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Water Management and the Global Industry Standard on Tailings Management

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ABSTRACT

In January 2019 the Brumadinho Tailings Storage Facility (TSF) failed, resulting in the deaths of 270 people. This was the second major fatal TSF failure in four years, which led to an industry-wide review of tailings management and the subsequent release of the Global Industry Standard on Tailings Management (the Standard) in August 2020.

The Standard provides a framework for the management of tailings facilities, with a goal of zero harm to people and the environment, and zero tolerance for human fatality. It specifies the implementation of best practices to the whole life cycle of the facility (planning, design, construction, operation, closure, post-closure) with water management an important part of this. Water is a key risk to TSF management and the underlying source of many failures.

Since the release of the Standard, there has been increasing interest in improving the governance and management of water in TSFs, primarily in areas such as the integration with wider site water management throughout the mine life, improved monitoring and change management, dam break assessments, and the incorporation of climate change assessments. To better understand these changes an online survey was established, to collect information on the current understanding of the Standard and its relationship with water management across different areas of the industry and at different levels of organisations.

This paper presents current thinking around how the Standards will affect mine water management, through the presentation of industry feedback and the results of an industry survey.

INTRODUCTION

Tailings are waste material generated in mine processing, once target minerals have been extracted from ore, and consist of a mix of fine ground rock, chemicals, and effluent from the processing system. Tailings are commonly diluted with water and transported in a slurry form out to tailings storage facilities (TSFs) for long-term containment. The intention is that the solids will separate out of the slurry and gradually form a consolidated, stable 'mass'.

There are two typical above ground storage facility types built to contain slurry tailings: retention dam (built to its full required height prior to operations) or raised embankment (constructed over a number of 'raises' or 'stages', as materials become available and as additional tailings storage is required). Construction of raised tailings dams uses either the upstream, downstream, or centreline methods (Figure 1). While all construction types have some risk of failure, the upstream construction type is the most likely to fail, as it relies on the integrity of the tailings for embankment stability; however, there have also been more dams built using the upstream method than other types (ICOLD, 2001; Lyu, et al., 2019).

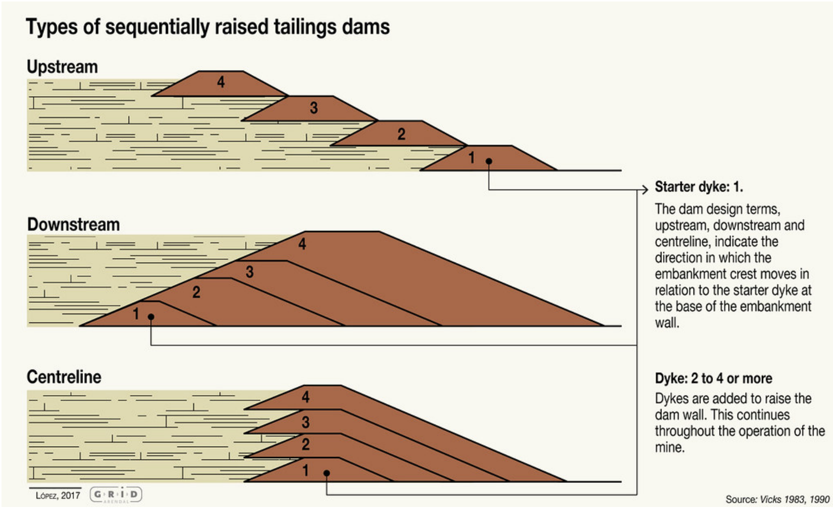

Figure 1. Tailings dam construction methods

TSFs present a high level of risk to both people and the environment. Failure of these facilities can lead to loss of life, destruction of housing and infrastructure, and contamination of watercourses and the environment. Lyu, et al. (2019) noted that on average three of the worlds approximately 3,500 tailings dams fail every year, a risk more than 10 times higher than for water retaining dams (Lemphers, 2010, in Berghe et al. 2011).

A breakdown of the causes of tailings dams failures between 1915 and 2016 is presented in Figure 2. Whilst tailings facilities are active, the highest drivers of incidents are slope instability, earthquakes, and overtopping. When facilities are inactive the highest risks are earthquake and overtopping (ICOLD, 2001).

