Developing Recovery Plans for Catastrophic Tailings Dam Failure Events

Caius Priscu, Priscu and Associates Consulting Engineers Inc., Canada
Doina Priscu, Priscu and Associates Consulting Engineers Inc., Canada
Janis Shandro, Arrowsmith Gold Inc., Canada

Abstract

A Recovery Plan is a practical and necessary document that tailings storage facility (TSF) owners need to develop, implement, train on, and test via desktop exercises. Such a plan becomes applicable following a tailings dam catastrophic failure. Lessons learned from the recovery efforts after several historic TSF failures that took place over the last 10 years have highlighted the needs and the obligations of TSF owners to act quickly and swiftly, should such a catastrophic event take place. Having a plan in place on "who's supposed to do what" in a crisis context is critical to improve response time, be effective in actions, mitigate human and environmental impacts, and in some cases can potentially save lives.

This paper outlines core elements and associated details of a Recovery Plan for TSF owners to develop in case of catastrophic TSF failure, and highlights necessary activities and communication protocols to be included. Even though such events are extremely rare, the Recovery Plan framework as presented herein is based on an industry-wide recognition that successful recovery begins before a disaster ever occurs. Pre-planning, training, and testing can help to produce more effective, sustainable, and resilient recovery capabilities that can assist communities associated with mining operations. Through the development of a recovery plan, partnerships with communities, first responders, government organizations, private entities, and specialized recovery contractors are established well before an event takes place. This paper presents a novel approach for the mining industry, drawing on the experience gained in the industrial water management and water resources industries. Several case studies are discussed and specialized guidance on international, country, and state-level emergency planning and recovery are referenced. An approach to adapt and apply these lessons to the mining industry is presented here.

Introduction

In 2020, The Global Industry Standard on Tailings Management (GISTM) was jointly launched by the United Nations Environment Programme (UNEP), the Principles for Responsible Investment (PRI) and the

International Council on Mining and Metals or ICMM (GTR, 2020). The standard consists of six topic areas covering fifteen principles and 77 requirements ultimately aimed at safeguarding people and the environment from catastrophic failures of tailings storage facilities (TSFs). The GISTM requirements are supported by conformance protocols (ICMM, 2021) and equivalent standards including (but not limited to) the International Finance Corporations (IFC) Performance Standards for Environment and Social Sustainability (IFC, 2012), and UNEP's Awareness and Preparedness for Emergencies at Local Level (APELL) (UNEP, 2015).

While many of the GISTM principles and associated requirements have become a standard of practice for many ICMM member and several non-member companies (such as the implementation of human rights assessments, community/worker grievance redress mechanisms, and emergency planning), Principle 14 requires TSF owners to prepare for long-term recovery in the event of catastrophic failure. This particular Principle and associated requirements represent a new expectation for the mining sector, with no equivalent conformance standard provided. Given this scenario, it is the objective of this paper to support the mining sector in achieving full conformance to requirements under Principle 14 by drawing attention to work accomplished in other sectors and providing a framework for what a long-term Recovery Plan (RP) could entail for further corporate/site specific adaptation.

Why do we need a Recovery Plan?

Over the last decade, on a global scale, there has been broad recognition that there is a need to strengthen disaster preparedness, management, and response for effective recovery. For example, FEMA established the four pillars of effective emergency management as: mitigation, preparedness, response, and recovery (FEMA, 2013), as noted schematically in Figure 1.

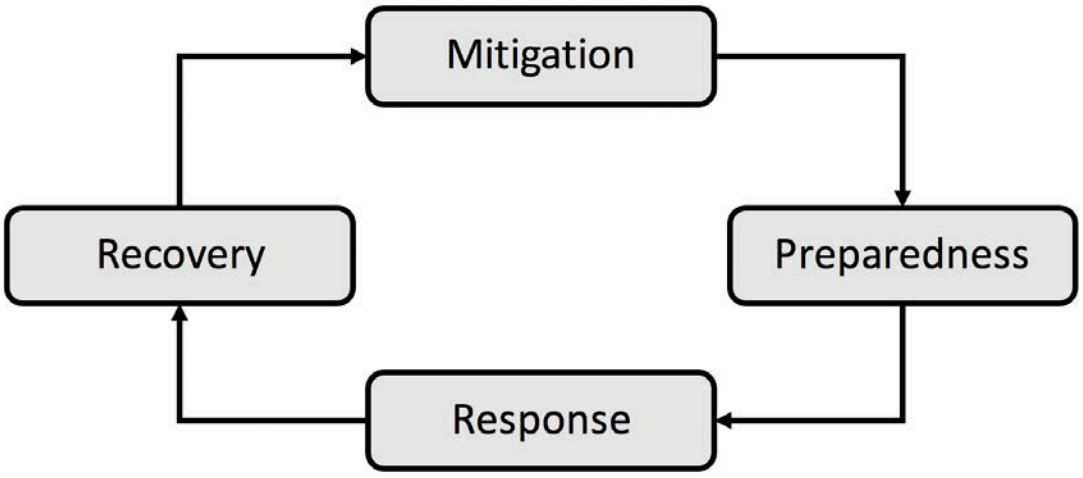

Figure 1: FEMA's four phases of emergency management (adapted from FEMA, 2013)

FEMA notes that "… The significance of the emergency management cycle is that all communities are in at least one phase of emergency management at any time." The Recovery stage is acknowledged as one integral pillar of the emergency management efforts. Lessons learned from natural disasters, war, and sector-specific events have articulated that the recovery phase needs to be planned ahead to enable effective recovery and to safeguard those most vulnerable (United Nations, 2015). For the mining sector, preparing and planning for long-term recovery in the event of a catastrophic TSF failure is at the heart of what the GISTM is looking to achieve. Medium- and long-term recovery efforts not only support global efforts, they also align directly with the commitments towards sustainable development that the mining sector has made over the last decades.

