When the bottom-line impacts dam safety: Case studies of commercial realities leading to increased risks

James Thorp[1]
Ryan Singh[1]
Jiri Herza[1,2]
[1]HATS Consulting Pty. Ltd,.[2]Czech Technical University

Responsible management and operation of tailings and water storage facilities comprises a series of activities and projects that must be delivered within the commercial realities of the organisation and operation context of the facility owner. All projects are constrained by several variables, which are commonly represented by the Project Management Triangle of Scope, Time, and Cost. These variables are often finite and mutually exclusive, and delivery of the required outcome is accomplished by successfully managing each variable. The activities (variables) associated with the long-term dam safety are sometimes omitted to meet the immediate project requirements. In addition, the commercial realities, such as a selected project delivery model, can have a significant impact on dam safety risks through the allocation of risk, ability of the key decision makers, and the undue commercial pressures applied by each project delivery model. This paper presents several case studies where the project and commercial realities have led to decision making that impacted dam safety and increased the risk presented by the storage facility. While the immediate impact of these decisions may appear to be minimal, all stages of a tailings or water storage facility's life span are impacted. This paper presents learnt lessons with the aim to prompt both owners and consultants to reconsider their commercial processes and project delivery strategies and limit unforeseen risks to the safety of tailings or water dams.

Keywords: *dams, tailings, risk, commercial, procurement, project delivery*

Introduction

The paramount goals of tailings and water storage facility management are to ensure that the facility is operated and managed to improve and maintain dam safety according to current industry practice and to keep the risk presented by the facility within tolerable levels. Facility management consists of a series of activities and projects to achieve these goals.

All projects are required to be managed within constraints imposed by commercial processes and procedures. The reality is that a project will not have sufficient scope, time or budget to meet the outcomes expected from all stakeholders. Owner organisations have processes to ensure that outcomes meet required levels of quality despite the project constraints. While defining cost and time requirements is relatively straightforward (by way of a budget and schedule, respectively), clearly defining the quality requirements is challenging due to the abstractness of such criteria. Minimum quality requirements may therefore be either improperly stated or neglected in favour of cost or time pressures.

Tailings and dams projects are also subject to other commercial realities that may not align with the goals of increased dam safety and managing risks within tolerable levels. These commercial processes and mechanisms, such as tender reviews, procurement processes and various project delivery models, are undoubtedly important. They achieve accountability, transparency, repeatability and streamline the commercial processes required to effectively manage storage facilities. However, these processes and mechanisms have been created to accommodate a broad spectrum of management, project, and operational activities, and may not account for the unique risks presented by storage facilities.

Where the goal or performance indicators of these commercial realities and processes, such as procurement processes or project delivery methods, do not align with dam safety or risk reduction, the goals of the commercial processes are often given priority over the goals of facility safety. While this may be justified, for example with risk assessments, the true impact on facility safety may not be well understood by decision makers involved in the particular, discrete project.

This paper presents case studies where processes imposed by the commercial realities of mining and water infrastructure projects resulted in a potential or actual increased risk to the safety of tailings or water dams. As an introduction to the case studies, pertinent aspects are discussed including their ability to potentially increase dam safety risks if inadequately managed. These aspects include the unique economic restrictions experienced for tailings management, commercial contracts, project funding, and project delivery models. The outcomes of the case studies are discussed and several recommendations for improvements are presented. These recommendations may be considered by both owners and consultants to review their commercial processes and project delivery strategies and limit unforeseen risks to the safety of a tailings or water storage facility.

The authors recognise that projects must ultimately be conducted within the various processes adopted by companies to reduce replication of onerous responsibilities, procedures, reporting and paperwork. Further, no two organisations use the same commercial processes and mechanisms to carry out their management and operational activities. As such, the lessons and recommendations presented in this paper are broad to allow owners to consider how they could be implemented within their existing commercial processes.

