



DECEMBER 2016

INTERNATIONAL COUNCIL ON MINING
AND METALS (ICMM)

REVIEW OF TAILINGS
MANAGEMENT GUIDELINES
AND RECOMMENDATIONS
FOR IMPROVEMENT

Submitted to:

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REPORT





Table of Contents

1.0 INTRODUCTION	1
2.0 LESSONS FROM THE PAST	1
3.0 REFLECTION ON RECENT SUDDEN CATASTROPHIC FAILURES	2
4.0 DEFINITIONS	2
5.0 GOOD PRACTICE	3
5.1 Tailings management framework	3
5.2 Governance	4
5.3 Minimum requirements for design, construction, operation, decommissioning and closure (including post closure management)	4
6.0 NATIONAL GUIDELINES COMPARISON	5
7.0 REVIEW OF MEMBER COMPANY DOCUMENTATION	6
7.1 Review process	6
7.2 Review findings	7
8.0 RECOMMENDATIONS	7
9.0 CONCLUSIONS	7
10.0 REFERENCES	9

TABLES

Table 1: Recent sudden catastrophic failures	2
Table 2: Clusters and cluster leads	6

APPENDICES

APPENDIX A	
DOCUMENT LIMITATIONS	



1.0 INTRODUCTION

The International Council on Mining and Metals (ICMM) represents 23 of the world's largest mining and metals companies and recognises the significant role that mine tailings plays in the overall risk profile of mining operations worldwide. Following from the Samarco tailings dam collapse in Brazil in 2015 and the earlier Mount Polley failure in Canada in 2014, ICMM's members unanimously agreed to respond as an organisation with a commitment to leadership in environmental and safety performance within the mining and metals industry.

The response has been to convene a global review of tailings storage facility standards, guidelines and risk controls. The review has been led by ICMM and has included external experts and member company representatives. The review focuses on corporate level surface tailings management across the membership, including standards, guidelines and risk controls, governance and emergency preparedness related to the prevention of and response to sudden catastrophic failure of tailings storage facilities.

Golder Associates has been appointed by ICMM to provide expert input into the evaluation of Member Company guideline documentation. Golder Associates has also been tasked with generating recommendations based on the findings of the review.

A review of each of the member company guideline documents and selected national guideline documents and standards has been carried out by designated Golder regional cluster leaders.

2.0 LESSONS FROM THE PAST

The mining industry can learn from recent incidents and sudden catastrophic failures of tailings facilities. ICOLD Bulletin 121 (2001) provides a comprehensive report on some of these lessons and identified the main causes of failure to have been (our amplification in brackets):

- Lack of control of the water balance (leading to overtopping)
- Lack of construction control (primarily quality)
- A general lack of understanding of the features that control safe operations; and
- Lack of responsibility and ownership by operators (probably meaning poor governance, management and assurance)

Significant failures were reported by ICOLD in its 2001 report to be occurring at a rate of approximately two per annum. The ICOLD report concluded that all of the failures could be explained. Notwithstanding the above findings some 15 years ago, the appearance of corporate requirements, the publication of a number of national guidance documents and extensive regulation failures, continue to occur. Clearly either the combination of guidance and regulations is inadequate or there is a problem with the implementation of these requirements. It is therefore timely and appropriate that the existing corporate level practices and standards be reviewed with a view to moving the industry towards an objective of “zero catastrophic failures” resulting from their sudden structural failure.



3.0 REFLECTION ON RECENT SUDDEN CATASTROPHIC FAILURES

Three sudden catastrophic failures have been covered by extensive investigations that have reliably identified the failure mechanisms via official investigations or commissions where the scope is confined to physical stability and cause of failure. The main reasons for the failures are given in the table below.

