What does it mean to be the Engineer of Record (EoR) for a Tailings Storage Facility (TSF)?

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ABSTRACT: One would think the term "Engineer of Record (EoR)" is an easy concept to grasp. For most public infrastructure projects (e.g., roads, bridges, buildings, water dams, etc.), the Design Engineer and the EoR are one and the same. This concept has also been applied, to some degree and in a similar manner, to tailings storage facilities (TSFs). However, TSFs do not apply a "conventional" construction process, nor do they adhere to a typical construction schedule. Instead, they typically apply the observational method described by Peck (1969), with a construction life that covers decades. The usual application of the EoR concept does not necessarily translate well in these instances. The Mount Polley (Canada) tailings dam reportedly had five named individuals serve as EoR during a four-year period prior to the failure that occurred in August 2014. That incident served as the catalyst for review of the EoR concept by the mining industry and those that regulate it. This paper provides results of a survey conducted to obtain information on the current state of practice for TSF EoR services, and identify concerns within the engineering community who perform such work.

1 INTRODUCTION

The Geoprofessional Business Association (GBA) sponsored a workshop on January 26, 2017, addressing the subject of the Engineer of Record (EoR) for tailings storage facilities (TSFs). This workshop, held in Denver, Colorado, was supported by the United States Society on Dams (USSD) and the Association of State Dam Safety Officials (ASDSO), and included participation of more than fifty tailings dam practitioners from the United States, Canada, and Chile. While most of attendees were consulting engineers, seven of the participants were employed by state regulatory agencies and one was employed by a mine operator. Many of the participants are currently serving as EoR on TSFs around the world with distinguished careers as tailings dam designers, and have first-hand knowledge of the issues associated with this responsibility.

A survey was prepared in advance of the January 2017 workshop to obtain information on the current state of practice. Two breakout sessions were held during the workshop to further characterize concerns held by the participants and identify possible solutions and approaches to improving the state of practice with the ultimate goal of preventing future failures. GBA is currently preparing a practice guideline for the TSF EoR similar to the guideline GBA (formerly ASFE, 2010) developed for the Geotechnical Engineer of Record (GER), which is applicable to conventional design/bid/build construction. Although GBA is preparing this guideline, the workshop organizers believed the industry as a whole would value from distributing the findings of the workshop, leading to the development of this paper.

2 SURVEY RESULTS

A web-based survey was conducted in advance of the workshop using SurveyGizmo to gauge the attitudes and concerns of the group regarding ongoing efforts to better define the roles and responsibilities of the owners, engineers, third-party reviewers and regulators involved in maintaining the safety of tailings dams around the world. The results of the survey are presented herein. For the purposes of the survey, a TSF was considered a mine or mineral processing tailings dam and impoundment, or a coal combustion residuals (CCR) or coal refuse impoundment. EoR services were defined as formal designation as the EoR, as well as situations where an engineer's endorsement of the design and/or construction is required. The survey was used to compile information on the participant roles (e.g., EoR, owner) and usual work products (e.g., construction plans, specifications, etc.) of TSF projects, and to identify concerns among the engineering community about providing EoR services for TSFs.

2.1 *Demographics*

A series of demographics questions were asked to assess the backgrounds and experience levels of the survey respondents. Fifty-one responses were tabulated (although not all respondents answered each question). The survey was distributed to workshop attendees and to a wider audience via LinkedIn. Accordingly, the response rate cannot be determined.

The average years of experience of the respondents was 25, with a general range from 8 years to 45 years of experience (though one respondent had zero years of experience). The average amount of tailings dam experience was 18 years, indicating that most of the respondents had dedicated a significant portion of their careers to the tailings practice. Ninety percent (90%) of respondents were registered professionals, with 65% registered in the United States, 29% registered in Canada, and 10% registered in other countries (some respondents registered in multiple countries).

