Panel Discussion

Disclaimer

The following notes on the panel discussion are not verbatim transcripts, but rather a summary of some key discussion points. These notes attempt to capture the content and intent of the dialogue and may not always precisely reflect all participant comments.

Question for Panel

You are the manager/regulator/downstream resident of a 50 ha soil cover system that must reduce the volume of infiltrating water by at least 80%. The cover system includes 5 km of ditches to remove the clean water from the site.

- What triggers should be used to initiate repairs or replacement of the soil cover system?
- In the post-construction budget for your design, how often and extensive would you predict these repairs or replacement to be.

Panel Members

The selected panellists were cover designers, researchers and builders. They were people who might be consulted by a manager, regulator or downstream resident to answer the above questions. The members of the panel were:

- Iain Bruce, BGC Engineering Inc.
- Ron Nicholson, EcoMetrix Incorporated
- Dirk van Zyl, University of Nevada
- Michel Aubertin, École Polytechnique

Presentation by Iain Bruce

The following is a direct transcript of Iain Bruce's notes used for his presentation.

Given the questions asked by Bill Price:

- What triggers should be used to initiate repairs or replace the soil cover? *Or what do you need to look at to know the cover is broken?*
- How often and extensive do you predict these repairs to be? *Or how often do you have to fix it and how much will it cost?*

The answer to the above questions unfortunately requires asking additional questions. The area of the hypothetical cover is 50 hectares, the equivalent of 10 to 12 covered football stadiums. The thickness of the dumps or piles is at least 5 m and differential settlements across the covers may be as much as 1 to 2 m. Ditches in the surface may be as deep as 5 m. The cover is a very thin skin in comparison to the size of the dump.

These relatively thin covers may have been built with the lowest cost contractor or by the mine fleet using haul trucks and large bulldozers. With potential variability in cover source material, potential segregation in the cover grain sizes, and the possibility of winter construction with snow and ice in the fills, what makes us think the covers were built adequately to begin with?

We are spending lots of time looking at cover design and assessing whether or not the cover is designed well. We are looking at cover layer design, slope aspects and all sorts of numerical methods to design covers. But how often do we look at how the cover will be built and modify the design to account for that? How often do we look at the big picture to assess the seepage out of the natural slopes on which the waste rock dump is built, the effects of slope stability on cover durability, or runoff from above inundating our ditches? A failure to look at the big picture while concentrating on details of design may lead to failure.

Where has the dump been built; in the freezing north, the rainy tropics or the dry jungles? Each will have an impact on how the cover behaves and what targets should be aimed for.

The moderator's hypothetical cover was intended to divert 80% of the infiltration? Is that 80% of the annual mean precipitation, 80% of the 200 year event or 80% of the Probable Maximum precipitation. What is the target? Do we need to reduce infiltration or do we need to limit loadings that are released to the environment? Differences in the potential targets may have an impact on how we build the system. We need to keep the system simple but robust enough to address all of the issues noted.

Once we have built the cover, how do we go about assessing the need for maintenance? Can we look at water quality as it exits the dump or is that too late? Will the water exiting the dump actually daylight so that it can be easily monitored? Can we rely on obvious signs of distress on the cover? Remember we need to keep this simple and robust. That means that the triggers that initiate repair must be recognizable and quantifiable.

Do we need instrumentation or will the instrumentation readings be misleading? A good OMS (Operation, Maintenance and Surveillance) plan is useful, particularly for the instrumentation, and the MAC (The Mining Association of Canada) guideline for OMS is a good place to start *(available from www.mining.ca)*. Regulators, who might be using the data to assess the need for maintenance, should remember however, that instrument readings can be misleading.

Each system will be different and a really good risk assessment is required to assess each cover. This would include the following steps:

- Step 1 is to define the possible failure modes that might affect the cover.
- Step 2 requires assessing the likelihood of failure by asking ourselves, was the cover designed well, was the cover built well and are there records to prove it?
- Step 3 is to define the consequences of a failure. If the seepage rises from 20% infiltration of the mean annual rainfall to 60%, has the cover failed? What are the consequences?

Then, most importantly, we need to assess if the consequences are acceptable. This falls on the regulators, the public and the owners.

There are no easy answers, but we need to have robust systems, simple systems, economical systems and most of all systems that will last a long time.

A copy of his slides is included.