Since the late 1990s, the mining sector has undergone a significant period of transition with tremendous pressure to improve its social and environmental performance. The Mining, Minerals and Sustainable Development Project was launched in 1999 to identify how the sector could make positive contributions (IIED, 2002). Shortly after this, in 2003, the International Council on Mining and Metals (ICMM) first published 10 Principles for Sustainable Development for member companies. These Principles were further enhanced in 2018 after global review and consultation and supported by updated performance expectations (ICMM, 2023).

In addition, as a response to the tailings dam failures at Mount Polley operations in Canada in 2014, and at Samarco operations in Brazil in 2015, ICMM developed and published a position statement on tailings governance, supported by all its members (ICMM, 2016). This document includes one of the six main elements related to emergency preparedness and response: it clearly states that processes need to be in place to recognize and respond to impending failure of TSFs and mitigate the potential impacts arising from a potentially catastrophic failure. Within the GISTM, many of the Principles and their requirements are preventative in nature. Principle 14 seeks to support people and the environment in the best way possible to recover from what would be a devastating scenario, that if left unsupported would have lingering impacts for decades and potentially generations.

A TSF failure is a *"never should happen event,"* and yet unfortunately, they do occur, for many technical and human-induced reasons. In some devastating instances, the impact on people and the environment has been catastrophic, with sustainable recovery, especially in the human context, challenging to achieve. Many ICMM companies have recognized this and have made public commitments to recovery efforts (Freeport-McMoRan Inc., 2021), and will report on conformance with long-term recovery requirements under Principle 14. In essence, commitments, preparation, and planning for long-term recovery, in light of a *"never should happen"* catastrophic event, mark an ultimate corporate commitment recognizing that people and the environment potentially affected by such a scenario will likely require long-term efforts and support. The old say *"failing to plan means planning to fail"* has never been more relevant

than in preparing for the outcome of a low-probability, high-consequence catastrophic failure of a TSF, where multiple fatalities may occur. Some lessons learned are discussed below.

Lessons learned from past incidents

On August 4, 2014, in British Columbia (BC), Canada, the perimeter dam of Mount Polley Mine TSF breached and released approximately 25 million cubic meters of mine waste into the Fraser River watershed (Petticrew et al., 2015). Following the TSF failure, the BC government and the Mount Polley Mining Corporation released technical and environmental assessment reports describing pre-event infrastructure issues, post-event impacts to the receiving environments, and future pathways for re-permitting (BC Ministry of Environment, n.d.; Morgenstern et. al., 2015; Swan et al., 2014). Notably lacking was a systematic, rigorous, fast-tracked assessment that identified (a) who was impacted by this incident, and (b) how impacts were experienced by these communities and their associated outcomes. To address these gaps, the First Nations Health Authority (FNHA) commissioned a health impact assessment (HIA) (First Nations Health Authority, 2016). Results from the assessment indicated that the TSF failure had a devastating and lingering impact on communities.

The TSF failure occurred on the first day of the salmon fishing season for Indigenous First Nations along the Fraser River. Community leaders and members first received information about the TSF failure from various unofficial sources, including the media, Facebook, and word of mouth. Fear for the safety of the fish (for consumption) was of paramount concern and many First Nations, hundreds of kilometers north and south of the Mount Polley mine site, did not fish that year due to the lack of transparent and trusted information. This trend continued for many years. Furthermore, one First Nation had established a sustainable fishing business the previous year. Due to the spill (dam breach with release into the river), the business closed and never re-opened. For the closest community of Likely, a globally renowned location for eco-tourism, community residents had their entire lives altered with a total loss of business income and housing devaluations. Shandro et al. (2016) assessed and documented the extent of emotional trauma experienced by communities, an aspect that is many times minimized or considered as secondary. This impact was exacerbated by a lack of reliable information from trusted sources in the aftermath of the breach and strongly highlighted the need for emergency preparedness and response planning *with* communities (especially regarding communication and alert protocols), as well as medium- to long-term recovery planning with an assurance that *people* would be central to such efforts (Shandro et al., 2016).

On November 5, 2015, the Fundão Dam at Samarco operations in the state of Minas Gerais, Brazil, failed, releasing over 40 Mm^3 of tailings in the downstream areas in Rio Doce and its tributaries. The tailings reached the Atlantic Ocean; 19 people died in this unfortunate event. The Renova Foundation was founded on June 30, 2016 (https://www.fundacaorenova.org/en/) and began its operation on August 2, 2016, almost

nine months after the event took place. This multi-stakeholder institution was established as "the entity responsible for the creation, management and execution of actions to repair and compensate the areas and communities affected by the collapse of the Fundão dam."