2.2 *Scope of Practice*

The survey respondents and their organizations exhibited experience with effectively all types of tailings dams, ranging from TSFs at metal mines, to coal processing facilities and coal combustion plants, and other tailings dams (e.g., oil sands, phosphates, etc.). Notably, 90% of the respondents indicated that their organizations had experience with more than 20 tailings dams in the prior five years, while individually more than 20 respondents had experience with more than 10 tailings dams in the prior five years, further highlighting the level of tailings experience of the respondents. Approximately 84% of respondents indicated that they, or their respective organizations, were involved with TSFs for metal mines, with 53% involved with tailings dams other than those at metal mines, coal processing facilities, or coal combustion residual (CCR) facilities. Eighty-five percent (85%) of respondents noted that most to virtually all of their TSF projects involve "conventional" tailings dams that are raised on a regular schedule over a long period of time. In this context, facilities that are designed, constructed and operated to a single configuration that is modified only through a separate and subsequent design and construction process, similar to a water storage dam, were considered to be "unconventional." This latter process is more common with CCR facilities.

About 85% of respondents declared they are "aware" or "very much aware" of the challenges in providing EoR services for TSFs. Thirty-seven percent (37%) indicated their firms either already have formal internal policies defining standards for tailings EoR responsibilities or are in the process of developing such policies. Eighty-eight percent (88%) also indicated they believe there is a need for an industry document that clarifies the role of EoR for tailings dams and the responsibilities of owners and engineers in maintaining the safety and security of these facilities.

Respondents indicated their opinion on what constitutes the elements of TSF projects considering a list of studies, programs or engineering work products that reflect the standard of practice for a TSF project. These elements essentially comprise the TSF services discussed below.

2.3 *TSF Services Typically Performed by the Respondents*

Survey respondents were asked which work products (from the list in Figure 1) are incorporated into the projects they undertake, and how frequently these work products are produced. Many of these elements are engineering service products, but they may not necessarily be originated by the EoR and sometimes are prepared or conducted by the owner or other consultants. The most common services, as indicated in Figure 1, were conceptual and feasibility-level designs; geotechnical site characterization and borrow material investigations; development of issued for construction (IFC) plans and specifications; dam safety reviews (including inspections and/or instrumentation review); surface water management plans; site-wide water balance analyses; development of operation, surveillance, and maintenance (OMS) manuals; and development of facility closure plans and cost estimates. The least common elements of service were risk assessments, failure modes and effects analyses (FMEA), preparation of environmental monitoring and response plans, regulatory compliance programs, and input or support to NI 43-101 reports.

