Abracadabra – the Disappearing Tailings Dam

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Abstract

The independent expert review panel for the Mount Polley Tailings Storage Facility failure came out strongly recommending changes to the technology of tailings dams in British Columbia (and by inference, world-wide). The Panel had examined the historical risk profile of tailings dams in British Columbia and recommended, amongst other things, that best available technology (BAT) be adopted for tailings disposal. Examples of BAT, described by the panel, included "dry-stacking" of filtered, unsaturated, compacted tailings and reduction in the use of water covers in a closure setting. The recommended technologies would require a major shift in current practice and raises many questions, such as:

Are these recommendations appropriate in Australia?

Does this signal the end of the tailings dams as we know them?

Do the current Australian National Committee on Large Dams Guidelines (ANCOLD) apply to these new BAT technologies?

If not, is there a role for ANCOLD in setting standards for the future?

This paper discusses the Mt Polley tailings dam failure and searches for answers to these questions. In particular, this paper reviews the background to "dry-stacking', to explore the implications for the Australian mining industry.

Keywords: *Tailings Dam, Dry Stacking, Best Available Technology*

Background – The Mt Polley TSF Failure

There have been a number of tailings dam failures over recent decades, averaging around two per year, with release of tailings and significant environmental and economic impact. However, the recent failure of the Mt Polley Tailings Storage Facility (TSF) in British Columbia, Canada, shown in Figure 1, is particularly important given the media coverage and the outcomes of an in-depth independent expert panel review with unprecedented public reporting of findings (Morgenstern et al, 2015).

Figure 1 View of the Mt Polley Tailings Dam Failure

The breach occurred within the Perimeter Embankment, during its raising, early on August 4, 2014 at a crest elevation one metre short of its maximum permitted level. Loss of containment was sudden, with no warning. The recorded pond elevation at 6:30 pm on August 3, 2014 was 2.3 metres below the crest. Subsequent studies by an independent expert panel appointed by the Government of British Columbia, together with the Williams Lake and the Soda Creek Indian Bands, identified the cause of failure to be insufficient undrained shear strength of a glaciolacustrine layer in the foundations. This particular layer and the associated failure mechanism had not been identified in previous design investigations.

The failure was triggered by construction of the downstream rockfill zone at a steep slope of 1.3 horizontal to 1.0 vertical being allowed partly. Such a steep slope was deemed satisfactory partly because the design was based on a minimum factor of safety (FoS) of 1.3 recommended for construction loading conditions by the Guidelines from the Canadian Dam Association. Subsequent calculations of the failure surface shown in Figure 2, suggested that the foundation failure have caused a vertical crest displacement of approximately 3 m. This deformation then led to overtopping causing progressive erosion of the embankment and a release of an estimated 10 million m^3 of water. The large volume of released water resulted in a much larger loss of solids from the TSF than might have occurred if a smaller pool was maintained at the time of the failure. Indirectly then, a poor water management over a number of years was the major contributor to the extent of the resulting devastation.