Presentation by Ron Nicholson

The focus of Ron's presentation was on the conceptual design. He noted that owners or operators should be on the panel to provide their perspectives. His role, as consultant, is to provide advice. The final decisions are made by someone else (the operator or owner) with direction provided by the regulators.

In his presentation earlier today, Michel Aubertin made reference to Ron Nicholson's early work on covers with capillary barriers as a piece of seminal research in this area. In the late 80's the thought was that sulphide oxidation could be substantially reduced by controlling oxygen ingress through water saturation of the cover. The implication was that by decreasing the diffusion coefficient, one could reduce the contaminant loadings by 2 to 3 orders of magnitude or more. However, based on case histories to date, this does not seem to be the reality.

To determine the reality one has to deal with real cover systems. Test plot (constructed) structures show good agreement with theory and performance. However, there is a need to work on actual cover systems to determine their long-term behaviour and see how they fit into the overall scheme. There are different uses for covers and these comments relate to those intended to reduce contaminant loadings from the underlying mine waste.

It is important to see the differences between theory and reality. Can we reconcile these differences and manage our expectations? Many stakeholders such as operators/owner and regulators may expect that covers will solve problems related to long-term contaminant release to the environment. However, many covers are built without really understanding how they work or what performance objectives are required to prevent downstream contamination.

Covers on mine waste present a monitoring dilemma. Protection of the receiving environment is the target of a monitoring program. However, there are many factors to consider in monitoring (i.e. surface flows, underground flow pathways, contaminant loadings) that have significant time lags associated with them. The critical triggers that will direct rehabilitation or maintenance action need to be carefully assessed in terms of potential for future contaminant loadings to the environment and the lead time needed to prevent future contamination. One issue related to timing is that once contaminants leave the facility it may be costly to mitigate and the mitigation will not likely be related to repair of the cover but more likely will involve some downstream activity such as collect-and-treat, for example.

A copy of his slides is included.

Discussion by Michel Aubertin

At this time, I would not be able to provide specific answers to the posed questions. The experience with actual large size covers in still limited, so we are still learning from the different cases, such as the ones presented during the workshop. Nonetheless, one can look at manuals, such as the MAC OMS manual for dams and dykes, and offer direction on ways to monitor and maintain the covers. Because of the lack of information on the long-term behaviour of layered covers, another 20 to 40 years of data may be needed to fully understand their long-term behaviour. Actual monitoring data are needed for specific assessment (field observations and data), which can then be used for comparison with prediction work. Modelling by itself is not the sole answer. However, when paired with monitoring, modelling results can be used to develop a better understanding of the *in situ* behaviour, which should lead to more specific guidelines. Modelling (performed before and after construction) should complement the monitoring work.

Another important point to keep in mind is that when covers fail (i.e. do not meet their design objectives), they do so progressively, rather than catastrophically. If they are properly designed, monitored, and re-evaluated, corrective measures can be taken. The design can be continually evaluated and corrected if needed as data becomes available. This is not necessarily the case for other methods (e.g. water covers) of acid drainage prevention. If properly evaluated, covers are a good technology for the long term and a strong tool for AD control.

No slides were prepared, as it was felt by Michel that the information was available in his morning presentation.

Presentation by Dirk van Zyl

This is a serious issue in Nevada, especially in regards to closure of lined heap leach facilities. Assume that we have a 50 hectares heap leach operation, with a liner that is essentially a perfect lysimeter in place. Say the task is to reduce water infiltration by 80% or more through the installation of a cover. How does one determine this?

We can measure the seepage that comes out at the bottom of the heap leach. If the quality is poor, the site would have to add a treatment process, which is expensive. How does one tell if the cover is failing? Possibilities include:

1. Flow
2. Look at the cover itself, vegetative growth on the protective layer
3. Quality of the water in the ditch
4. Erosion in the ditch

Other considerations. What are the closure objectives? Is there a post-closure maintenance budget?