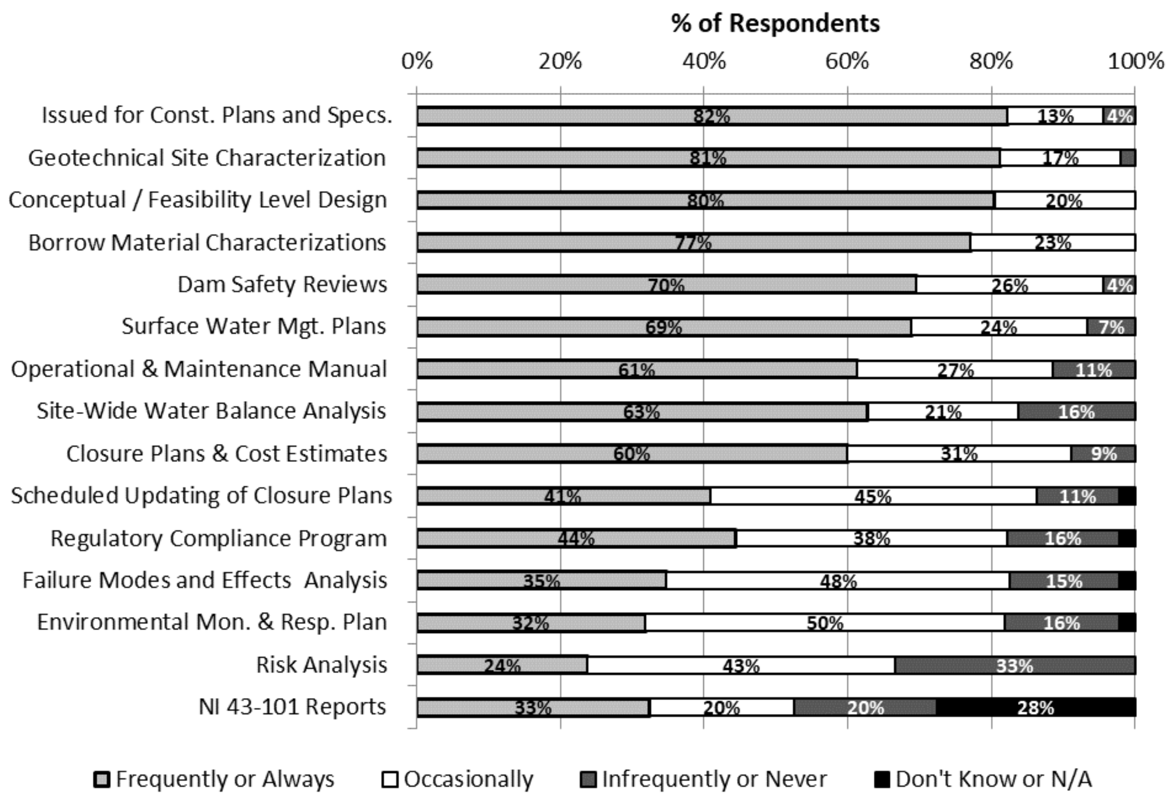

Figure 1. TSF elements incorporated into projects requiring EoR services.

Survey respondents were also asked to describe the typical work products provided during the design phase versus the work products and services performed during construction and/or operations phases. No clear trends were evident from the survey, but it appears that for most projects, some degree of continuity of services from the designer is usually carried forward into construction and operations. Thus, it appears from the survey that changes in the EoR from the design phase into the operations phase may be the exception rather than the rule.

2.4 *Owners' Responsibilities*

Respondents were also asked to provide their opinions on the responsibilities of TSF owners from a provided list, the results of which are illustrated in Figure 2. Respondents believed, in general, that the owner is responsible for providing qualified personnel, managing safety and health programs, procuring services based on qualifications, managing risk, and regulatory compliance and auditing programs. The majority of respondents viewed that owners had the responsibility to provide an independent technical review board (ITRB), particularly for high risk facilities. Respondent comments identified two additional owner responsibilities, including procedures to address EoR concerns and processes for implementation of corrective actions.

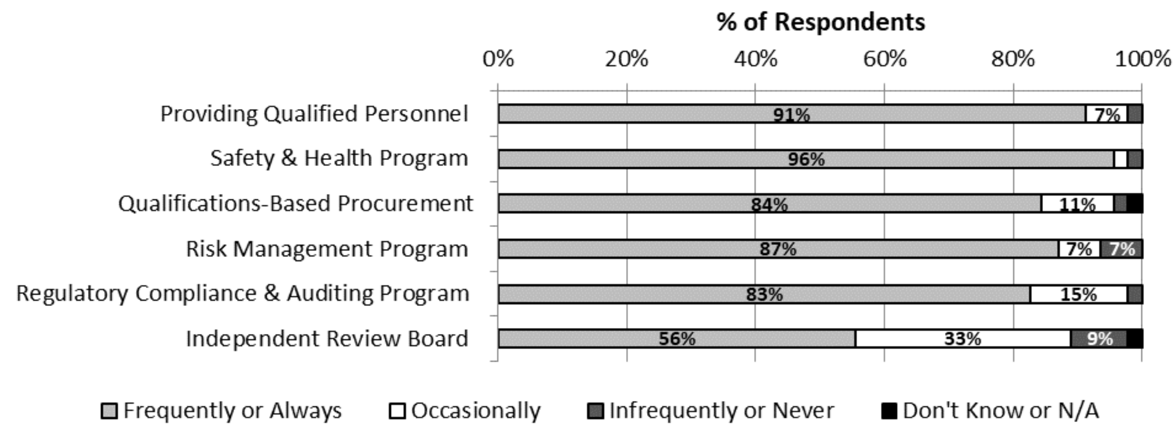

Figure 2. Survey respondents' position on responsibilities of the Owner on TSF projects.