Table 1: Recent sudden catastrophic failures

FACILITY	YEAR	FAILURE MECHANISM	FAILURE MECHANISM
Los Frailes	1998	Foundation failure	Change of downstream slope from 2H:1V to 1.3H:1V resulting in progressive foundation failure
Mount Polley	2014	Foundation failure	Change of downstream slope from 2H:1V to 1.3H:1V resulting in undrained failure of unidentified clay layer in foundation
Samarco	2015	In dam failure	Multiple changes to dam section triggered initially by failure of basal drain and other subsequent events, allowing high saturation and deposition of weak slimes layers within sand dam originally intended to be drained and non-susceptible to the realized failure mechanism.

If one were to focus on the three case histories in isolation and ask the question “what needs to be done in order to prevent a recurrence” then the answer might be as follows:

For all tailings facilities a comprehensive understanding of the properties and behaviour of the foundation and in slope materials upon which the stability of the facility relies is required. These properties and behaviours should be assessed by a competent engineer who should also develop designs and mitigation measures to ensure that adequate stability is achieved over the full life of the facility. A formal review of the dam stability should be carried out before any changes in the dam section or construction method are implemented. The review should include a restatement of the critical operating criteria and constraints imposed by the dam section and method of operation.

Conversely, if one were to focus on these and other such case histories through consideration of a greater number of failures and investigation results over the last 20 or so years, and ask the question is there anything missing from existing standards and guidance documentation that if known and applied could have forestalled such events, then the answer might be as follows:

Existing published guidance and standards documentation fully embrace the knowledge required to prevent such failures. The shortcoming lies not in the state of knowledge, but rather in the efficacy with which that knowledge is applied. Therefore, efforts moving forward should focus on improved implementation and verification of controls, rather than restatement of them.

It would therefore follow that a higher level of governance and assurance is required for the effective implementation of good practice. It should however be noted that site level guidance and standards need to be tailored to the specificities of the site and dam. Site level guidance and standards are however unlikely to be effective in the absence of the higher level governance and assurance.

4.0 DEFINITIONS

The following definitions have been adopted for the purposes of this report.

ANCOLD: Australian National Committee on Large Dams.

CDA: Canadian Dam Association.

Engineer of Record: The Professional Engineer responsible for ensuring that the tailings facility is designed, constructed, operated and decommissioned with appropriate concern for health and safety and the environment. The Engineer may in some circumstances be an employee of the mining company.

FEMA: U.S. Federal Emergency Management Agency



Good practice: In this instance the model of “good practice” selected by Golder to compare national standards and guidance and member company tailings specific corporate level guidance documentation against.

Guidelines: Recommended non-mandatory controls often defining good practice

ICOLD: International Commission on Large Dams

Management Framework: A management framework sets out the requirements for objectives and principles, planning (including design), operation, conformance assessment, corrective action and review. A management framework thus includes a governance framework as a subset.

MAC: Mining Association of Canada.

Requirements: As per Oxford Dictionary definition and in this instance pertaining to a prescription of a corporate guideline. A minimum requirement is therefore the lowest level of conformance that is prescribed.

Risk control: A control minimising the likelihood of an event occurring or mitigating the consequences of an event.

SANS: South African National Standard.

Standards: A threshold, limit or specific mandatory way of doing things.

USACE: United States Army Corps of Engineers.

5.0 GOOD PRACTICE

There are a number of good practice guidelines covering the management and the physical stability of tailings storage facilities available though no one set is used across all jurisdictions. For the purposes of the review it has therefore been necessary to take a view of what might constitute “good practice” and then to compare current member company guidance against this.

Golder has elected to synthesise a “good practice” summary out of a combination of national guidelines, input from the working group and its own experience rather than adopting one or other of the existing companies’ standards or national regulations and/or guidelines. Golder has also compared the most comprehensive and better known of the national guidelines in order to validate this work. The intention is not to create a new standard that survives beyond the review covered by this report. Our summary of good practice is set out below and incorporates three core elements: management framework, governance and minimum requirements.

5.1 Tailings management framework

The first requirement is for companies to have a published tailings management framework that has been endorsed by the Board of Directors and that is mandatory for its subsidiaries.