The Mining and Minerals and Sustainable Development (MMSD) Project has developed "The Seven Questions to Sustainability" to assess an operation's sustainability. These questions are:

1. *Engagement.* Are engagement processes in place and working effectively?
2. *People.* Will people's well-being be maintained or improved?
3. *Environment.* Is the integrity of the environment assured over the long term?
4. *Economy.* Is the economic viability of the project or operation assured, and will the economy of the community and beyond be better off as a result?
5. *Traditional and Non-Market Activities.* Are traditional and non-market activities in the community and surrounding area accounted for in a way that is acceptable to the local people?
6. *Institutional Arrangements and Governance.* Are rules, incentives, programs and capacities in place to address project or operational consequences?
7. *Synthesis and Continuous Learning.* Does a full synthesis show that the result will be positive or negative in the long term, and will there be periodic reassessments?

These can be applied to review the cover/closure plan.

Government has a role in determination of O & M costs. They have the ability to enforce the regulations. The covenants of the company establish long-term trust. There may be a high liability in design/maintenance and repair for covers. Costs would be particularly heavy the first 5 years as the design is constructed and tested. For example, a large thunderstorm that occurred a few years after cover placement resulted in significantly erosion gullying that required maintenance at the Barrick Goldstrike mine in Carlin. Costs would possibly be lower in the long term if there was good governance. There is a need to budget for on-going repairs. If there is no reliability in design or governance, may need to budget for annual costs and replacement of cover every 15 years. A financial instrument of assurance needs to be in place.

Questions & Comments from the Floor

Dirk van Zyl. Risk = Hazard x Consequences or = Hazard + Outrage (from a risk communications perspective). If we don't get to 80% reduction in infiltration for the cover performance, what is the outrage that needs to be addressed?

Peri Mehling. Asked about the maintenance costs at Equity Silver. Are the dollar figues identified in earlier presentations based on actual operational costs to maintain the cover? Are there other sites with realistic dollar figures for cover maintenance that can be checked against earlier predicted costs, and provide insight into general long-term maintenance issues and costs associated with a new cover?

Dirk van Zyl. Barrick's Goldstrike leach pad is an example. The company built the cover pad. A 1/500-yr storm occurred after construction, which resulted in major erosion. Lessons were learned, and the cover was rebuilt to higher standards. This information has been published and should contain costs. Multiple $000s were used to reconstruct. (Gold Strike Leach Pad, 2001).

Michel Aubertin. Dirk is right about the cover on the leach pad project, which is based on the CCBE principles described this morning. Papers written with Johnny Zhan from Barrick show that this SDR (Store-Divert-Release) cover behaves as expected, when compared to modelling results, even in for extreme events. Experience was also gained with the Les Terrains Auriferes (LTA) site located in northwest Québec. The cover was built in 1996 and monitoring has been ongoing since. On this site, only low-level maintenance has been required to date. Side slopes are well maintained, and vegetation is well established, preventing erosion on the slopes. Deep rooting plants are removed as they seek water and could cause deterioration of the cover. This was a low cost cover, and so far, it also has low maintenance costs.

Ron Nicholson. Aside from examples of physical failures, we do not have "triggers" to understand other types of failures. If the cover is in place to reduce infiltration and the chemistry of the drainage is known, we need to monitor or estimate the flow (Q) through the cover system to see if the quality is acceptable downstream in the receiving environment.

Iain Bruce. Agrees the big picture numbers are needed. There is not enough performance data to tell if the covers are working as designed. The companies/operators are building covers, but not monitoring their performance. It is question of engineering versus civil works for mine covers.

Mike O'Kane. Mike Aziz's data is a good illustration of how things operate based on a trend. A problem for the cover system is when a trigger is above a compliance limit. For cover systems, it may be possible to first monitor physical components, such as directly on the cover system to serve as "triggers" for evaluating performance, and then over time use chemical triggers in terms of evaluating stability, and then finally biological aspects (e.g. sustainability of vegetation species, density, coverage). This does not preclude using the chemical and biological monitoring earlier, but the point is that the site should be monitored for physical, chemical and biological triggers, and that the triggers should change over time and trends should be studied to monitor changes in the long-term performance.

Ron Nicholson. Agrees with Mike O'Kane, but there may be a long lag-time for draining. For Equity the water reports quickly into the ditches. But for some sites it may be too late if groundwater quality trends are used as triggers, and the receiving environment may be impacted. Need other monitoring techniques or *in situ* tests to obtain early-warnings. But they are not generally available or not standard procedures and require careful interpretation. The question of what should be measured needs to be answered. Infiltration estimates are key for most sites. A conservative number tends to be used – one needs to complete a risk assessment that includes evaluation of loadings to the environment.