The commercial realities of tailings

Tailings are the resultant materials from the process of separating and obtaining valuable ore products from the rest of an ore body which contains waste rock and the fraction of ore that would be uneconomical to obtain, as well as process chemicals. It is part of the mining process that yields little to no economic value for a mining company and which requires significant capital expenditure and resources to manage responsibly. The low asset value may result in less commercial attraction for allocation of a mining company's resources and budgets, which can threaten the ability to achieve satisfactory tailings management.

Recent tailings storage failures have demonstrated the immense financial consequences of insufficient tailings management. The Mariana TSF failure in 2015 cost Samarco US$4.8 billion in fines, not including the cost of rehabilitation and compensation to affected parties (CNBC, 2016), while the Brumadinho failure in 2019 was estimated to cost Vale approximately US$5 billion (Gluyas, 2019). Aside from the financial impacts, the failures were highly publicised and resulted in loss of life. These failures have party instigated revised or new tailings management standards and guidelines to be produced by organisations such as the Global Tailings Review, International Commission on Large Dams, International Council on Mining and Metals, Canadian Mining Association and others.

While these new standards and guidelines provide improved tailings management and operational guidance, tailings storage facilities are still subject to the commercial processes and mechanisms utilised by the owners to manage and operate all of their assets.

A key objective for a water or tailings storage facility project must be to identify, assess and control the risk of a facility failure and the achievement of such objective must contribute to the measure of overall quality of the solution. The project objectives must go beyond the tangible items such as the physical dimensions of a facility (e.g. how much tailings storage is achieved) and the commercial attributes (e.g. the cost of construction and the time to complete) and focus on the quality of the solution. This requires overcoming the commercial realities of tailings and accounting for the consequences of a potential failure.

Project management principles – Cost, Time, and Scope – and the impact to TSFs

The Project Triangle presents the restrictions inherent in delivering any project (Figure 1) (Ten Six Consulting, 2014). While potentially overly simplistic, it nonetheless illustrates that the final outcome of the project from a project management perspective (illustrated by Project Quality being placed in the centre of the triangle) is subject to factors and constraints in a project that must be satisfied and are often mutually exclusive. Changing one constraint will affect one or both of the other constraints.

Figure 1 The Project Triangle (Ten Six Consulting, 2014)

The most common interpretation of the Project Triangle is that we can only ever control and "optimise" two factors of Time, Cost and Scope. The expectations of the third factor must change, otherwise the resulting Project Quality will suffer. A geometrical interpretation of this relationship is that in order for the project to be successful, the Project Triangle must remain equilateral. However, this is very much a Project Management focussed definition of "success", and does not account for meeting minimum technical expectations or objectives (referred to as Technical Quality for the purposes of this paper) which could be threatened by a reduced Scope. This Technical Quality could be represented by the area of the triangle, and as the scope is reduced, the area (i.e. Technical Quality) is reduced. As demonstrated in

Figure 2, a minimum required triangle size, representing minimum acceptable Technical Quality, must be achieved, and therefore the allowable scope reduction must be limited for the project to be successful.

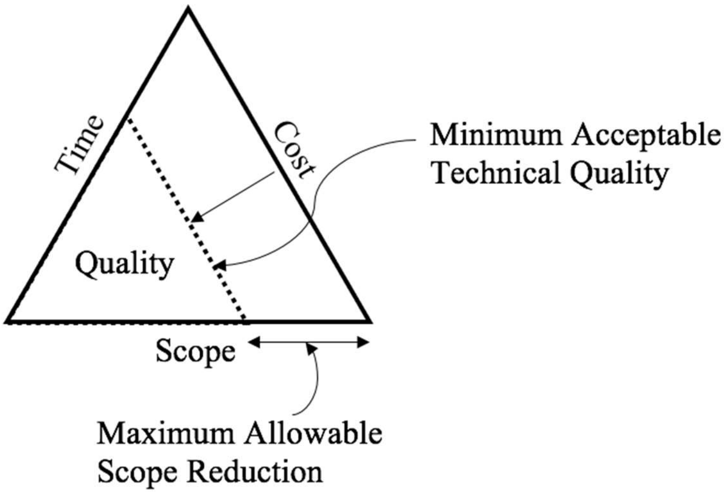

Figure 2 The Project Triangle with minimum acceptable technical quality bounds when scope is reduced