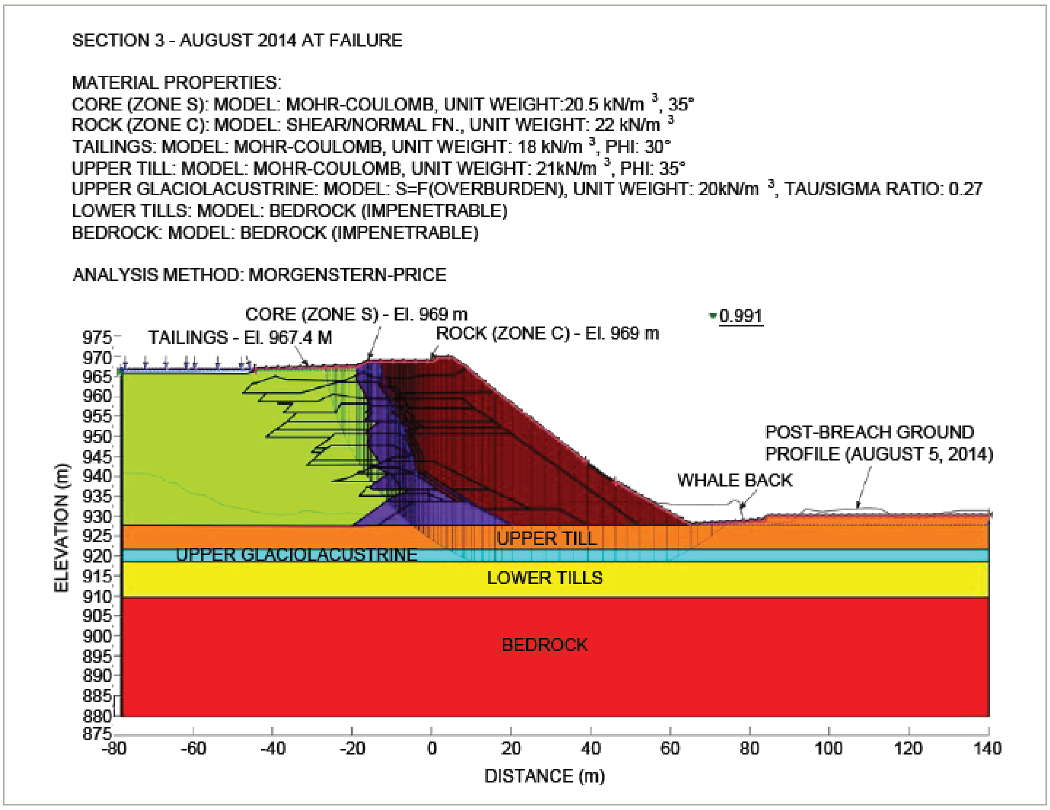

Figure 2 **Calculated failure surface Mt Polley Tailings Dam (reproduced from Panel report)**

The Mt Polley Expert Panel examined the historical risk profile of the current portfolio of tailings dams in B.C. It was found that of 123 active tailings dams with contained water as well as tailings, over the 46-year period since 1969 there had been seven failures resulting in breaching and release of tailings. The Panel equated this to a failure frequency of 1.2x 10^{-3} per TSF per year and predicted that, if the inventory stayed at a similar number of, there would be a failure approximately every five years.

Such high risk has been found intolerable where environmental impact or worse is at stake. The panel therefore concluded that, for British Columbia, the concept of "tolerable risk" is unacceptable and suggested moving towards zero risk. To achieve this goal, the panel suggested not only an improved adoption of Best Applicable Practices (BAP), but also an adoption of the Best Available Technology (BAT) concept.

Examples of BAT suggested by the panel included filtered, unsaturated, compacted tailings and reduction in the use of water covers for closure. Examples of BAP quoted by the panel included improvements in corporate design responsibilities and adoption of Independent Tailings Review Boards.

As stated by the Panel:

"*Ultimately, the problem stems from how many active tailings dams there are in the province. To ensure against future failures for all of them would require roughly a hundredfold reduction or more in the current failure frequency. While advances in practices, procedures and policies are imperative, the Panel does not expect these measures by themselves to achieve this degree of improvement. The path to zero needs an added dimension, and that dimension is technology.*"

The Mt Polley Panel were unconvinced that improved tailings management practices would be sufficient to meet the required reduction in risk and consequently proposed moving away from water based technology. The proposed BAT has three components that derive from first principles of soil mechanics:

- Eliminate surface water from the impoundment.
- Promote unsaturated conditions in the tailings with drainage provisions.
- Achieve dilatant conditions throughout the tailings deposit by compaction.

Specific recommendations of the Panel were

- For existing tailings impoundments, rely on best practices during their remaining active life.
- For new tailings facilities, BAT should be actively encouraged for new tailings facilities at existing and proposed mines. Safety attributes should be evaluated separately from economic considerations, and cost should not be the determining factor.
- For closure, BAT principles should be applied to closure of active impoundments so that they are progressively removed from the inventory by attrition. Where applicable, alternatives to water covers should be aggressively pursued.