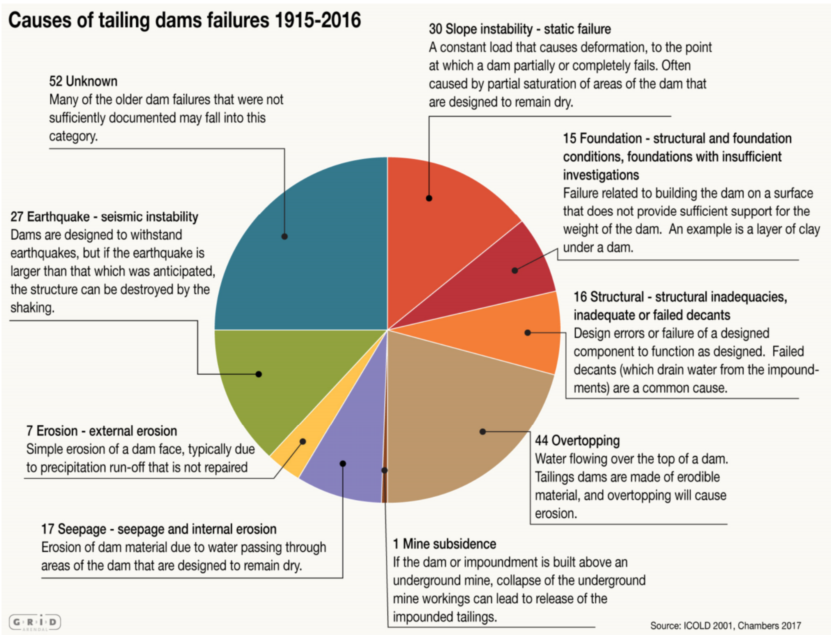

Figure 2. Cause of tailings dam failures: 1915 to 2016 (Thygesen, 2017)

In January 2019 the Brumadinho TSF failed, resulting in the deaths of 270 people. This was the second major (fatal) TSF failure in four years, after the failure of the Fundao tailings dam at Samarco in November 2015. These events lead to an industry-wide review of tailings management and the subsequent release of the *Global Industry Standard on Tailings Management* (the Standard) by the International Council on Mining & Metals (ICMM), in August 2020. The Standard was developed in partnership between the ICMM, the United Nations Environment Program (UNEP), and the Principles for Responsible Investment (PRI).

Although it could be argued that the Standard is a natural progression of improving industry standards and community requirements, the impact of the catastrophic failures of the Brumadhinho and Samarco tailings dams should not be underestimated as a trigger.

The Standard provides a framework for the management of tailings facilities, with a goal of zero harm to people and the environment, and zero tolerance for human fatality. It specifies the implementation of best practices to the whole life cycle of the facility (planning, design, construction, operation, closure, post-closure) with consideration for social, environmental, governance, and technical issues. Water management is an important part of this, as water is the underlying source of many tailings dam failures, as shown in Figure 2.

ICMM also released the *Tailings Management Good Practise Guide* in May 2021, which focuses on the implementation of the technical issues identified within the Standard. Conformance against the Standard can be assessed using the ICMM *Conformance Protocols for the Global Industry Standard on Tailings Management,* also released in May 2021.

The Standard does not replace industry technical guidelines such as ANCOLD, ICOLD, CDA, etc. but provides an overarching framework for tailings management.

THE STANDARD

The Standard consists of six topic areas, and explicitly covers all stages of the facility lifecycle, including Closure and Post-Closure. In summary, these are:

Topic i. Affected communities – Respect the rights of project-affected people and meaningfully engage with them.

Topic ii. Integrated knowledge base – Develop and maintain an interdisciplinary knowledge base throughout the tailings facility lifecycle, covering social, environmental, local, economic, and technical aspects. Use this to inform decision making and support safe tailings management.

Topic iii. Design, construction, operation and monitoring of the tailings facility – Planning and design criteria should be robust, incorporate the Integrated Knowledge Base, and minimise risk to people and the environment (Risk could include TSF embankment failure, unintentional discharge, contaminated seepage, dust issues, etc.). Ongoing management and monitoring should incorporate appropriate systems and reviews that ensure the quality and adequacy of the construction, operation, and closure phases.

Topic iv. Management and governance – establish policies, systems, and accountabilities to support the safe management of the facility. This includes appointment of an Accountable Executive, Engineer of Record, Responsible Tailings Facility Engineer, and Independent Tailings Review Board along with multiple levels of review as part of a robust quality and risk management system.

Topic v. Emergency response and long-term recovery – prepare site-specific emergency management response plans for tailings facility failures, and plan for long-term recovery in the event of a catastrophic failure.

Topic vi. Public disclosure and access to information – make information about the tailings facility publicly available, to support external accountability.