So, of importance is the definition of Quality, and what a "successful project" means both to the Project Manager and the technically focussed stakeholders, such that any scope reduction measures do not result in unacceptable Technical Quality. For most TSF projects, Quality, as it is viewed by the wider project team, is the delivery of a fit-for-purpose tailings storage area which will provide storage for a nominal period. Often, projects to expand TSFs will be initiated based upon estimates of the time for existing tailings storage to be exhausted and the time the project will take (Time). The budget of the project will be allocated from pre-determined capital project funds which is based on previous costs incurred, predicted market forces and any design work for the expansion that may have been completed at a higher level (Cost). As such, the Scope, while not completely fixed, is highly constrained. If no other objectives apart from additional storage are identified with enough forethought, the scope is constrained to only the activities that will lead to the provision of additional storage.

This is an issue as by virtue of providing additional storage capacity, the risk profile of the TSF is likely to change. Should this change result in intolerable levels of risk, it will only be identified during the design stage, when costs and schedules are somewhat fixed. As a result, only limited Scope changes can be made to address this increase in risk without severely impacting the project Time and Cost.

Of concern is the common situation where Time and/or Cost become an issue for a project. Because Time and Cost are quantifiable, finite and relatable concepts, the comparatively less quantifiable Scope is reduced to not impact the Quality of a project (i.e. to maintain an equilateral project management triangle). Activities which are seen to not be imperative to the current project are then removed.

While a certain number of activities can be removed without impacting the Technical Quality of a project or facility, it is foreseeable that items that may have been included to reduce the overall and long terms risks of the TSF (e.g. geotechnical investigation, testing or more extremely, remedial works) may be removed as they do not directly prohibit the ability to fulfil the Project Quality objectives.

The example above shows that it is important that Quality objectives be reviewed to ensure that "quantifying and at a minimum not increase the risk of a facility" is included and that the Technical and Project Quality objectives are aligned at the project outset.

Commercial contracts

Contracts are legally binding agreements that provide and govern the rights and duties of the parties to the agreement (Ryan, 2006). In the context of dams and tailings projects, commercial contracts between the owner and designer or the owner and contractor stipulate the responsibilities of each party to each other in the delivery of the design or construction of the works.

A key negotiation item is the Limit of Liability that the contracted party has to the owner and third parties should any damages occur as a result of the supplied services. Parties negotiate to improve their position with respect to owning liability to any given party. While these negotiations are inevitable, the owner must consider this activity as part of the project schedule. Given the recent perception of risk associated with dams and tailings facilities, it is understandable that negotiations could be protracted. The risk is that these lengthy negotiations may erode critical project schedule and ultimately lead to reduction of important risk-reducing activities from the scope to achieve a rigid completion milestone.

Project funding

While heavily dependent on the internal processes of an organisation, funding for a dams or tailings project generally comes from an allotment of money allocated for a particular purpose. Broadly, these purposes could include operation and maintenance, capital projects (further divided into new or existing capital) or closure.

Projects are allocated funding from each of these allotments based on urgency and need of the project, with the amount based on estimates which are, at the time, an order-of-magnitude or concept-level cost at best.

While this system works when the requirements of a facility are known and can be planned for, it does not allow for flexibility and reactiveness when a hazard is identified that results in an increase likelihood of failure of a facility. This is further complicated when it is not clear what fund (e.g. capital expenditure or operations) the costs to address the hazard should come from.