2.5 *Oversight and Review in TSF Design, Construction, and Operation*

One of the recommendations brought forward in the aftermath of the Mount Polley failure is the use of independent expert review panels or other third-party reviews throughout the design, construction and operational phases of a TSF (IEEIRP, 2015). Review panels are not a new concept in the tailings dam practice (e.g., Ridlen et. al., 1997; McKenna, 1998; Martin et al., 2002; Morgenstern, 2010). The survey respondents were asked to comment on the relative frequency that external reviews or oversight (e.g., regulatory agency, third-party review, etc.) occur on TSF projects. Figure 3 illustrates the relative frequency of the types of formal oversight of TSF projects experienced by the survey participants.

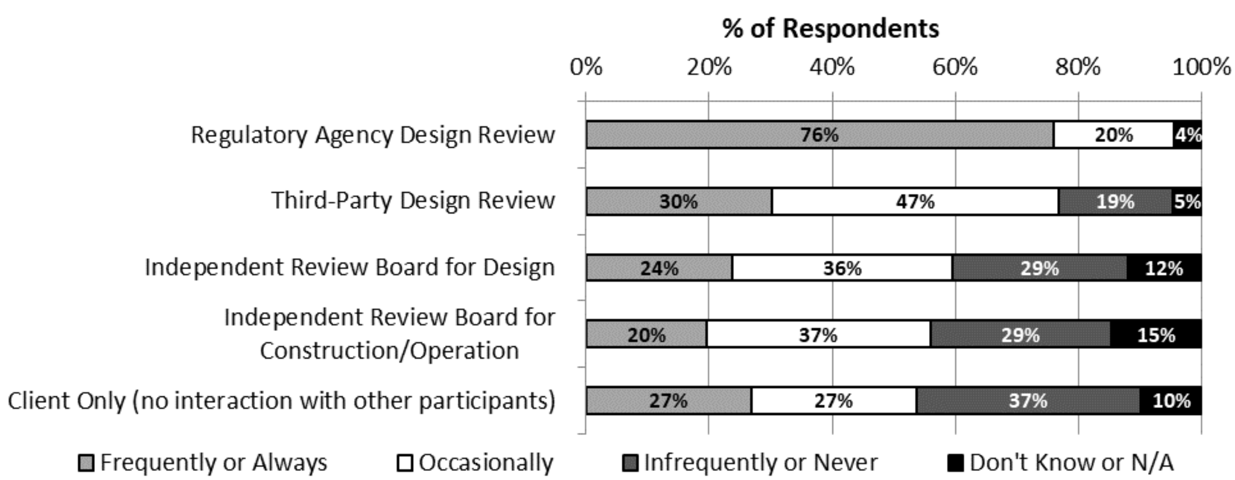

Figure 3. TSF project participants and relative frequency of involvement in TSF projects.

Only about 24% of respondents said that independent design review boards were frequently used on projects for which they are involved, and only 20% said that review boards were used regularly during construction and operation. Nearly 30% indicated that review boards were infrequently or never used on their projects, while an additional 12 to 15% did not know. Of those who responded on whether or not regulatory agencies are involved for design review, 76% indicated that regulatory agencies are frequently or always involved. In limited cases, the client is the only other project participant that the designer interacts with on TSF projects.

3 CONCERNS RAISED BY SURVEY RESPONDENTS

Survey respondents were asked to indicate if they viewed any of the issues from the list presented in Figure 4 as concerns when providing EoR services. The results are presented in Figure 4.