Research shows, however, that only 0.17 Mm^3 of tailings had been removed one year after the event (Fonseca do Carmo et al., 2017; Gabriel et al., 2021). The same source (Fonseca do Carmo et al., 2017) notes that: "After the tragic environmental disaster caused by the collapse of the Fundão dam, several articles addressed a setback in the environmental legal regulations. Law relaxation, the decrease of resources for regulatory agencies and the absence of effective environmental recovery measures were often mentioned." Gabriel et al. (2021) note that "…metal(loid)s concentration […] levels still remain well above the baseline reference values for the estuary and often reach sediment quality thresholds. […] the potential health risks to the environment, biota, and consequently, to local communities remain at unacceptable levels and effective actions for decontamination of the Rio Doce estuary are a priority. […] results support the maintenance of the fishing bans, the need to monitor public health near the estuarine region, as well as implementation of recovery and decontamination actions along with integrated coastal and freshwater management."

The additional extensive research quoted in the papers overwhelmingly shows that it is critical to have a RP in place, to act quickly and swiftly, and to implement it as soon as practically possible, to minimize long-term risks to humans and the ecosystem.

A third case study is discussed hereafter from the water resources industry. While not mining dams, the Edenville and Sandford dam failures in Michigan in 2020 have been devastating for the communities and the Counties. More than 4,000 structures across the region were reportedly impacted by the floodwaters, with estimated losses of roughly $245 million. Fortunately, approximately 11,000 residents successfully evacuated the area with no serious injuries or loss of life reported (FEMA, 2022). Given the large extent of the events and the areas impacted, these surprisingly limited impacts on human life were considered to be a direct result of a solid and well-coordinated emergency preparedness and response plan at multiple levels. Some of the conclusions of the report, fully transferrable to the mining dams and TSF conditions, were as follows (FEMA, 2022):

- Relationships and collaborative planning before an incident greatly impact effective communication, coordination, and response during and after an emergency incident.
- Exercises build preparedness and provide a valuable opportunity to test pre-event and post-event recovery plans, to confirm roles and responsibilities, and to identify areas for improvement.
- Data analysis is critical for planning and for impactful *post-event analysis*. Consistent, quality data are key to any analytical analyses. The better the data, the better the results and outcomes.

- Open communications with the community are essential to explain risks and to create more effective alerts and warnings for evacuations and shelter-in-place guidance. Educating community stakeholders, businesses, and the public at large help in both pre- and post-failure evacuation efforts.

The above three cases studies are examples of how a good quality RP (or a lack thereof), can impact tremendously on the minimization of consequences, and on initiating a well-defined, fast-tracked recovery and restoration effort.

Phases of a Recovery Plan

An RP is a succinct site-specific document outlining administrative and document control details; the scope/objectives; associated jurisdictions/authorities and agencies; reference documents; the management team; catastrophic failure scenarios; select and relevant baseline information; short-term recovery and rescue operations; intermediate- and long-term efforts, and reporting and monitoring requirements. Such details are for the most part consistent with recovery plans for other sectors and natural disasters (Asian Development Bank, 2023; Emergency Management BC, 2022; Government of British Columbia, 2019; Health Canada, 2020; Nuclear Energy Agency, 2022; United Nations, 2015; World Bank Group, 2020, 2021, 2022) and have been further refined in this paper for the mining sector and TSFs. Additional textbooks, such as Alexander (2002) and Lindell et al. (2007), are references with relevant information on disaster management and recovery. The above content is elaborated on below.

Proposed structure and approach to develop a Recovery Plan

In this paper, the authors present a focused approach to building and developing an RP document. A practical, hands-on approach has been proposed and described. The structure of the paper walks the reader through the various sections and the organization of an RP. Following a generic table of contents, based on the multitude of leading practice referenced documents in this paper, the authors convey a suggested structure of the RP, with details for each section on their purpose, their content, and typical information that would be useful and necessary to include for a recovery situation. While the authors are very much aware that each TSF and operational context and location may trigger different regulatory requirements related to recovery and restauration efforts, this proposed RP structure is one of the many ways to approach developing the document.

Foreword section

This section, while optional for an RP document, is recommended and is meant to include a concise (one page or less) introduction on the purpose and objectives of the overall document. Generally, the foreword

section is a message that may be written and signed by the accountable executive or a general manager or similar, showing the full company support in developing and maintaining a quality RP document, as part of the company commitments to leading practices in the tailings management space. This section is not to be confused with the introduction section, which should describe the structure and content of the RP document.

Document ownership section

This section should clearly highlight who is the owner of the RP document, as well as authors, reviewers, approvers, and ownership. The information would typically include names, roles, dates and signatures. It is similar in nature to the document ownership of an operation, maintenance and surveillance (OMS) manual, an emergency preparedness and response plan (EPRP), or a crisis management plan (CMP).

Record of changes

This section highlights, preferably in a simple tabular format, the changes made over the years: who, why, what, when, and which section or page. This is a key change management section that documents gradual changes and adjustments to the RP document, and how it evolves over time while remaining current.