In addition, there is a preference from an accounting standpoint to capitalise costs where possible. Capitalising costs refer to the accounting for costs over the period that the asset will be used, via depreciation (Tuovila, 2020). By doing so, accounted costs are reduced per period, resulting in an increase in reported profits. While this is an acceptable business practice, an issue may arise when deferring costs is selected over undertaking works which can increase dam safety due to the costs not being able to be capitalised. An example of this is the deferral of progressive closure works. As closure costs do not contribute to the production of goods or services (like a TSF expansion does) it may not be capitalised. Thus, progressive closure works, which can have a secondary objective of improving dam safety during the operational phase, may be deferred until closure is imminent in favour of achieving a more beneficial accounting standing in the short-term.

This example highlights that accounting considerations, while important, should never drive dam safety and risk reduction decision making.

Project delivery models

There are a number of different project delivery models, however the main models are either the "traditional method" of separating the design phase and the construction phase, or the "design and construct (D&C) method" of engaging a single contractor to deliver the design and construction of an asset. The selection of an appropriate delivery model with suitable personnel nominated for key project decisions is a common thread through the case studies presented in this paper, therefore a brief description of the two primary delivery models is provided.

In the traditional model, the principal (owner) separately engages the design consultants who remain responsible to the principal, and subsequently called tenders from contractors on essentially complete design documentation prepared by the principal's designers. This model provides greater control to the principal in the selection and direct engagement of their designers. The principal, with adequate in-house or advisory technical expertise, is best placed to manage the technical dam safety risks, working directly with the designer to develop a solution. However, if such expertise is not readily available, the owner makes decisions without the necessary involvement or input from a designer and these decisions may increase the risk of the facility.

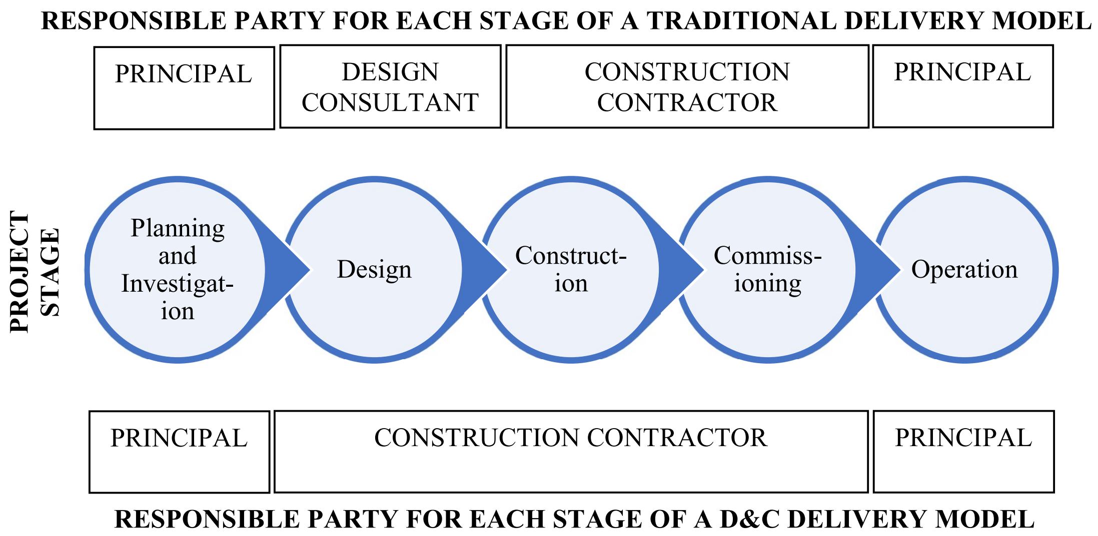

Figure 2 Responsible parties for each stage of a project – traditional vs. design and construct delivery model

The design and construct (D&C) delivery method has become a popular method of project delivery in Australia over recent years. The essence of a design and construct contract is that the contractor undertakes the responsibility and liability for the final design, as well as the construction (Charrett, 2003).