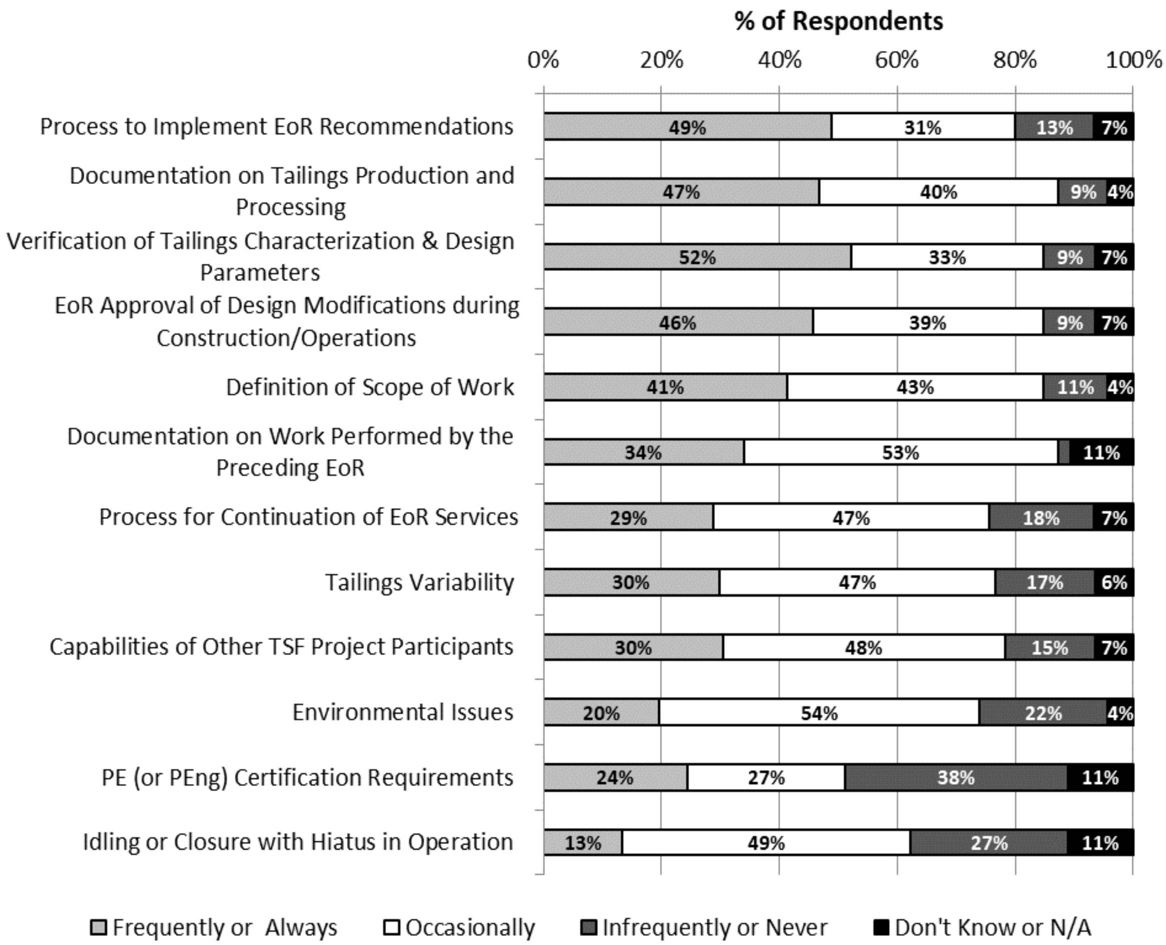

Figure 4. Survey respondents' concerns with providing EoR services.

Interestingly, the issue generating the most frequent concern was verification of tailings characteristics and design parameters, a primarily technical issue. Tailings production and characteristics are affected by variations in the ore body, as well as mining and processing activities. In most cases, the performance of the facility is highly dependent on the realized tailings characteristics over the life of the facility, and how well they correspond to the design assumptions. Since most tailings dam designs invoke the observational method, it is important to observe the site conditions that develop over time and potentially adjust the design accordingly. GBA (formerly ASFE, Undated) developed a document titled, *"The Observational Method in Construction – A Message to Owners"* that further elaborates the observational method for providing geoprofessional services.