Record of distribution

Any RP document should have a section that includes the names, roles, department, e-mail, and date when they received copies of the current version of the RP. The named individuals will also be the ones receiving subsequent updates of the same document and be part of an internal training process on the recovery and restoration processes.

Reference documents

This section, not to be confused with the list or references at the end of the RP document, lists associated documents to be used as foundational for the RP activities, at both corporate and operational levels. This may include references to dam breach analyses (DBRs), maps, crisis management plans and emergency preparedness and response plans, and their owners, and versions/dates. It is good practice to include also a select list of relevant local legislation, as well as state and federal guidance (as a ready-to-use collated list of references).

Introduction

This section provides a brief explanation of the intent of the recovery plan and the relationship between the plan, TSF site location, and local context. This section should refer to credible failure modes and the remoteness of such events, and should highlight how the content of the RP has been developed using hypothetical scenarios and inundation models.

Scope of the RP

This section of the RP will highlight the exact scope, exclusions, and battery limits. It will refer to how this RP document is linked with other site and TSF relevant emergency documents, and identify the limits and transition points between crisis management plans, emergency preparedness and response plans, and the RP.

Goal and objectives

This section should identify the ultimate objective of the RP document, and outline expectations in terms of quality and timely implementation. Essentially, this section articulates what the ultimate RP aims to achieve, and what are the key performance indicators for its successful development and implementation.

Jurisdictions, authorities, and agencies involved

This section will identify and describe the local, regional, state, and country jurisdictions that would be involved in an RP implementation. This section should also list the local, county, and regional agencies with which the Company would potentially work, and their roles (high level). The purpose is to understand who needs to be involved, consulted, and what their roles and capabilities might be. Include a connectivity or rapport between the external recovery team and various individuals noted in the sections below (internal recovery team). List authorities with type of support, location, and possibly a phone number or website address. Examples may include the Sheriff's office, the Department of Health, Child Services, Environmental Health, Office of Emergency Response, the Department. of Justice, Environment, Infrastructure, etc.

RP internal management team

This section may include and describe a concise internal organizational chart of the senior and intermediate management levels that would be involved in leading the implementation of the RP. Generally speaking, less is more. A brief organizational chart, with assigned key roles to various areas is easier to follow. Roles would ideally follow the specific areas of interest described in the table of contents and/or in the list of impacted categories. Governance aspects and role descriptions would need to cover both corporate and operational-based team members, and how they would interact internally and externally with consultants, specialists, contractors, media, communities, etc.

Catastrophic failure scenarios

This section extracts the summary from a DBA (dam breach analysis) or a runout analysis in terms of extent, impact areas, and maps from any inundation studies or runout analyses (with or without tailings release). This information is needed to understand in summary what could go wrong theoretically and what could be

the extent of impact area, including depth of tailings, flow velocities at various sections, etc. It is important to remember that not every manager or executive is familiar with the outcomes of the failure mode and effects analysis process or a DBA. In most cases, those in charge of the recovery would use such maps to immediately initiate actions, until such time the full extent of the impact has been confirmed (actual versus model outcomes).

Failure mode 1:

Summary explanation of the failure mode and its effects, as well as the extent. Include inundation map and zone of influence (ZOI) map in appendix, overlapped on satellite imagery with key cities, towns, topography and infrastructure. Note that a ZOI is usually much greater than the inundation map, and this needs to be outlined beyond the original impact area maps. ZOIs may be defined by impacts to major power lines, secondary impacts from damages to a water treatment plant or potable water sources, roads and bridges collapses, impact to other industries in the region, small businesses, and agriculture, and so on.

Failure mode 2:

For each failure mode considered as credible, repeat collating the information and maps as noted above. It is important to note that for some facilities, different failure modes may have different impact areas and ZOI (sunny day versus flood-induced versus a simple runout analysis). In addition, the impact may be different (release or no release of tailings, water versus water and tailings, localized slump of earthfill material or compacted tailings material, time length of developing the breach, etc.).

Baseline information to support recovery planning

This section provides key baseline information available at the time and is based on maps prepared in other sections, included in the appendices. This information provides the basis of evaluating the magnitude and scale of the potential impacts, and the levels of effort expected for short- and long-term recovery.

Population at risk (PAR)

This section describes the location of the PAR within the impact and ZOI areas, using maps prepared in the other sections. This RP document section may include dwellings' locations and descriptions, number of people, schools, hospitals, daycares, businesses, temporary or seasonal houses and campgrounds, businesses, shopping malls, sports fields, or any other facility where residents or workers may be present, regardless of the time of the day or season. Indigenous sites or communities also need to be included.

Such maps and tables must also include the following: location of first responders, location of firehalls and ambulance dispatchers, clinics, and hospitals outside the ZOI that could be counted on, with potential available number of beds, Red Cross areas, etc., as well as sports arenas or schools where people could get

shelter. Areas and locations for potential loss-of-life infrastructure should also be considered, in agreement with coroner/local agencies, in case the loss of life that occurs is beyond normal local management capacity. The map can be built using the general regional and local maps, with various symbols or numbers added, to understand the location or presence of people (residents, workers, tourists, etc.). Include the same on the ZOI, as well as on the mining property (workers, contractors, mine personnel). This is of critical importance as it will guide more focused search-and-rescue activities with limited undue delays, as well as recovery efforts. Each sub-section should also list preferred external specialized consultants, contractors, government agency or rescue organizations, and specialists with specific experience in each recovery activity.