A D&C project in its most basic form requires a lump sum construction contract to be executed based on only a preliminary tender design with limited input data produced in a highly competitive commercial environment. The design is not fully detailed at the outset, leaving scope for the tenderers to provide their own unique input in an endeavour to reduce costs in a competitive environment. This introduces risks – a cost saving measure could be introduced to the win the job, potentially to the detriment of dam safety. In such situations, preliminary designs are inherently less conservative than they otherwise would be in the traditional delivery model for the same level of input data, with the contractor required to understand the commercial risks of adopting such non-conservatism.

The skill in tendering design-construct contracts is in the extrapolation from incomplete documentation to cost the entire project. As Australian contractors do not have any substantial 'in house' design capacity, they normally engage consulting engineers to prepare the dam designs. There can be poor understanding of the design assumptions made, potentially leading to cost estimation errors, if the designer is not adequately involved in the contract pricing process. Such an example is provided in Case Study 1. A particularly important inclusion is a statement of the way in which the contractor would use the preliminary design in the tender e.g. nomination of the percentage contingency that would be applied to the cost determined from a take-off from the preliminary design (Charrett, 2003).

Roles and responsibilities

As seen in many storage facility standards and guidelines, several roles and responsibilities are required in the management and operation of a storage facility. While these roles and undoubtedly important for the safe management and operation of a facility, the standards and guidelines are often silent on how these roles connect and relate to the commercial processes that managing and operating a facility will be dependent on. A key theme of the presented case studies (aside from Case Study 1) is that the suitably experienced and qualified person responsible for the safety of the facility was not involved in the commercial decisions that could impact the safety of the facility.

Case Studies

Case Study 1 - Risks associated with a design and construct project delivery method for an irrigation supply dam

Overview

In this example, a design and construct (D&C) delivery model was adopted for an irrigation supply dam project for a private company. The preliminary tender design was completed under a restricted schedule and budget, with limited available foundation geotechnical data. The spillway concrete dimensions and ground anchoring details were subsequently increased during the detailed design with the benefit of additional geotechnical data and completion of more detailed analyses. This resulted in a significant increase in construction cost for that portion of the works. In the lump sum D&C scenario, the contractor and designer were not able to claim a cost variation for such change. In order to limit the cost overrun, further optimisation and less-conservative approaches to the design were required. This reduced design conservatism was justified by utilising more advanced spillway analysis techniques, which was outside the project scope and therefore performed at no additional cost by the designer. The residual increase in construction cost for the final design was then borne by the construction contractor.

The risk

The constraints of a D&C contract led to a less conservative spillway design being adopted than what may otherwise have been in a traditional delivery method. The potential risk in this scenario is that the spillway may not have met the functional requirements if the contractor and/or designer succumbed to the financial pressures to implement a solution of inadequate scope or quality in order to meet the project budget constraint.

The commercial realities that caused the risk

There were several factors that caused the risk including:

- The tender design was required to be completed under undue time and budget pressures, with insufficient detail commensurate with the required level of accuracy of the construction tender.
- There was limited available geotechnical data due to the spillway area not being accessible prior to the construction phase.

- There lacked a clear understanding of the assumptions behind each design element such that the Contractor could account for the level of design detail for each element by including contingency. It is likely that this was due to the time pressures of the tender period.
- The contractor performed a material take-off from the drawings, which were limited in detail and scope. Some incorrect assumptions or interpretations were made that should have been clarified.

Lessons learned

Whilst the project outcome was satisfactory, the process could have been improved in several ways, including:

- An alternative delivery model could have been considered to allow for completion of the detailed design with the suitable level of input data prior to the construction tender pricing. This would have included the complete geotechnical investigation and analysis of the spillway area. The construction contractor could then price the project based on a complete set of details and be under less pressure to restrict the scope of the works to limit budget overrun.
- Greater understanding and alignment between the designer and the cost estimator was required to allow for sufficient contingency for items of unknown, such as the ground anchoring and spillway floor slab thickness. Such alignment needed a clear understanding of how much contingency should be applied to each element based on the accuracy of the input data and analyses completed.
- The tender period was apparently too short to allow for sufficient discussions and alignment between the designers and construction contractor's estimators to occur.