The concern expressed by the survey respondents may reflect difficulty in gaining access to the information necessary to confirm the design assumptions, as well as concerns that the operators may not fully appreciate the need for ongoing observation and reconciliation. It can be inferred from these responses that more emphasis on routine confirmation and documentation of tailings production, material characteristics and comparison of actual parameters to the design parameters by owners is required.

Additional concerns encountered frequently or always by the respondents relate to the clarification of responsibilities and designation of proper authority that should accompany those responsibilities. Specifically, the following items ranked high on the list of concerns:

– Process for implementing EoR recommendations
– EoR approval of design modifications during construction/operations
– Definition of the scope of work (of the EoR)

The responsibilities and expectations of the design EoR are generally relatively straightforward and often are defined in distinct contractual scopes of work that have significant precedent and examples to guide each party. Responsibilities during construction/operations, however, can vary significantly. Ideally, the design EoR has a role in quality assurance/quality control (QA/QC) processes, which may include a resident engineer during initial construction works. However, with dams that are raised sequentially over long periods of time, the construction and operational phases of these facilities overlap, and many owners experience market pressures to reduce operational costs, often by reducing (or eliminating) the scope of the EoR and his or her team to support operations. In many cases, mine operations self-perform the construction instead of a contractor, and the owner may have such technical resources on staff as construction managers, geotechnical engineers, civil designers, and other technical specialties. As a result, there is no "standard" or "typical" role and scope of work of the EoR during construction and operations, and the roles and responsibilities often become blurred with those of the mine owner's employees.

The observational method inherently involves adjusting the design in response to actual conditions; thus, changes to the design frequently occur over the life of the facility. Under these conditions, the understanding and continuity of the intent and underlying assumptions of the original design may become lost over time, especially if the EoR does not have regular, ongoing involvement. The risks associated with losing continuity of the EoR throughout the TSF life cycle are what bring the concerns expressed by the survey and workshop participants to the forefront, and are becoming better understood by the industry. One of the recommendations for improvement adopted by the International Council on Mining and Metals (ICMM, 2016) is for widespread implementation of *"a formal change management process that is designed to ensure that when material changes are contemplated and subsequently made to the life of facility plan or to the Engineer of Record they are fully considered, formally adopted and embedded into the operations, maintenance and surveillance manuals, into budgets and into training and that the implications of the change are communicated"* (Golder, 2016). Workshop participants were in agreement with this recommendation.

As a facility makes a transition into a relatively routine operation, usually with recurrent cycles of construction, it is customary for the EoR to make regular site visits (typically at least once per year) to observe progress and consider whether the actual conditions are consistent with the design intent. Preparation of an annual dam safety inspection (DSI) is mandated in some jurisdictions, and should be considered a Best Management Practice (BMP). If an ITRB, third-party reviewer, or auditor is in-place, site visits are performed on a regular frequency with similar intent as the EoR's inspection. A clear process is needed for addressing observations of concern raised by the EoR, ITRB or other parties, with follow-up to ensure that recommendations are followed, or a sound technical reason given for why they are not implemented (if they pose a safety risk). Although not always clearly understood within many organizations, the EoR and independent reviewers are valued by a company's stakeholders. Most leading mining companies have established, or are now establishing, internal stewardship, governance or oversight departments or committees dedicated to ensuring that risks related to TSFs are managed according to the company's strategy and objectives.

Survey respondents emphasized the importance of a clear definition of the responsibilities and authorities of the EoR (and the EoR team), the owner, any third-party reviewers, and regulators. In addition to the importance of communication throughout the engagement, the respondents cited the value of identifying risks and concerns upfront, implementing design reviews and QA/QC programs.

The process for transitioning from one EoR to another was identified as a concern by several of the participants. This concern applies whether a planned hand-over of responsibilities from the design phase to the construction and operational phases exists, or when a change in the EoR due to contractual or other business reasons is contemplated. Several potential additional actions are considered or applied when respondents have taken over the EoR services from another party, including dam safety reviews (including design review based on comprehensive historical documentation) as part of the transition and independent assessment of potential risks.