Critical infrastructure

This section needs to describe and present the location of both critical and social infrastructure in the inundation area and the ZOI. This may include highways, roads, bridges, power lines, wastewater and water treatment plants, potable water sources, houses, hospitals, airports, powerplants, major industrial areas, etc. Maps created under the previous sections can be upgraded and updated with this information. Each sub-section should also list preferred external specialized consultants, contractors, and specialists with specific experience in each recovery activity. In some situations, there may be a need to engage critical infrastructure sectors and specialists directly, with some 16 infrastructure areas identified by the US Department of Homeland Security (US DHS, 2021).

Environmental

This section describes and notes the ecosystems, sanctuaries, and protected areas, parks, recreational areas, water bodies, lakes and rivers, and any areas with sensitive ecosystems. Maps and tables created in previous sections can be upgraded with this information. Each sub-section should also list preferred external specialized consultants, contractors, and specialists with specific experience in each recovery and restoration activity.

Cultural heritage

This section describes and notes on maps the various heritage sites, archaeological site, grave sites, historic monuments, ethnic communities' monuments or places of worship, etc. Maps created under previous sections can be upgraded with this information. Each sub-section should also list preferred external specialized consultants, contractors, and specialists with specific experience in each recovery activity.

Economic impacts

This section should assess impacts on small, mid-size and large businesses, agriculture, construction etc., and evaluate both time and financial impacts for critical work. It would provide a measure of potential

consequences in the region and the ZOI. High level estimates provide an order of magnitude of impacts within the region and the ZOI (e.g., powerplant not producing electricity for a certain number of months, or water supply or water treatment plant non-operational for a few weeks in a row, etc.). Each sub-section should also list preferred external specialized consultants, contractors, and specialists with specific experience in each recovery activity.

Other potential impacts

Additional site-specific impact categories may be added to the above list. This may include impacts on natural conservation areas, national or provincial parks, infrastructure of critical nature to the national, state or regional levels, ocean coastline impacts, electric power generation plants, to give only some examples.

Short-term rescue and recovery operations

The key objectives of short-term recovery operations are to assess and identify damages, impacts, and immediate future risks. In the short term, situational awareness is established, with community needs and resources identified. Restoration of shelter, services, and facilities would begin, and it would be determined if regional, state and/or federal assistance is needed. This section may include the rescue operations (by whom co-ordination is needed between the owner and external agencies), to limit or minimize as much as possible the potential loss of life (PLL) immediately after the event has taken place. This section would also include a brief plan on engagement with communities and local/regional/state/federal organizations, as outlined in previous sections. It would highlight how nearby communities can help in immediate and short-term recovery, and who would coordinate such activities, and the type of support that is available at community level (if any). This section may include the following, among others:

- The assessment of disaster impacts and needs.
- The assessment of the impact zone and ZOI.
- Gathering of key information in shortest possible time (aerial photography, Lidar, drone footage, satellite imagery) in the post-failure condition.
- Support with the RP, as needed and requested by the local agencies.
- The review of the recovery plan in place and development of a more cohesive recovery vision and goals based on actual filed conditions.
- The identification of recovery strategies, as well as the resources needed to execute those strategies.
- Engagement with communities and other relevant stakeholders throughout the recovery process.
- The implementation of the recovery vision, goals, and strategies.

This section would also need to include the establishment of the Owner's dedicated legal team, to support management during the Recovery and Restoration implementation. A company's legal team must

have the ability to properly function during and in the aftermath of an emergency. In some cases, the Counsel and his legal team may have their own emergency response plan, and they would need to be aware of and train on the company's emergency response plan and ensure consistency with their own emergency response plan, if any. The Owner's Counsel may need to prepare in case of major emergency situations, on aspects related to assessing possible threats to workers, employees, contractors, management, and the company, creating an emergency response team, drafting a written plan, conducting drills and training, and identifying post-emergency legal priorities. This may include evaluating contractual obligations, notifying insurance companies, preserve legal privileges, protect trade secrets, maintain confidentiality of information, adopt security measures to protect employees, and be ready to act or respond to potential charges, personal and business claims, lawsuits and court orders.

Intermediate Recovery Plan

Intermediate Recovery is a phase of recovery, which involves returning individuals, families, critical infrastructure and essential government or commercial services to a functional, if not pre-disaster, state. Such activities are often characterized as temporary actions that provide a bridge to permanent measures. Examples of interim activities may include:

- Providing accessible interim housing solutions.
- Initiation of widespread debris removal operations.
- Immediate infrastructure repair and restoration.
- Support re-establishment of businesses, where appropriate.
- Establishment of business recovery centers.
- Engaging community on strengthening facilities during rebuilding and possible mitigation actions.
- Coordinating with county assessor for reassessment of property damaged by the event.
- Engaging support networks for ongoing emotional/ psychological care (with County Health and Human Services).
- Ensuring continuity of public health care through accessible temporary facilities (with County Health and Human Services).