While the Topic Areas and Principles of the Standard are written at a high level, the glossary and summary tables provide significant detail around the requirements, roles and functions mentioned.

Key roles include:

Accountable Executive – Senior management within the mining organisation, accountable for overall safety and performance. Also responsible for appointing the Engineer of Record, Responsible Tailings Facility Engineer, and Independent Tailings Review Board.

Engineer of Record (EoR) – external consultant, responsible for the design of the facility, and ongoing construction and performance reviews.

Responsible Tailings Facility Engineer (RTFE) – usually site-based, and responsible for the implementation of the design, operations, and liaison with the EoR.

Independent Tailings Review Board (ITRB) – independent experts from a range of technical disciplines who undertake regular reviews of the safety and risk management of the facility.

Although the ITRB is commonly in place, the three other roles are new to many operations. Feedback received from mining companies indicates that they are experiencing a shortage of suitably qualified personnel to undertake these roles, particularly the EoR and the RTFE. As these roles require a good understanding of a range of technical disciplines, and how they relate to each other with respect to tailings management, it is likely that specific training will be required in order to upskill many engineers taking on these roles.

The EoR role is quite involved, and it will likely take some years to establish the systems and communication channels to effectively manage the design and review process, and to fully satisfy the objectives of the Standard.

Likewise, the RTFE role will take some time to fully embed within companies, with a major challenge being operational silos and current poor understanding of accountabilities across the different discipline areas within organisations.

WATER MANAGEMENT WITHIN THE STANDARD

The key objective for tailings water management is to minimise the volume of water sitting in the TSF. This acts to both increase tailings consolidation and stability, subsequently increasing the volume available in the TSF for additional tailings deposition, and also acting to reduce the risk of failure of the facility. Secondary objectives may be to maximise the volume of water reused on site, reduce site reliance on raw water, manage water quality, or reduce nuisance dust emissions from the tailings beach.

Of the six topic areas in the Standard, three explicitly refer to water or water management. These are Topic 2 (Integrated knowledge base), Topic 3 (Design, construction, operation and monitoring of the tailings facility), and Topic 4 (Management and Governance). These topics highlight a requirement for climate change assessments, breach and failure analysis, seepage investigations, groundwater modelling, water balance modelling and associated water management plans. These technical analyses rely on good data capture and management, with a requirement for adequate monitoring systems (outlined in Topic 3).

These are not new tasks; however, the Standard makes clear that these investigations should be carried out in a more integrated manner. That is, across the whole of the life cycle (planning, design, construction, operation, closure, and post-closure), and outputs should be incorporated in planning and design through multi-criteria assessments and with consideration for wider impacts to communities and the environment.

Change management is also highlighted within the Standard, as mine sites are dynamic operations. Modifications to operations is often made in a reactive or ad hoc manner and can be difficult to track down or quantify without a good change management system to capture details about the changes implemented.

In general, implementing the requirements of the Standard will need strong data management, documentation, and change management procedures.

Site Water Balance Modelling

The Standard places emphasis on water balance modelling encompassing the wider mine site.

TSFs have often been modelled in the past as stand-alone infrastructure, particularly during early design phases, and without integration into wider site water management. This can lead to overestimation of water reclamation from the TSF, with the potential risk of water accumulating in the facility during operations if the water balance (planned, modelled, and actual) is not regularly reviewed.

The following are typical examples of potential factors not taken into account in stand alone models:

- no pumping from the TSF during high rainfall or stormwater management events;

- reduced pumping from the TSF during the wet season, when management of excess water from other site areas is a priority;
- site uses a variety of water sources with a specific hierarchy and conditional operational requirements, which may minimise reclaim water use;
- infrastructure capacity restrictions may prevent full use of available water in the TSF, or may result in sending excess water to the TSF; and
- pumping downtime for site shutdown periods or infrastructure relocation during an embankment raise may not be considered.

These individual factors may cause small impacts on their own, but when combined, or ignored for a long period, they can cause considerable discrepancy between the predicted and actual water balance.

Calibration of TSF models is often limited, as two inflows (rainfall and tailings slurry water content) and one outflow (reclaim water) are generally well measured, but other inflows and outflows are often poorly quantified or understood. This includes factors such as the influence of dry and wet beach areas on rainfall-runoff and evaporation, seepage, tailings densities and consolidation, and catchment inflows.

Modelling is often limited to a short planning horizon, such as the current and next stage of TSF raising, or may only represent operations and not closure. These limitations often fail to identify and address long-term trends and risks, particularly with respect to seasonal water accumulation and climate change.