A good corporate tailings management framework will provide a set of objectives and principles that provide the basis for effective tailings management and the governance systems required to assure conformance to the guideline. The typical objectives and principles that should be included are:

- The levels of safety to be achieved in the spheres of third party safety, occupational health and safety, environmental impact and mine closure
- Reduction of hazards through the advancement and support of improved technologies with continuous improvement as a goal
- Consideration should be given to the impact that the tailings facility will have on stakeholder perception of safety and on the physical, social and economic environment. Such considerations speak to social license which should be articulated as a key objective within the framework.
- Full life cycle management that spans the conception, investigation and site characterization, design, construction, operation, decommissioning and closure phases as well as continuity across the phase boundaries



- Application of sound engineering practice to all phases of the facility life including the principle of appointing suitably qualified professionals
- Commitment to a formalised change management process
- Commitment from the Chief Executive Officer and prescription of roles, responsibilities accountabilities and authorities.
- The Board of Directors or Chief Executive Officer should commit to providing periodic oversight.
- Formal risk management and risk assessment commensurate with the consequence classification of the facility

The above objectives and principles should be elaborated in the guidance to a point which eliminates generality and ambiguity. Responsible and competent designees should develop the framework and manage implementation and must be provided with necessary resources.

5.2 Governance

The corporate guidance and/or standards should insist that governance takes place within a management system (as described in 5.1) that provides assurance that the following will be and has been carried out within each of the phases of the life cycle of the facility:

- An assurance program for each phase that provides among other things for the frequency and scope of the various levels of inspections, audits and reviews as well as the specification for the competence requirements for those undertaking the work. The assurance program should specify appropriate milestones for and frequency of independent review by suitably qualified professionals
- The outcome of independent reviews and assurance programs should be submitted to the Chief Executive Officer and the Board of Directors enabling them to provide appropriate oversight. The assurance process must be rigorous and must not be overly filtered by operational and functional layers within the organisation.
- A formal change management process within which corrective action and changes are taken up and incorporated into the requisite elements of the management system and life of facility plan

The tailings management framework should elaborate on the above governance elements to a level of detail that eliminates uncertainty and ensures that the framework will be implemented across different commodities, legal regimes and geographic settings.

5.3 Minimum requirements for design, construction, operation, decommissioning and closure (including post closure management)

The best of the currently available national and international guidance documents such as MAC, ICOLD, ANCOLD, CDA, USACE, FEMA and SANS all provide excellent good practice guidance and should as a minimum provide the foundation for the good practices that are referenced in company guidance documents. This review has, with the assistance and input from the ICMM members and the Golder team produced a view on the critical elements that should constitute minimum requirements. These are:

- A current life of facility plan comprising a mine and site specific sub plan for each phase in the life cycle of the facility.
- An operating plan and procedures for each phase that clearly communicate the operating constraints imposed by the dam section, construction method, the consequences of breaching these operating constraints, prescribes critical procedures, definitions of roles, responsibilities and level of competency required and clear identification of decision making authorities.
- A resourcing plan for each phase that defines the human, financial and system related requirements as well as the training that is required.