The RP document needs to present such strategies so that bridging between short- and long-term recovery is clear and understood by all. On many occasions, this could be confused with the short-term recovery, hence the need for clarity of scope and objectives.

Long-term recovery plan

This is a phase of recovery that may continue for months or years to addresses complete redevelopment and revitalization of the impacted area, rebuilding or relocating damaged or destroyed social, economic, natural

and built environments, and supports the transition of those impacted to self-sufficiency, sustainability, and resilience. For each type of impact (such as those noted in previous section and beyond), a preliminary recovery and restoration action plan and mitigation measures would need to be presented, without going into the technical details at this early stage. However, goals, objectives, and key steps to be taken in implementing mitigation measures need to be presented based on the site-specific conditions.

The primary goal of a long-term recovery operations is to rebuild safely and wisely, reduce future hazards, restore ecosystem and natural habitat, and optimize community improvements. As with all phases of RP, long-term Recovery should include whole community planning, engaging all of the Recovery support function stakeholders. The major objectives of these operations within a jurisdiction include efforts to:

- Develop long-term universally accessible housing solutions.
- Rebuild infrastructure to meet future community needs, including the needs of those with disabilities and others with access and functional needs.
- Implement economic revitalization strategies, particularly for small- and mid-size businesses.
- Facilitate applicable funding assistance for business rebuilding.
- Follow up for ongoing counseling, behavioural health, and case management services (with County Health and Human Services).
- Re-establish disrupted health care facilities (with County Health and Human Services).
- Develop ecosystem mitigation strategies.
- Recover eligible disaster-related costs through insurance, applicable fees, mutual aid reimbursement, and state/federal public assistance programs.
- Establish internal legal team of the TSF owner and maintain an active sub-committee to discuss, and answer any potential questions, legal requirements, or similar, at all times.
- Develop a business resumption plan.
- Beyond the long-term RP, consider adding a timeline for a development plan for the region, as a final section. Rather than just returning the region to what was “normal” before the failure occurred, the post-disaster communities, society, and local economies could become much larger, more successful, and grow with time.

Recovery plan monitoring and public reporting

A monitoring and reporting command center team needs to be established that would collate data and report on the recovery activities, as well as the progress made. This section highlights the activities of the team that coordinates elements of information to provide incident analysis; this activity includes monitoring and reporting of the current situation status through available technical expertise, and projecting and planning

for future contingencies through the revisions and updates of an action plan (sometimes referred to as an incident action plan, or IAP). Examples, including on-line dedicated websites for recovery and restoration progress reporting, could also be provided, and considered, for quick dissemination of information to the public. Fundacao Renova in Brazil has developed such a web-based dissemination portal at www.fundacaorenova.org and is considered a good example for such initiatives.

Developing situational awareness requires continual monitoring, verifying, integrating, and analysing relevant elements of information and developing hazards. At its best, situational awareness provides up-to-date information on the status of people, critical facilities, infrastructure, resources, and the environment. Monitoring and reporting on key recovery and response activities may include, but are not limited to:

- TSF status and associate risks.
- TSF reconstruction.
- Rescue and recovery.
- Community support status updates.
- Dwellings status and reconstruction.
- Hazardous and non-hazardous waste material collection.
- Permitting and monitoring of debris disposal.
- Water quality monitoring and protection.
- Air quality sampling and monitoring.
- Protection of biological resources and natural ecological resources.
- Status of construction projects to re-establish access roads, highways, bridges, power supply, water supply, and other critical infrastructure.
- Ecological restoration projects.
- Status of financial support and sponsorship of activities.
- Business continuity plan.
- Key contacts, documents available, and public information meetings set dates and locations.

Appendices of the RP

Appendices include information that is of equal importance in the RP main document. They may include, among other things: organizational charts, key contact information of support organizations and external consultants that would need to assist and help with specialized key tasks, as well as tabular summaries, charts, key maps of the area with potential areas of impact and key infrastructure locations supporting the recovery efforts, as noted above. To keep the document structured, one appendix could be prepared for each subsection – by specific topic, rather than stacking multiple documents into a single topic, for ease of use

and referencing. For example, environmental impacts recovery support and maps may differ vastly from those related to human impacts, life loss and support to impacted families.

List of references in RP

A list of references should be included with any RP in order to a) facilitate access to sources of materials used to develop the RP, b) provide examples of leading practices via conference proceedings, journal papers, government agencies, and guidance documents from various local and international emergency organizations, and c) cross-reference other crisis management and emergency preparedness documents in the company. Such references will need to be updated whenever the RP document is prepared, updated, or reviewed.

Conclusions

For many mining companies around the world, the increased emphasis on protecting people, the environment, communities, and critical and social infrastructure surrounding operations, has drawn additional attention to the need for recovery plans in case TSF failures occur. TSF owners should consider the need for a recovery plan as part of standard risk management processes. A recovery plan should be based on credible failure modes and associated best available technologies that evaluate impact areas and zones of influence.

The authors have presented in this paper a suggested, pragmatic approach to building and developing a RP document. The mining industry clearly lacks (at least in the public domain) specific guidance on developing recovery and restoration plans for conditions after failures of TSFs. This paper aims to fill that gap to the best extent possible, bringing leading practices and lessons learned from the mining and water resources industries, and suggesting specific content, structure, and details for a quality RP development.