Modelling for closure studies will represent the final landforms and land use, but may not be well integrated into the operational/planning process where a limited planning horizon is usually adopted. This is done better at sites with progressive closure and reclamation, and where modelling incorporates changing landforms and land uses over time.

Climate Change

The Standard identifies climate change impact assessments as a necessary part of uncertainty analysis, which should be assessed throughout the facility lifecycle, and with respect to potential social, environmental and economic impacts. This will be primarily assessed through water balance modelling, where integration of all water resources across the site will be essential for revealing the full extent of climate change risks and interactions of resources. For example, risks to external water supply availability and reliability, changes to rainfall-runoff, water requirements for dust suppression activities, etc. There are a wide range of impacts which will affect water requirements across the site, and these should be considered on a site-specific basis.

At the initial design stage, Life of Mine planning is typically short (in the order of 5-20 years) as it is based on the currently known resource potential. Once operational, the mine life is usually extended over the years as new resources are identified, but often with only a short-term horizon. This then creates uncertainty on how to apply long-term climate change projections.

There are two approaches to this which are currently adopted and one which could be considered. Currently climate change assessments are used as part of closure planning, adopting regional projections for impacts to evaporation and rainfall at a set year and for a set emissions profile. For operations, a ‘typical’ year or two of wet, dry, and average conditions may be adjusted to highlight potential climate change impacts, again using a set year and a set emissions profile. A limitation of these approaches is that they are static, representing conditions at a single year, and do not consider gradual changes over the long-term. Instead, it is suggested that long-term stochastic climate data is adjusted to reflect the evolving impact over the available forecast periods, and is then modelled over the whole of mine life.

Ideally, water balance modelling should be run over a long timeframe, representing all stages of the mine lifecycle (construction, operations, closure, and post closure), with climate change incorporated as a developing trend. Modelling should be reviewed and updated regularly, to ensure alignment with the evolving mine and closure plans.

Review of site climate data should also be undertaken regularly as part of the Integrated Knowledge

Base requirement (Topic 2) to identify current or emerging wetting or drying trends (ICMM, 2021).

Cultural Water

Topic 1 of the Standard (Affected Communities) infers peoples' relationship to water through a reference to resource rights and human rights risk. Within Australia, this ties in with a push for acknowledgement of Indigenous water rights and values, often referred to as Cultural Flows:

> Cultural Flows are 'water entitlements that are legally and beneficially owned by Indigenous Nations of a sufficient and adequate quantity and quality, to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous Nations'[1].

Although Australia's national water policy, the National Water Initiative (NWI) (Australian Government, 2004), explicitly recognised Indigenous interests in water, the rights granted under the NWI are limited (Jackson, 2015). In practice, this is gradually changing, with influence from projects and initiatives such as the National Cultural Flows Research Project (NCFRP), which has released a national framework for the planning, delivery, and assessment of cultural flows (Nelson, et al., 2018).

There is an emerging need to consider Indigenous water rights and values in water resource management and development projects. For example, the Murray Darlin Basin Authority is required to report on how environmental water holders consider indigenous values under the *Water (Indigenous Values and Uses) Direction* (Australian Government, 2018) and recent development projects in northern Australia have assessed Indigenous water rights (Barber & Woodward, 2018; Jackson, 2018).

For mining operations, the implication is that this is an area of developing interest and should be incorporated in planning and management. This would apply to both surface and groundwater.

TSF breach and failure analysis

The Standard has made a significant change to the approach for TSF breach and failure analysis. The previous approach has been to design the facility, provide an initial assessment of the failure Consequence Category (based on risk to human life, and severity of damage and loss) (ANCOLD, 2012b) and adjust the design to accommodate the management requirements for that Consequence Category (e.g. freeboard, Design Storage Allowance, Minimum Extreme Storm Storage).

The new approach is to adopt an 'Extreme' Consequence Category rating from the outset for the design of the facility. If the design can be justified to lower the consequence rating then this can be done, so long as the project retains the flexibility of design and availability of real estate to be able to upgrade the hazard rating in the future, should the consequence of failure change.

This is relevant for sites which may experience significant inward migration once construction or operations commence, or sites where infrastructure and buildings may expand up to and around the site. Sites may have to sequester land to ensure that it is available for this purpose should conditions change.