Case Study 2 - A procurement decision with large consequences for a tailings dam raise construction project

Overview

In this example, a simple construction procurement decision was made by the owner's project management team during the construction tender evaluation process for a tailings dam raise project which had dire consequences for the construction phase. The required product was ultimately delivered to the required quality, but not without lengthy delays, cost variations and high levels of workplace stress for all parties involved. The original decision was made, seemingly to reduce project costs. The author was not involved in this decision but can speculate that the perceived risks must have been deemed low enough to be acceptable on a cost vs. risk basis.

Background

The design of the tailings dam raise adopted iron ore beneficiation waste for the embankment construction material as it was readily available and provided a high strength, low permeability material when compacted. Due to the presence of iron ore gravel, the compacted density of the material was not able to be tested using common insitu testing equipment. Therefore, it was determined to adopt a method specification, with the results proven by construction trial pads using arduous sand replacement density tests. However, it was also required that the materials be tested regularly to confirm consistency with the original trial pad, including the material classification, as well as the moisture content when compacted.

This project was delivered by the traditional method, where the designer and the construction contractor were engaged directly and separately by the owner. The owner elected to conduct their own construction tender evaluation, without consultation with the designer. The successful tenderer had proposed a deviation from the technical specification where no further embankment material testing, beyond that undertaken during the trial pad construction, would be included in the scope. This was accepted by the owner for reasons unknown to the author, however we speculate that it was either an oversight, or a deliberate decision with the misguided aim to reduce project costs.

The designer was then engaged to carry out the quality assurance role for the works on behalf of the principal, by evaluating the conformance of the works with the technical specification. The designer was not made aware of this contractual deviation due to the confidentiality of the construction contract. It became apparent soon after construction commenced that the required embankment material testing was not being followed, and once this was raised and discussed, it was confirmed that any additional embankment material testing was to be awarded as a variation to the contractor.

The risk

The decision to allow the construction contractor to exclude embankment material testing from their scope beyond completion of the trial pad made it extremely difficult for the designer engineer to uphold the requirements of the technical specification. Works advanced despite several non-conformances, mainly related to insufficient embankment material testing and documentation. After a long and difficult negotiation process between all parties involved the situation was rectified by reconstructing a significant portion of the works.

The potential risk in this scenario was that the owner could be forced to accept works that did not comply with the technical specification, to avoid potential schedule delays and cost increases associated with redoing construction work. A substandard section of work could then remain in the embankment, potentially leading to an increased risk of an embankment failure event.

The commercial realities that caused the risk

In a tender evaluation process, there is a temptation to accept the lowest cost tender as it provides a directly measurable benefit to the project. Scope and quality are much more difficult to measure. Especially for personnel not adequately skilled or experienced to assess such criteria. The engagement of the lowest cost tenderer, which had been achieved by omitting a critical portion of the scope, caused the potential risk.

Lessons learned

There are several lessons to be learned from this difficult construction project. Whilst the events of this construction project in hindsight may seem readily avoidable, construction projects are high pressure situations that can cloud judgement and prevent efficient resolution of problems. The main factor influencing this outcome was the ill-advised decision to allow for a reduced scope of testing in the executed construction contract. Such critical decisions regarding technical details must be made by those personnel with the suitable skills and experience to make such judgement. This should be the person who is directly responsible for the safe operation of the facility. Furthermore, the designer, who is most aware of the intent behind the design and specification, must be consulted in the process.

Case Study 3 – Dam safety improvements impeded by rigid procurement processes

Overview

In this example, a rigid procurement process prevented the acquisition of a pump to safely manage the liquor levels in residue settlement ponds at a bauxite mine. In the interim, operational staff were raising the walls of the ponds which were reaching capacity. The raise was not executed in accordance with any design and no formal material and compaction testing was undertaken. As a result, the stability of the raised walls was in question. The consequences of failure for this facility included potential loss of life of several operators and significant environmental impact to a high-value river system.