The authors have also included in this paper a comprehensive list of references spanning available guidance and case studies from both the private and the public domains, so that the reader can further study, evaluate, discuss, and learn from several leading practices world-wide in the area of recovery and restoration. It is the hope of the authors that TSF Owners develop such RPs, test them and train on them, but never have to use them in a real situation, because tailings storage facilities can and should be built and operated safely.

Acknowledgements

The authors would like to sincerely thank Dr. Bill Johnstone, P.Eng., Principal Consultant with Spatial Vision Group Inc., Canada, for his review and feedback provided on this paper.

References

Alexander, D.E. 2002. *Principles of Emergency Planning and Management*. Harpenden: Terra Publishing.

Arizona Department of Emergency and Military Affairs, Emergency Management (DEMA-EM). 2018. Arizona State Emergency Response and Recovery Plan (SERRP). November 2018.

Asian Development Bank. 2023. Disaster Recovery Planning – Explanatory Note and Case Study. Accessed 6/30/2023 at: https://www.adb.org/publications/disaster-recovery-planning-explanatory-note-case-study

BC Ministry of Environment. n.d. (not disclosed). Private document shared with one of the authors.

Fonseca Do Carmo, F., Kaminoa, L.H.Y., Juniora, R.T., de Camposa, I.C., Carmoa, Felipe F., Silvino, G., da Silva Xavier de Castro, K.J., Mauro, M. L., Uchoa Alonso Rodrigues, N., de Souza Miranda, M. P. and Ferreira Pinto, C.E. 2017. Fundão tailings dam failures: the environment tragedy of the largest technological disaster of Brazilian mining in global context. *Perspectives in Ecology and Conservation* 15(3): 145–151. Accessed 6/30/2023 at: https://www.perspectecolconserv.com/en-fundao-tailings-dam-failures-environment-articulo-S1679007316301566

Emergency Management BC. 2022. Recovery Guide for Local Authorities and First Nations. Accessed 6/30/2023 at: https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/local-government/disaster_recovery_guide.pdf

Federal Emergency Management Agency. FEMA. 2013. Emergency Management Institute. Document IS-111 Livestock in Disasters. Accessed 8/14/2023 at: https://training.fema.gov/is/crslist.aspx?lang=en&page=2

Federal Emergency Management Agency. FEMA. 2015. Incident Planning Action Guide. Revision 1. July 2015.

Federal Emergency Management Agency. FEMA. 2019. Emergency Operations Planning: Dam Incident Planning Guide. Dam Safety Collaborative Technical Assistance. November 2019.

Federal Emergency Management Agency. FEMA. 2022. Michigan Dam Incident Response Review. An Analysis of the 2020 Edenville and Sanford Dam Failure Response. Accessed 6/30/2023 at: https://www.fema.gov/sites/default/files/documents/fema_michigan-dam-incident-response-review_report.pdf

First Nations Health Authority, 2016. Mount Polley Health Impact Assessment. Accessed 10/19/2023 at: https://www.fnha.ca/about/news-and-events/news/mount-polley-health-impact-assessment

Freeport-McMoRan Inc. 2021. Tailings Management Policy. Accessed 6/30/2023 at: https://fcx.com/sites/fcx/files/documents/policies/tailings-policy.pdf

Fundacao Renova. 2023. The Repair So Far. May 2023 update. Accessed 6/30/2023 at: https://www.fundacaorenova.org/wp-content/uploads/2023/05/caderno-da-reparacao_maio2023_ingles.pdf

Gabriel, F.A., Ferreira, A.D., Queiroz, H.M., Vasconcelos, A.L.S., Ferreira, T.O. and Bernardino, A.F. 2021. Long-term contamination of the Rio Doce estuary as a result of Brazil's largest environmental disaster. *Perspectives in Ecology and Conservation* 19(4): 417–428. Accessed 30/6/2023 at: https://www.sciencedirect.com/science/article/pii/S2530064421000766

Global Tailings Review. 2020. *Global Industry Standard on Tailings Management.* Accessed 6/30/2023 at: https://www.icmm.com/en-gb/our-principles/tailings/global-industry-standard-on-tailings-management

Government of British Columbia. 2019. Interim Provincial Disaster Recovery Framework. Accessed 6/30/2023 at: https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/local-government/provincial_disaster_recovery_framework.pdf

Health Canada, 2020. Guidance on Planning for Recovery Following a Nuclear or Radiological Emergency. Accessed 10/19/2023: https://www.canada.ca/content/dam/hc-sc/documents/services/publications/health-risks-safety/planning-recovery-nuclear-emergency/guidance-on-planning-en.pdf

International Council on Mining and Metals. ICMM. 2016. Tailings Governance Framework: Position Statement. Accessed 6/30/2023 at: https://www.icmm.com/en-gb/our-principles/position-statements/tailings-governance

International Council on Mining and Metals. ICMM. 2023. Mining Principles Performance Expectations. Accessed 6/30/2023 at: https://www.icmm.com/website/publications/pdfs/mining-principles/mining-principles.pdf?cb=59962

International Council on Mining and Metals. 2021. Conformance Protocols: Global Industry Standard on Tailings Management. Accessed 6/30/2023 at: https://www.icmm.com/en-gb/our-principles/tailings/tailings-conformance-protocols

International Finance Corporation. 2012. Performance Standards on Environmental and Social Sustainability. Accessed 6/30/2023 at: https://www.ifc.org/content/dam/ifc/doc/2023/ifc-performance-standards-2012-en.pdf

International Institute for Environment and Development (IIED). 2002. Breaking New Ground: Mining, Minerals and Sustainable Development. Accessed 6/30/2023 at: https://www.iied.org/9084iied

Lindell, M.K., Prater, C.S. and Perry, R.W. 2007. *Introduction to Emergency Management*. Hoboken, NJ: John Wiley & Sons, Inc. Chapter 11: Disaster recovery – managing the process.

