metres. Oxidation of the sulphur in the tailings has resulted in the generation of Acid Rock Drainage and Metal Leaching (ARD & ML), which is currently being treated downstream of the tailings area.

To reduce the generation of ARD from the tailings, in 1995 Falconbridge initiated studies to assess the performance of various potential covers for the facility. The results of this program showed the low sulphur slimes had an excellent potential for use as a cover for the existing tailings. Falconbridge then enlisted the expertise of several consulting groups to further evaluate this cover concept. This led to:

- pilot plant testing to investigate the potential achievable reduction in sulphur content. The results of the pilot plant test showed that the total sulphur levels were reduced from 0.65% to 0.34%, or a drop of approximately 0.3% sulphur within the range of interest. However, the pilot plant test also indicated that the neutralization potential was reduced as the sulphur content decreased.
- Static and kinetic testing to evaluate the effectiveness of the current tailings deposition method in generating a homogeneous, non-potentially ML/ARD generating cover. The test results indicated that the potential still existed for ARD generation and that limiting deep crack development through the low sulphur slimes cover was necessary to successfully limit the potential for ARD generation.
- Computer modelling to assess the performance of the proposed low sulphur tailings cover in inhibiting ML/ARD. This work helped define a minimum thickness for the cover layer.
- Hydrogeological / physical studies of the tailings also assisted in defining cover layer thickness.

The results of these studies have led to the development of revised operational management and closure plans for the Strathcona Mill tailings. The revised plan involves covering two areas of the tailings with a layer of thickened, low sulphur tailings slimes at least 1.4 metres in thickness, and on top of this placing a thin protective layer to promote vegetation and minimize erosion and evaporation. Due to the practical slimes placement issues, and the physical and chemical segregation issues, Falconbridge plans to switch to a thickened tailings discharge for the final low sulphur tailings cover. A thickener is to be installed at the tailings area in order to allow for the placement of a homogeneous and laterally consistent cover over that area as efficiently as possible. As a final due diligence measure, Falconbridge also decided to add lime to the low sulphur tailings slimes to ensure that operational variability's of the tailings quality were taken into consideration in the final cover.

This, combined with ongoing monitoring, will ensure that the cover is relatively uniform in composition and thickness. A third area, comprised largely of pyrrhotite, will be flooded to minimize future ML/ARD generation through the construction of permanent water retaining closure dams.

Conclusion

The process of Environmental Mining is a concept that has developed over the years and, while components of the process are used regularly, the concept as a whole deserves consideration at all stages of mine development. We have demonstrated through examples the application of the process and the successes that are possible with this approach.

Theriault, Frostiak & Welch, (2003) indicate that Bulyanhulu is among the first mines in the world to implement true surface paste disposal;

the environmental advantages of which are several and may yet be underestimated. The production and separate management of different tailings streams for different uses at Falconbridge's Sudbury Operations has resulted in a tailings management plan that both takes advantage of the existing mill circuit and provides a solution for closure. Meanwhile Falconbridge's Raglan mine operations revised their mine plans to reduce their overall environmental risk while maintaining credibility and offering opportunities for continued development in this very sensitive environment.

Each of these approaches holds promise for application at other mining operations around the world. Each will help to avoid significant reclamation costs to the operations and ensure long-term sustainability. And each is also an excellent example of the type of innovative thinking and willingness to try new things that will lead the mining industry to continued success as a sustainable industry.

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References

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