In addition recommendations for future BAP went beyond stability calculations, proposing that safety be enhanced by providing for robust outcomes in dam design, construction and operations, with implications for corporate responsibility, enhanced regulatory capacity and expanded technical review.

More explicitly, the Panel recommended that feasibility documentation should be required to contain the following:

- A detailed evaluation of all potential failure modes associated with the geological conditions of the site, the uncertainties associated with the project evaluation, the role of the Observational Method to manage residual risk and mitigation measures in case worse than anticipated conditions are encountered.
- Detailed cost analyses of BAT tailings and closure options, so that alternative means of achieving BAT can be understood and accommodated.
- A detailed declaration of Quantified Performance Objectives (QPOs), beyond those associated with regulatory compliance and ordinary design criteria, including beach widths, calibration of impoundment filling schedule, water balance audits and calibration, construction material availability and scheduling to ultimate height of structure, instrumentation adequacy and reliability, trigger levels for response to instrumentation, performance data gathering, interpretation, and reporting intervals.

Finally the Panel recommended the appointment of Independent Tailings Review Boards (ITRBs) to provide third-party advice on the design, construction, operation and closure. The International Finance Corporation/World Bank guidance and operating principles OP4.01 and OPR.37 already establish the requirement to review the development of tailings dam design, construction and initial dam filling.

Australian Experience

Thankfully, Australia has not suffered a failure on the scale of that in British Colombia. The majority of approximately 700 tailings dams in Australia utilise slurry technology and have an extent of stored water. There is only one Australian tailings dam incident recorded on the Wise Uranium list (reference) of significant tailings incidents and this relates to foundation seepage and not breaching and release of tailings. There are no Australian incidents recorded in ICOLD Bulletin 121 Tailings Dams – Risk of Dangerous Occurrences.

The authors are aware of some failures that have involved breaches but no release of tailings to the environment and a failure at Cracow Gold Mine, Queensland where up to 6000 m3 of tailings slurry was released due to a fault in the liner of an unused RSF but was retained by an empty stock watering dam downstream. Consequently, the failure rate of tailings dams (causing significant impact) in Australia using the same 46 year period used by the Mt Polley expert panel could be determined as less than $3x10^{-5}$, nearly two orders of magnitude less than the BC experience. This could be partly explained by climatic conditions with a significant proportion of tailings dams in Australia being in arid or semi-arid climates. However, this is not universally the case with a number of large tailings dams being located in wet areas of SE, SW Australia and also in the tropical and cyclone-affected north.

Another possible factor could be the active involvement of ANCOLD in developing Guidelines for Tailings Dams starting from 1999 along with attention from State and Federal governments with many guidelines, notes and other related publications. To a certain extent these documents may have contributed to a good understanding of risk in the Australian tailings industry and the commonplace use of qualitative and quantitative risk assessments in everyday operations and management.

ANCOLD have actively pursued promotion of these guidelines and improvement in industry practice for many years. The current 2012 Guidelines for Tailings Dams – Planning, Design, Construction, Operation and Closure are arguably the most comprehensive guidelines in the world and covers many of the issues raised by the Mt Polley expert panel including:

- Introduction of the concept of design evolution, whereby initial design should adopt conservative, "best estimate" design parameters on the basis of available data that can be progressively verified, validated, or refined, as real data becomes available. This is commonly known as "the observational approach" to design.
- Promotion of the concept of Sustainable Development requiring the safety of the storages into the extreme long-term, well after the closure of the mining operation, extending the concept of stewardship and enduring value.
- Requirement that the viability of a surface storage tailings dam needs to be properly explored, taking into account the potential costs of closure and long-term post-closure maintenance including reference to some of the BAT raised by the Mt Polley Panel.
- Focus on risk management during design and operational phases referencing AS/NZS ISO 31000:2009 and ISO/IEC 31010.
- Requirement that a Consequence Category to be determined. If the Mt Polley TSF was assessed in accordance with ANCOLD 2012, it would have been at least a High C Category dam with appropriate design and operational parameters assigned.
- Focus on planning for long, medium and short terms, including the recommendation for annual review of plans.
- Recommendation for 3rd party external reviews at regular intervals.
- Focus on water management and storage of wet-season and extreme storm events and water balance. This is a particularly strong section of ANCOLD Guidelines and also State and Regional legislation possibly due to our climatic extremes.
- Focus on undrained strength analysis for design and also FoS for construction cases being 1.5 where there is a risk of tailings release as opposed to the FoS 1.3 used at Mt Polley.
- Recommendations for high level of documentation of design and construction phases and definition of the responsibilities of construction QA/QC personnel and as-built drawings and construction report.
- Focus on need for training of management and operators in dam safety and the need to have OMS manuals and emergency management plans.
- Well defined and well understood requirements for routine inspections at different levels from internal and external personnel.

Based on the above, the Australian tailings industry should be well placed to reduce future risk to levels potentially lower than other jurisdictions, but this will depend on the rigour in which the industry follows the guidelines, which, after all are just that. Furthermore, the human error aspect is also present and, as noted ted by the Mt Polley Panel, that is very difficult to guard against.

That said, Australia already has examples of BAT including dry-stacking from filter-pressed tailings at Karara (FLSmidt, 2012) and by mud-farming at various sites, particularly in the Alumina industry. This type of construction (Munro, 2012) could indicate an appropriate way to BAT without the power cost and availability issues of filters.

Impacts of Mt Polley Failure in Australia

The design procedures and legislative requirements for tailings dams in Australia are significantly different from those used for the design of the other mine structures including open cuts, underground workings, waste dump, offices, process plants and other infrastructure. As a result of these differences, comparatively extreme loads and very conservative factors of safety are adopted in the design of tailings dams to prevent damage and loss of life in assets that were designed and constructed for much lower loading conditions.

Despite the excellent track record of tailings dam safety in Australia, it is likely that the concept of BAT will come to Australia. This will be beneficial, provided the BAT concept is implemented in the correct context and allows the industry to develop in a cost effective manner, rather than just as a knee jerk regulation based approach. It seems that the model proposed in British Columbia, would only widen the gap between the design of tailings and other mining infrastructure and may not lead to a reduction of the overall risks associated with mining in Australia. Industry needs to put BAT into context with other issues (Hoekstra, 2015)

Where would ANCOLD sit if dry-stacking became common as suggested by the review panel? Do the current guidelines apply?

The current Guidelines are written on the basis of wet storage in tailings dams. However, that is not to say that all the basic principles of risk, stability, consequence, design and construction would not apply. Water management is still going to be a major design and operation factor. Dry-stacking will still result in a landform that will be subject to stormwater flows with potential for "dam-break" if drainage is not adequate and also build-up of pore pressures within the storage.

Dry stacking using filtered tailings is still a developing technology and prone to mechanical problems that can result in out of specification materials. Consequently, current designs often have an outer shell of "dry" material with the wet lower density material inside, which may not differ much from a well-managed "wet" tailings design.

Judging by media information, the industry in British Columbia responded strongly regarding the feasibility of changing to dry-stacking. It is likely that a long transition period, experience and further development is needed for dry-stacking to become an universally common practice. Additionally, the ANCOLD Guidelines are considered to cover the "dry-stacking" option adequately as they are based on a risk assessment methodology that allow the "fall-back" parameters to be varied if appropriate if a lower risk environment is demonstrated. With reduced potential for "dam-break" impacts, the Consequence Category of Dry-Stacked tailings dams could be reduced leading to acceptance of lower design and operation management parameters.

In conclusion, the authors believe that there is no magical and universal solution envisaged for tailings management. BAT for any individual project is likely to be an evolving issue into the future. ANCOLD should be built upon its input into the safety of tailings dams in Australia and internationally and should continue to push for industry adherence to the practices suggested in the current ANCOLD Guidelines as the best way to continue that safety record.

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