Background

The operation of a bauxite mine included mine waste residue (tailings) settlement ponds constructed as a series of turkey-nest ponds, featuring homogenous embankments of clayey gravels and sands/gravelly clays. The settled fines were regularly dredged from ponds and stockpiled. Due to the limited space available for stockpiling of dredged waste resulting in the storage capacity of the storage ponds being exhausted, additional settlement ponds were required and were being constructed. However, the forecasted capacity of the existing settlement ponds indicated that storage would be exhausted prior to the new ponds being available.

One of the identified and robust solutions included the procurement of a moveable pump which could be used to pump liquor from ponds with limited storage, to ponds with surplus storage. Due to the owner’s procurement process, purchase of the pump required a tendering process taking several months. It was stated that the process could not be bypassed as there was no formal mechanism to do so.

The risk

Without the ability to adequately control the liquor levels, operational staff were raising the walls of the ponds to increase their capacity without following a formal design or construction quality control practices. This approach increased the likelihood of failure or overtopping, leading to uncontrolled release of contaminated liquor into the a high-value river system and potential loss of life and thus, an unacceptable risk to the environment and operator safety.

The commercial realities that caused the risk

A procurement process is a necessary element of any successful operation to manage the quality of equipment procured, ensure a fair an honest process of high integrity, and to control expenditure. Those responsible for implementing the process have a duty to abide by these requirements, usually as part of a company’s formal internal procedure. However, if this process is upheld without the ability to circumvent under special circumstances, then this commercial reality can increase the risk of a dam safety event occurring. In this circumstance, application of procurement processes without context or the ability to bypass the process on a risk-basis resulted in increased social, environmental, and business risks.

Lessons learned

Where there has been insufficient forward thinking to procure equipment, or indeed services, within the normal procurement timeframes, there must be an overarching process that allows for circumventing such processes in a special risk circumstance, guided by the suitably qualified and experience person responsible for the safe operation of the facility.

Case Study 4 – Important risk-reduction activities impacted by lengthy contractual negotiations

Overview

In this example, lengthy contractual negotiations between the owner and designer for a TSF raise design project led to the risk of the project schedule not being met and thus exposed the owner to the risk of no available storage when the existing capacity was exhausted. As a result, the scope and execution strategy were amended to maintain the completion date. The originally planned geotechnical investigations were reduced and executed in parallel with the detailed design, with the rationale that any design or redesign required to address identified geotechnical issues would be completed during the construction tender period. Furthermore, a detailed geotechnical investigation scope, as recommended by a recent dam safety review, was combined with the TSF raise design project. This scope was then susceptible to the same commercial pressures and was also limited to meet the project completion date.

Background

The available tailings storage within the existing TSF at an iron ore mine was forecast to be exhausted within 24 months. As a result, a capital project was initiated, and a project schedule developed to ensure continuation of available tailing storage. Upon award of the design, a lengthy contractual negotiation period ensued, as there were no pre-existing agreed terms, and commencement of design was delayed.

To reduce the schedule risk, the proposed geotechnical investigations scope was staged and reduced. Originally, the aim was to carry out a scope to investigate the foundation conditions, tailings beach, existing embankments and to identify borrow materials prior to the design activities occurring. Adding further complications was that additional investigation scope was included by request of the owner's technical advisory team because of a recent dam safety review. It was included with the aim of achieving cost and time efficiencies by combining the geotechnical investigation scopes required strictly for the TSF raise and the dam safety review scope. The reduced scope included only borrow investigations prior to design, with the remaining geotechnical investigations occurring during the detailed design activities. Much of the dam safety review scope was agreed to be delayed until during or after construction activities for the TSF raise, though this raised questions over why they were not included in the base scope, if they were identified to be "essential" in reducing the risk of the TSF in the dam safety review.

The schedule pressures resulted in the project team being stuck between increasing the risk to the project schedule and the operation of the mine by carrying out the complete geotechnical investigation in a timely manner, and increasing the risk to the facility by not carrying out the geotechnical investigation as a result of the dam safety review. Given commercial pressures, the risk to the project schedule was decided to be the more important risk to be addressed.