John Errington. Briefly discussed how regulators would treat the construction of covers. He mentioned that tailings dams are regulated carefully because of the risks involved. Tailings dam are highly designed by civil engineers and are built with 24-hour supervision. Consequences of a failure are huge. For cover systems, the company decides the closure option to be used and the assurance bond is based on the selected option. For the Equity Silver site, a $56 M bond would have had to be posted if no cover was used. If a cover was placed, the amount of the bond was reduced to $32 M. The same reasoning was used for TeckCominco's Sullivan Mine site. The choice between huge capital cost (dry covers) versus huge operating cost (treatment) needs to be looked at. Question to Mike Aziz on what would prompt Equity to redesign the cover.

Mike Aziz. Pointed out that the Equity Silver site will require collect-and-treat in perpetuity. At present the cover has 5 -20% water infiltration and this is likely partly due to groundwater inflow. Cover would have to be redesigned to take into account these new findings. Until a cover is developed that guarantees 100% reduction in water infiltration, Equity will continue to monitor and treat. If a solution to the cover system could be found that would guarantee a significant reduction in infiltration and ARD production then the company would spend the money to replace the cover. Would have to explain the problems with the current cover and how the new design would be more effective.

Ron Nicholson. Questioned the regulator's response if Equity had not gone acid early on, and there was a potential for a significant lag-time to occur. There is a question of how to evaluate the risk of incremental "chemical" failure and relate that to bonding.

John Errington. The risks need to be taken into account. There were many consultants involved at Equity throughout the years. This resulted in a wide range of predictions being made on the performance of the cover. Prediction is not perfect – the question to ask is how much variation would be acceptable. For example several recent upset events would have originally been considered 1/1000-year events.

Audience Member. Municipal solid waste covers (covers for landfills) may be more advance in their technology as compared to the mining industry. There are thousands of covers. These sites are in the public eye since they tend to be near cities, and getting closer with rural expansions. In general, these landfills are owned by the municipalities but some are private. They usually are stringently managed, are constructed to high standards and are well monitored. Money is available to ensure their safety. Recommended that the mining industry look at the solid waste management industry with regards to their use of covers.

Bill Price. Four years ago at the 7th Annual BC/MEND ML/ARD Workshop (*Dry Covers, Prediction Solubility Constraints, Research and New Developments*), we had a presentation on the state-of-practice for covers and liners at landfill sites. Like covers used at mine sites, there was considerable effort in cover design at landfills, some drainage monitoring, but a lack of durability monitoring and process control. It appeared that if the issue was considered, the contingency plan for landfill cover failure was that the impacted groundwater or surface drainage would be collected (e.g., pumped) and treated. The assumption appeared to be that municipalities have sufficient resources in terms of people and money to deal with any long-term concerns, if and when they occur. Unlike mines, municipalities will be around to deal with any adverse effects from their actions.

The challenge for mines and mine regulators with soil covers is what design, operating procedures and financing is required to ensure there is pro-active detection and resolution of problems prior to significant environmental impact to other resources. This includes ability to handle future changes to waste and site conditions, what repair and replacement & contingency plans are required, and the need for regularly updated operating manuals and monitoring database, and the financial resources to conduct the above.

Dirk van Zyl. In the US, the available data is from landfill covers. There is a lack of good data on alternate covers that don't follow the standard clay cover design.

Mike O'Kane. Surface area for landfills is very different than that for mining. At a recent EPA Conference on Covers that he attended, he found that the US researchers are struggling with the same issues. How to build covers? How to maintain and monitor the covers? Triggers? The application of cover technology in the US is not really further ahead than the mining industry.

Michel Aubertin: The City of Montreal had test plots built for their landfill in the mid 1990's. This was about the same time that the test cells were constructed and monitored on the Manitou site (Northwest Québec). École Polytechnique was asked to provide input into this landfill project, which was largely motivated by the developments in mining. The good results obtained with the CCBE (cover with capillary barrier effects) largely influenced their final design, which had to allow for some infiltration of water, while preventing the outward flux of biogas. In this case, the main concept was the result of previous work in the mining industry – and, it can be said that the mining industry is further ahead than landfills in many cases (at least for cover technology).