- The tailings facility infrastructure and management requirements must be informed by the potential for the facility to do harm. As such the baselines that characterise the residue source and the potential impacts on the environment and the extent of physical impact in the “zone of influence” associated with a potential dam break must be well understood at the outset. The consequence classification of the tailings facility must follow from this understanding.
- All phases of the life cycle and in particular the design and operational phases should be informed by and take into account the possible failure consequences identified in a formal risk analysis which is recorded in a risk register and periodically updated. The identification of failure modes, assignment of likelihoods of occurrence and development of mitigation strategies should be carried out by suitably qualified individuals.
- The stringency of the design and analysis methods used should be based on the consequence classification of the facility and should include the use of state of practice analysis methods and references. The design must be informed by the risk assessment and the essential requirements for operation upon which success of the design depends should be comprehensively captured in the construction and operational specifications. The designer should also explicitly define the resourcing implications that are key to the achievement of the design objectives.
- Design, construction and operation, as a minimum, should take place under the supervision of a suitably qualified team led by an “Engineer of Record”. The Engineer of Record may be changed during the life of the facility but the mine owner must ensure that this process of transition takes place within a structured change management process that ensures that the new Engineer of Record internalises the background and basis for the design.
- Independent review by suitably qualified and experienced professionals should take place at appropriate milestones and intervals during each of the design, construction, and operation phases.
- In the operational and decommissioning phases the operations, maintenance and surveillance manual should be viewed as the definitive reference that sets out the operational, requirements, constraints and limits of the design and construction method. As such the manual must be comprehensive and must cover aspects that provide background and context such as the basis for the design, minimum competence and training requirements and especially why monitoring and reporting must be diligently carried out. It should also define the responses to observations that need adaptive changes in operating management. The design engineer must formally communicate the content and intent of the manual to the operators and should be engaged to update this communication on a regular basis. The emergency preparedness and response plan also forms an important part of the operational readiness and must be updated regularly and informed by the current consequences that could be associated with a dam break.

6.0 NATIONAL GUIDELINES COMPARISON

The summary of good practice was used to evaluate the degree of alignment and conformance of the Canadian guidelines and codes, the ANCOLD guidelines and the South African SANS 10286:1998 code of practice. The outcome of the review is as follows:

■ Canadian Guidelines:

The Canadian guidelines (MAC and CDA) when taken together represent the most comprehensive of the national frameworks. Member companies that adopt the Canadian guidelines guidance would be rated as adequately complying with good practice. The MAC guidance, with a strong management focus, was written to complement, rather than repeat, content within the primarily technical CDA guidance. CDA in 2014 published a technical bulletin specific to mining dams.

The one area of non-alignment to our definition of good practice is that the MAC guidance is not based on a consequence classification system given that such a system is provided by CDA, albeit not focussed specifically on tailings dams. The MAC (2011) “Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities” document does identify consequence classification as a requirement or criterion to be used in the design process but does not provide guidance on how the consequence classification is to be carried out or on the categories that would apply. This requires that the user select another guideline – such as the CDA guidance - that provides the needed guidance on selecting



categories or develop criteria for categorization. There is also no specific requirement regarding change management. The strength of the guideline is that it is explicit and that checklists are included that provide the user with a basis for consistent implementation.

In July 2016, as a response to the Mount Polley incident, the Province of British Columbia in Canada implemented changes to the mining code that defines the role of the Engineer of Record and when independent review is required. This sets a precedent that should be considered to represent current good practice.

■ **ANCOLD Guideline:**

Member companies that adopt the ANCOLD guidance would be rated as adequately complying with good practice.

The ANCOLD guidance is more technical than the MAC guidance and is comparable in its technical focus to the CDA guidelines and does not prescribe systematic management. The technical nature of the guideline is one of its strengths and in particular the emphasis on the “observational approach” that recognises the evolving nature of the tailings facility structure and the need to learn and adjust as it grows is valuable. There is also no specific requirement regarding change management.

■ **SANS Code of Practice:**

Member companies that adopt the SANS code would be rated as adequately complying with good practice.

The SANS code does not prescribe roles and responsibilities. There is also no specific requirement regarding change management.

What is important about the comparison that has been made above is that the best of the national and of the corporate guidance rate well when measured against our summary of good practice. We can therefore infer that the review outcome for the member companies would be similar if the best of the national guideline documents were to be used as the measure of good practice.

7.0 REVIEW OF MEMBER COMPANY DOCUMENTATION

7.1 Review process

The summary of good practice set out in section 5 of the report was also used as the basis for a review of member company documents by one or more designated Golder cluster lead. Cluster leads were selected on the basis of their respective regional location and experience Table 2.