Finally, almost two-thirds of the respondent expressed concern about the risk of angering mining clients in the process of clarifying (and attempting to enforce) the role of an EoR in the tailings dam lifecycle. The consensus of these participants was that most major mining companies understand the need for — and value of — an EoR with clearly-defined responsibilities and authorities. More inconsistency exists in the perspectives of junior mining companies. Approximately 75% of the respondents perceived that the clients they worked for were supportive or very supportive of the EoR concept, and only about 8.5% remarked that some clients are antagonistic or hostile to the notion. However, the broad consensus of respondents was that any risk of losing business by angering clients was worth taking because of the potential consequences to the public safety and environment, as well as the integrity of the profession.

4 WORKSHOP RESULTS

During the January 2017 workshop, attendees were divided into two breakout sessions. Participants of the first breakout session were tasked with collectively addressing the rationale for the position of TSF EoR, while participants of the second breakout session focused on identifying the specific roles and responsibilities of TSF project participants. This latter exercise resulted in the creation of a RACI (*R*esponsible, *A*ccountable, *C*onsulted, *I*nformed) matrix for the various elements of TSF projects.

4.1 *Value Provided by a Competent EoR*

The workshop participants agreed that designation of an EoR is anticipated to provide the following benefits:

- Continuing involvement of the responsible engineer having in-depth knowledge of the TSF, capable of implementing the observational approach to ensure the design philosophy and intent is met over the life of the project
- Delivering leadership across disciplines, providing a resource for the owner in making sound technical and business decisions
- Demonstrating owner’s safety and sustainability commitments to project stakeholders
- Fulfilling regulatory requirements and ensuring QA/QC programs are implemented, project documentation is completed, and inspections are conducted and submitted
- Confirming that the owner’s staff understands the proper methods of operating the facility and are prepared to respond should adverse conditions develop

The workshop participants expressed a firm belief that owners have the responsibility to arrange for independent technical review and to appoint an ITRB for high consequence facilities. The presence of independent technical review, and particularly an ITRB, can provide assurance that the EoR’s observations and recommendations are addressed or other corrective actions implemented, and also provides assurance to the owner that the EoR’s recommendations are consistent with the current state of practice.

4.2 *On the Definition of Engineer of Record*

Following the Mount Polley failure, the Canadian Dam Association (CDA), with input from the Mining Association of Canada (MAC) and several other organizations, has spent considerable effort in developing a consensus definition of the EoR for a tailings dam for inclusion into the

CDA dam safety guidelines (e.g., Small & McLeod, 2015). The workshop reviewed the definition in progress at the time, and generally found agreement with the concept and framework of the definition, but identified several comments and some concerns.

The draft CDA definition frames the EoR for a tailings dam as an individual. From a regulatory standpoint, this makes sense because an agency typically wants a single, competent engineer—duly registered in the relevant jurisdiction—to "sign off" on the design of a facility, and in some cases "certify" or "affirm" that the facility was constructed in accordance with the design. As a note, GBA (formerly ASFE, Undated) has brought problems associated with "certifications" to the attention of engineers, owners and regulators, and offers several alternatives for addressing the issue (e.g., replace *"I certify"* with *"I state in my professional opinion"*). Likewise, in many jurisdictions, dam safety inspections are required on a regular basis (often annually), and these are also to be signed and sealed by a registered professional engineer; however, from a contractual and professional liability perspective, most owners prefer (perhaps even demand) that the licensed professional is backed up by a firm with substantial resources that can provide the financial assurances that the design conforms to the standard of care normally exercised on these typically high-risk facilities. It is likely that regulators also view the full resources of an established firm as preferred. Typically, owners will contract with an engineering firm who then designates a duly-registered individual as the EoR. As insurance companies have become wary of the risks associated with tailings dam design and operations, it may become increasingly difficult for individuals to obtain even minimal levels of insurance (professional liability or commercial general liability) to cover services related to tailings dams, making it increasingly difficult for an individual to function as an EoR independent of a firm. In the GBA breakout session, the group reached consensus (although not unanimously) that the EoR is a designated individual employed by a firm with necessary financial resources to manage liability, and that flexibility should exist for the EoR to be an employee of the owner.