Tailings dewatering

Management of tailings dewatering (or thickened tailings) has been evolving over recent years, with the development of increasingly sophisticated dewatering systems. Dewatering aims to reduce the volume of water discharged with the tailings, and has the benefit of reducing raw water demands at the same time as improving geotechnical stability of the TSF and reducing water related risks, such as groundwater contamination. Figure 3 presents a summary of the impacts of tailings thickening.

The traditional approach for tailings disposal is as an unthickened slurry, with a solids concentration of less than 30% (by weight). While this approach is low technology and low cost, it also requires significant amounts of water for the slurry. This creates ongoing water management issues as the water losses from this approach are high (via seepage, evaporation, and entrainment) and water recovery from the storage requires ongoing management.

More recently, the industry has adopted dewatering of tailings prior to disposal. This is either as

[1] This definition was endorsed by representatives from thirty-one Indigenous nations at a joint meeting of the Murray Lower Darling River Indigenous Nations (MLDRIN) and the Northern Basin Aboriginal Nations (NBAN) -The Echuca Declaration, September 2010

thickened tailings or as filtered tailings (also referred to as dry stacking). Thickened tailings can achieve a solids concentration, generally, in the range of 45-70% (by weight), depending on the thickener process adopted and the specific gravity of tailings solids. Filtered tailings can achieve a solids concentration of up to 85% (by weight) and are generally too thick too be pumped, and must be transported by truck or conveyor.

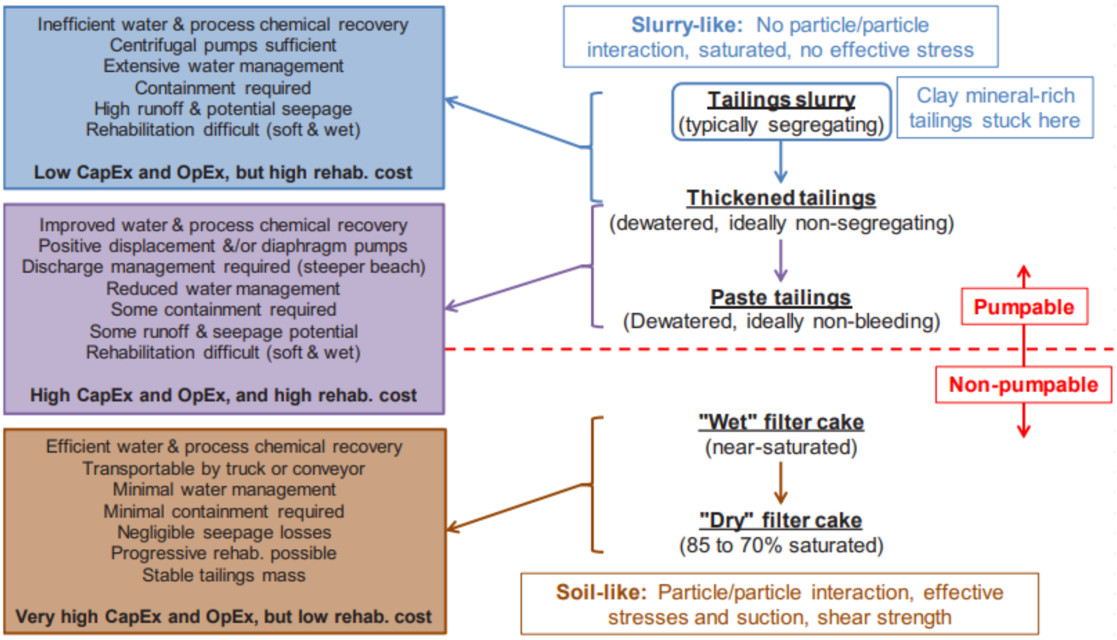

Figure 3. Tailings continuum (LPSDP, 2016)

Where possible, dewatering of tailings should be considered, although constraints do exist to the adoption of these technologies. Consideration should be made of factors such as tailings rheological properties, pumping distance, water availability, climate, etc.

RECENT CHANGES OBSERVED IN THE INDUSTRY

ATC Williams has already seen significant changes caused by the new Standard. In particular, the Engineer of Record role requires significant time and attention to understand in full, and to clarify channels of communication within large organisations.

In terms of water balance modelling, several sites where an integrated modelling approach was previously recommended but not adopted have now transitioned to a site-wide model, integrating the TSF and wider site water management infrastructure and operational rules. The Standard has provided the impetus for the sites to combine these models, which has subsequently identified potential operational risks and opportunities for improvement.