Morgenstern, N.R., Vick, S.G. and Van Zyl, D. 2015. Report on Mount Polley tailings storage facility breach: Independent Expert Engineering Investigation and Review Panel. Accessed 6/30/2023 at: https://www.mountpolleyreviewpanel.ca/final-report

Nuclear Energy Agency. 2022. *Building a Framework for Post-Nuclear Accident Recovery Preparedness*. Paris: OECD Publishing.

Persson, E. and Granberg, M. 2021. Implementation through collaborative crisis management and contingency planning: the case of dam failure in Sweden. *Journal of Risk Research* 24(10): 1335–1348. https://doi.org/10.1080/13669877.2020.1863845

Petticrew, E.L., Albers, S.J., Baldwin, S.A., Carmack, E.C., Déry, S.J., Gantner, N., Graves, K. … and Vagle, S. 2015. The impact of a catastrophic mine tailings impoundment spill into one of North America's largest fjord lakes: Quesnel Lake, British Columbia, Canada. *Geophysical Research Letters* 42(9): 3347–3355. https://doi.org/10.1002/2015GL063345

Shandro, J., Jokinen, L., Stockwell, A., Mazzei, F. and Winkler, M. 2017. Risks and impacts to First Nation health and the Mount Polley Mine tailings dam failure. *International Journal of Indigenous Health* 12(2): 84–102. https://doi.org/10.18357/ijih122201717786

Shandro, J., Winkler, M., Jokinen, L. and Stockwell, A. 2016. Health impact assessment of the 2014 Mount Polley Mine tailings dam breach: screening and scoping phase report. Accessed 6/30/2023 at: https://www.fnha.ca/Documents/FNHA-Mount-Polley-Mine-HIA-SSP-Exec-Summary.pdf

Swan, C., Epps, D. and Miller, L. 2014. Impact assessment monitoring in the Quesnel Lake watershed after the Mount Polley Mining Company tailings dam breach (BC Ministry of Environment poster).

Unified San Diego County Emergency Services Organization (USDCESO). 2019. San Diego County Operational Area Recovery Plan. September 2019. Accessed 6/30/2023 at: https://www.sandiegocounty.gov/content/dam/sdc/oes/emergency_management/plans/Operational-Area-Recovery-Plan/SDC_OPERATIONAL%20AREA%20RECOVERY%20PLAN_FINAL_20190815.pdf

United Nations Environment Programme. 2015. *Awareness and preparedness for emergencies and local level.* Accessed 6/30/2023 at: https://www.unep.org/explore-topics/disasters-conflicts/what-we-do/response-and-recovery/awareness-and-preparedness

United Nations. 2015. *Sendai Framework for Disaster Risk Reduction*. Accessed 6/30/2023 at: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf?_gl=1*1ferlol*_ga*MTAzNDkzNjE5NC4xNjg4MTUzNTI4*_ga_D8G5WXP6YM*MTY4ODE1MzUyNy4xLjEuMTY4ODE1MzY2NS4wLjAuMA

US Department of Homeland Security. US DHS. 2015. Presidential Policy Directive 21 (PPD-21): Critical Infrastructure Security and Resilience. Cybersecurity and Infrastructure Security Agency. Accessed 08/14/2023 at: https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors

US Department of Homeland Security. US DHS. 2021. Dams Sector Crisis Management Handbook. A Guide for Owners and Operators. Cybersecurity and Infrastructure Security Agency. July 2021. Accessed 6/30/2023 at: https://www.cisa.gov/resources-tools/resources/dams-sector-crisis-management-handbook

World Bank Group. 2020. *Disaster Recovery Framework Guide (English)*. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/692141603785003050/Disaster-Recovery-Framework-Guide

World Bank Group. 2021. GFDRR Strategy 2021 – 2025 – Scaling up and Mainstreaming Resilience in a World of Compound Risks. Accessed 6/30/2023 at: https://documents1.worldbank.org/curated/en/955811620194170587/pdf/GFDRR-Strategy-2021-2025-Scaling-Up-and-Mainstreaming-Resilience-in-a-World-of-Compound-Risks.pdf

World Bank Group. 2022. *Ready to Rebuild: Disaster Rehabilitation and Recovery Planning Guide Workbook - Philippines: Virtual Training Manual (English)*. Washington, D.C.: World Bank Group. Accessed 6/30/2023 at: http://documents.worldbank.org/curated/en/235411642695076177/Virtual-Training-Manual