Andy Robertson: Two key issues regarding cover failure are permeability and erosion. There has been lots of work done/presented at this forum dealing with permeability. However, erosion has not been sufficiently addressed. Erosion is characterized by the removal of material. Sedimentation follows, which could change flow paths. This could lead to deterioration of the cover and vulnerability. Erosion is one major cause of poor performance of slopes, and could be a major factor for the longevity of the cover system. Currently, erodability of covers is not being monitored other than through observation and maintenance. Erosion needs to be taken into account at the design stage of the cover and methods to control erodability need to be developed.

Dirk van Zyl. Barrick's Goldstrike Mine mapped the watersheds for the topography of the adjoining hills. A design to mimic the natural terrain was completed. Detailed modelling of the pads to address erosion was completed. Another key issue in Nevada, because of the climate, is vegetation. Brush fires on sites destroy the vegetation and affect the evapotranspiration from the cover system.

Michel Aubertin. Interaction with colleagues in forestry at UQAT addressing the question of vegetation growth on CCBE has taken place in the past. The mining industry needs to interact more with the forestry experts regarding surface layer. Their knowledge on surface vegetation layer (e.g. non-invasive shrubs or trees) would benefit the mining industry by integrating their expertise in cover design.

Iain Bruce. Which value of permeability does one use in the design of covers when one considers the various parameters that need to be taken into account (e.g. material characterization, convection)? Erosion is more difficult to design for. Hard to visualize what a PMP will do to a slope. One can design for a 1/200 or 1/500 year event but there could and probably will be damage. Some maintenance will be required. It's difficult to maintain an artificial landform.

David van Dieren. Discussed the issue of contaminant storage/release from an ARD-generating waste. He noted that the infiltration into the waste material can be reduced but this increases the amount of stored oxidation products. The question is what does this accomplish in the long-term. It just extends treatment times. The same amount of contamination will eventually enter the environment and will need treatment. These contaminate loadings represent a risk and could/will be released during a flushing event. Are we not creating a time bomb by not dealing with the problem now? Two options - let it oxidize and treat it now, or cover and treat forever.

Ron Nicholson. The tolerance on the receiving environment is one key parameter for the design of the cover. What can the downstream environment assimilate; we do not want to exceed these tolerance levels. The nuclear industry has a concept referred to as derived release limits based on the releases from a facility that will not exceed regulatory limits down stream at any time in the future. What is the tolerance for cover systems and downstream environments at mines? Where do you set your targets (i.e. zinc)? Oxidation will still occur below a cover and some level of contaminant will be released. What performance do you need from your cover? Question of 80% reduction is linked to flow rate and chemical loading. Go back and see if you can achieve this in real life. Need to monitor for incremental failure of the system.

Steve Januszewski. Equity Silver looked at monitoring data over a 15-year period. Trends can be extrapolated to predict future loadings. But there are always new factors coming up that need to be dealt with. There may be major uncertainties. Only real solution can be found in case studies such as Equity that can be examined and evaluated through post-closure for the long term. More case studies are needed to evaluate the data and pinpoint the uncertainties.

Michel Aubertin. There has been an evolution of knowledge of cover performance over the last 12-15 years. Covers are not evaluated and built the same now as they were in the past. Progression of knowledge has been, and continues to be transferred to field applications. Today we have better understanding of the key mechanisms that control cover performance (e.g. oxygen and water inflow) and more representative conditions.

Ron Nicholson. Can we manage our expectations for covers? Initially we had thoughts to achieve walk away with covers being the closure solution. Now we know this is unlikely for ARD/ML systems. We have achieved a reduction in acidity loadings, but expectation that dry covers on sulphide wastes will be walk-away is probably not realistic.

Elizabeth Gardiner. Climate change is a new issue that needs to be considered. Communities of interest (stakeholders and non-governmental organizations (NGOs)) are highly interested in what occurs downstream of tailings facilities. A key question is how are facilities being designed to take into account climate change.

Iain Bruce. The effects of climate change are unknown but do need to be considered over the long term.

Michel Aubertin. Another consideration for tailings management is underground storage in open stopes. Much progress has been made in recent years with paste backfill. Pyrite and pyrrhotite separation (i.e. desulphurisation at the mill) could be used to better manage reactive tailings, with the contaminated portion of the tailings being placed underground as paste backfill. This would result in the placement of non-acid generating tailings at surface. This is a promising area that could be worth considering by the mining industry. The Industrial Research Chair is actively pursuing this research area with its mining partners.