Increasingly there have been discussions of incorporating climate change in hydrological modelling, both for long-term water balance and design event modelling. This is being adopted more readily for closure planning than it has been for operations. In addition, closure planning is becoming more comprehensive and starting earlier (spurred on by requirements such as the Queensland Government's Progressive Rehabilitation and Closure Plan guideline), with some studies now requiring the assessment of water management throughout the closure construction and implementation phase, not just post-closure.

To improve the understanding of these changes an online survey was established, to collect information on the current understanding of the Standard and its relationship with water management across different areas of the industry and at different levels of organisations. In addition, a number of interviews were undertaken with mining staff working with tailings.

There was a relatively low number of responses to the survey (x 28), and this may reflect a slower adoption of the Standard than expected. However, all responses were from people working in mining or mining engineering consultancies, and all had roles that intersected with tailings management. While the majority of the respondents worked within Australia (77%), many also worked across multiple countries.

Based on these limited reponses, the following trends were identified:

Within mining organisations there are varying levels of awareness and understanding of the Standards, and how to implement them. In general, among the respondents there was a very high level of awareness at the Group Manager or Principal level (where technical experience is highly relevant to the role), with more variable understanding at both the Senior Management and Superintendent / Senior Engineer levels, and generally low awareness at the Operator level. This reflects the early nature of the implementation of the Standard, which is very much driven from management down to sites. There was also some frustration evidenced with poor communication of the requirements of the Standard to departments that were not directly involved in managing tailings, such as environmental or stakeholder engagement.

Respondents had quite mixed responses in terms of understanding the objectives of the Standard themselves, with 22% stating a poor understanding, 30% moderate understanding, 26% good understanding and 22% fully understand. However, in their view organisational understanding was generally good to moderate, with 13% stating a poor understanding, 35% moderate understanding, 39% good understanding and 13% fully understand.

In terms of implementing the Standard, most (65%) indicated that discussions of the Standard and its application were regular or extensive within their organisation. Overall, although respondents had a mixed view on how well they thought their organisation understands the Standard, they generally (68%) thought that their organisation was making moderate to significant changes to operations and planning because of the Standard.

Of the six topic areas of the Standard Topic 1 (Affected Communities), Topic 3 (Design, construction, operation and monitoring of the tailings facility), and Topic 4 (Management and Governance) were seen as the priorities for water management. Respondents generally (84%) thought that the Standard would affect water management at TSFs to a moderate-significant degree, throughout the facility life cycle. However, in terms of wider site water management the Standard was generally (63%) viewed as having a low-moderate impact.

Respondents anticipated a moderate-high requirement for additional or new technical work to be undertaken (79%). Integrated site water management and dam failure assessments were identified as the leading priorities for water management. However, a range of other issues were also seen as important, including climate change, tailings dewatering, change management, TSF water management, monitoring, and cultural values of water.

CONCLUSIONS

The release of the *Global Industry Standard on Tailings Management* in August 2020 has created significant change in the tailings management industry, both within mining companies and engineering consultancies. The Standard provides a framework for the management of tailings facilities, with a goal of zero harm to people and the environment, and zero tolerance for human fatality. It specifies the implementation of best practices to the whole life cycle of the facility with consideration for social, environmental, governance, and technical issues. The Standard also requires more personal accountability for tailings management, specifying three roles: Accountable Executive, Responsible Tailings Facility Engineer, and Engineer of Record, as well as an Independent Tailings Review Board.

Although the Independent Tailings Review Board is commonly in place, the three other roles are new to many operations and there is a shortage of suitably qualified personnel within the industry to undertake these roles. It is also likely that it will take some years to embed the systems and communication channels to effectively manage the design and review process, and to fully satisfy the objectives of the Standard. A major challenge to effectively implementing the Standard are operational silos and current poor understanding of accountabilities across the different discipline areas in organisations.

In terms of water management, while the Standard highlights a requirement for a range of technical studies these are not new tasks. However, the Standard does place a higher requirement for these studies to be incorporated in more detail into the whole of the life cycle, through planning, design, construction, operation, closure, and post-closure.

This paper has identified four areas of water management which require change or improvement; site-wide water balance modelling, climate change, cultural water, and TSF breach and failure analysis. In general, implementing the requirements of the Standard will need strong data management, documentation, and good change management procedures.

While the major benefits of adopting the Standard are around reducing risk and uncertainty, and increasing safe management of TSFs there are a number of other benefits that could potentially be realised, including those brought about by better water management. These could include increased water return and recycling from TSFs (leading to reduced raw water use), improved infrastructure and closure planning, and improved environmental performance.

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BIOGRAPHY

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