Table 2: Clusters and cluster leads

REGIONAL CLUSTER	RESPONSIBLE PERSON
North America	Terry Eldridge
South America	Alistair Cadden
Africa and technical lead	John Wates
Europe	Roger White
Asia	Brian Wrench
Australasia	David Williams
Project Management	Francois Marais Mike Abbott Heidi Wenger



7.2 Review findings

The review of member company tailings management documentation provides the basis for a perspective on the current state of practice with the following general conclusions.

- Some of the corporate documents were found to be comprehensive and in themselves examples of good practice as summarised in Section 5.
- The majority of the member companies have corporate documents that substantially follow good practice
- A minority of the member companies either have corporate guidance documents or adopt a surrogate that partly follows good practice. Hence most member companies either conform or partly conform to good practice

8.0 RECOMMENDATIONS

Five areas of improvement that could be applied to the best of the corporate and national guidance documents were identified. It should be noted that these recommendations do not apply to all of the best guidance documents since some already have one or more of these in place. The recommended improvements are:

- A tailings storage facility classification system based on the consequences of a failure and the introduction of safety standards commensurate with the different consequence classifications
- A formal change management process that is designed to ensure that when material changes are contemplated and subsequently made to the life of facility plan or to the Engineer of Record they are fully considered, formally adopted and embedded into the operations, maintenance and surveillance manuals, into budgets and into training and that the implications of the change are communicated. It is likely that change management processes exist at a generic level within most of the member company management systems. It is however important that a change management system be explicitly part of the tailings management system either by cross reference or by customisation
- Prescriptions for formal communication between the Engineer of Record and operators and owners in order to transfer and confirm shared understanding of the intent and constraints of the design and the operation in its specific context
- Formal risk assessment for tailings storage facilities by suitably qualified persons and ensuring that the mitigation measures arising out of the assessments are embedded into the design, the life of facility plan and the operating manual
- Independent review by suitably qualified and experienced professionals

9.0 CONCLUSIONS

The review that has been conducted on behalf of ICMM has found that although member companies' systems/guidelines may vary in terms of content and comprehensiveness, most have corporate guidance documents that meet and sometimes go beyond what would be considered to be good practice in tailings management.

Golder's primary recommendation is that a tailings management framework, supported by a governance framework that meets minimum requirements, should be adopted by all members. A working group of ICMM could serve to develop such a management framework on behalf of its members or alternatively each member company that does not yet have a complete management framework may elect to develop their own.

The second step is to implement assurance protocols that will verify that the new tailings management framework has been implemented.

Owners and operators starting with the board of directors and chief executive officer should commit to assigning responsible competent persons and giving them authority and resources to implement systems required to manage their tailings facilities in such a way that the potential for a catastrophic tailings dam failure is minimized. To further embody this commitment the owners and operators will need to be apprised periodically of the assurance findings and thereby satisfy themselves that the following questions have been answered satisfactorily.



REVIEW OF TAILINGS MANAGEMENT GUIDELINES AND RECOMMENDATIONS FOR IMPROVEMENT

- Are all tailings facilities designed with a full understanding of the site conditions and all reasonably-expected operating conditions?
- Are all tailings facilities being constructed and operated in accordance with defined thresholds and performance indicators with particular reference to containment integrity and overtopping?
- Are all facilities managed in accordance with the tailings management framework and are construction, operation, maintenance and surveillance of the TSF proceeding in conformance to design intent and associated plans and controls?
- Is compliance and performance verified at the intervals defined by the management framework and are there any non-conformances that may increase risk to the point where the design intent may not be achieved?
- Have the above items been independently verified by review by suitably qualified professionals
- Has an emergency response plan based on a comprehensive understanding of the consequences of failure been developed, maintained and tested?

The assurance system that is deployed should serve to answer these questions.

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APPENDIX A

DOCUMENT LIMITATIONS



REVIEW OF TAILINGS MANAGEMENT GUIDELINES AND RECOMMENDATIONS FOR IMPROVEMENT

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