The risk

The reduction of geotechnical scope increased data uncertainty and potentially increased the likelihood of a facility embankment failure from an undetected geotechnical or performance anomaly. It is difficult to determine what level of geotechnical investigation detail adequately reduces risk and then agree between project stakeholders the acceptable scope for a geotechnical investigation. ANCOLD has recently produced guidelines for geotechnical investigations (ANCOLD, 2020) which should assist in aligning the project stakeholders' expectations and objectives.

The commercial realities that caused the risk

There were two different commercial realities leading to the risk. Firstly, the lengthy contract negotiation period eroded critical project schedule. Whilst the contractual risks were deemed worthy of such attention, the lengthy contract negotiation period, and subsequently reduced geotechnical scope, introduced new risks by indirectly limiting the geotechnical data available for the design. Owners may be exposing themselves to greater risks to project quality by placing too much emphasis on the importance of enacting a design contract that transfers contractual risks to the designer. Furthermore, such difficult negotiations may preclude some designers from providing services to the owner, reducing the owner's access to the necessary skills and personnel. This example shows how critical project schedule can be consumed by contractual negotiations, which may not be the best use of time in the context of the overall project risks.

Secondly, combining the delivery of the dam safety review geotechnical scope with the TSF raise project to attempt to achieve project efficiencies created competing objectives. The main objectives for the key technical stakeholders for the dam safety review project was obtaining the required geotechnical data, with the aim of better understanding the hazards to the TSF and therefore the risks that the TSF presented. However, this was not explicitly included as a key outcome of the TSF raise project, and thus was excluded as it did not align with the TSF raise team's primary objective of providing additional storage within cost and time constraints.

Lessons learned

It is recommended that the following is considered by owners when planning time critical projects:

- Time critical projects must have access to designers that have already negotiated agreed terms of engagement.

- If contractual negotiations, or other potentially delaying procedures, are required, they must be undertaken in full consideration of the overall project risks.
- Consider separating projects if there is a risk that key outcomes may not be achieved due to commercial pressures and competing objectives.

Most importantly, the person responsible for the safety of the facility must be more involved in the commercial project decisions to close the gap between the owner's tailings governance principles and the commercial processes.

Conclusions

This paper presents case studies where processes imposed by the commercial realities of mining and water infrastructure projects resulted in a potential or actual increased risk to the safety of tailings or water dams. There are lessons to be learnt from these case studies, and several recommendations for improvements are made by the authors. The owners, consultants and contractors may consider these recommendations and review their commercial processes and project delivery strategies in order to limit unforeseen risks to the safety of a tailings or water storage facility.

The fundamental issue for the presented case studies was a misalignment in project quality objectives with regards to dam safety or risk reduction. To address this, clear definition of quality objectives are required at project commencement. The person responsible for the safety of the facility is the most appropriate for setting such objectives. While the requirements for this role as part of an organisational structure is included in several dam management standards and guidelines, the responsible person needs to be more intimately involved with the project's commercial aspects to close the gap between the owner's tailings governance principles and the commercial processes. This could be achieved by assigning the responsible person as an "internal client" to the project, or a major project stakeholder.

Other findings of the paper are:

- A design and construct project delivery model does not always produce the best outcomes (in terms of time, cost and quality) for the owner. The transfer of risk to the contractor can inadvertently increase dam safety risks due to the commercial pressures faced by the contractor when preparing a tender based on only a preliminary design.
- Any project delivery strategy must allow for adequate involvement of the designer during the construction tendering process, and / or have suitable expertise on the owner's team to make key technical procurement decisions.
- A rigid procurement process aims to control capital and operational expenditure but can be detrimental to overall dam safety. There must be an overarching process that allows for circumventing such processes in a special risk circumstance, managed by an overall technical advisor on the owner side.
- Care should be taken when considering combining delivery of projects if there is a risk that important activities may not be carried out due to commercial pressures and competing objectives.

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