The EoR team concept (Morrison & Hatton, 2016) was discussed at length in one of the breakout sessions. Participants confirmed that safe and responsible management of a TSF requires a team; however, this concept was clarified that the EoR is a member of the team and must rely on various experts to supplement his or her own technical expertise and experience.

Minimum requirements for EoRs were discussed at length. In addition to professional registration in the jurisdiction of the project, workshop participants indicated that an EoR for a TSF should possess a minimum of 10 years of relevant experience, but that more experience would be needed as complexity, scale, and downstream consequence increases.

4.3 *Roles & Responsibilities*

The RACI charts developed during the workshop breakout session provide perspective on the obligations of the various TSF project participants. The TSF project was broken into typical phases: design; initial development and construction for startup; operation and ongoing construction; and closure. Within each phase, specific TSF project elements were identified by workshop participants and RACI designations assigned to the project parties (EoR, owner's management and various designated positions, independent technical reviewer/board, and regulator). Table 1 presents general TSF elements incorporated in the various phases for the RACI charts.

Subsequent to the GBA workshop, the Dam Integrity Advisory Committee (DIAC) of the Alberta Chamber of Resources, members of which participated at the workshop, developed RASCI (*R*esponsible, *A*ccountable, *S*upport, *C*onsult, *I*nform) tables for the following two scenarios: (i) large organizations with multiple dams and sophisticated internal resources; and (ii) small organizations with few dams and limited internal resources (DIAC, 2017; Boswell & Martens, 2017). These RASCI tables divide accountabilities and responsibilities among the participants (e.g., Accountable Executive, Operations Manager, Dam Safety Responsible Engineer [DSRE], Engineer of Record [EoR] and Design Engineer [DE]) pertaining to organizational requirements; investigation and design; construction; operations and maintenance; surveillance and reporting; emergency preparedness and response; decommissioning and closure; and risk, documentation and review.

Table 1. TSF elements and project phases for RACI charts.

Design	Initial construction for start-up	Operation and ongoing construction	Closure
– Designation of design team – Plans and specifications – Cost estimation – Permitting support – Site investigation, analysis & reports – Operation, maintenance & surveillance (OMS) manual – Emergency action plan (EAP) – Action threshold levels – Regulatory reporting – Environmental impact analysis and protection – Risk and FMEA – Closure plan – Financial assurance	– QA & QC – Instrumentation – Construction management – Construction reports and as-builts	– Operations tailings management – Inspection and monitoring – Instrumentation and key performance indicators (KPIs) – Dam safety program – Closure plan updating – Environmental management – Change management – Succession planning – Permitting support – Periodic site investigations – Risk and FMEA – Training programs – Design changes – Major construction changes	– Final closure plan – Construction management – QA & QC – Dam safety program – Long-term care and monitoring

The FMEA process (or similar processes such as Failure Modes Effects and Criticality Analysis [FMECA] or Potential Failure Modes Analysis [PFMA]) was identified during the workshop as a potential step in accepting an EoR engagement on an existing project. The authors note that while engineering risk assessments and FMEAs have been widely-used in water dam practice for several years, the mining industry has only recently begun to increase the use of these methods.

5 NEXT STEPS

Through collective identification by TSF professionals of the elements of TSF projects, definition of the EoR, and TSF participant responsibilities, the standard of practice can be communicated and the potential risks and liability for the parties recognized. An EoR and an EoR's firm can then begin to identify the internal and external programs to help manage the responsibilities and risks. Internal programs may include the firm's QA program and special risk assessment, design review, and construction/operation review steps, along with contract positions and insurances. External programs, such as the adoption of industry practice guidelines, are most effective when broad support by practitioners, owners, and even regulators is obtained. The need for direct engagement with industry groups (such as MAC, ICMM, and others) was emphasized at the workshop and by the survey respondents.

Using information from the workshop supplemented by survey results and the work of others (e.g., CDA, DIAC), GBA is in the process of developing a document titled "*National Practice Guideline for the Tailings Storage Facility (TSF) Engineer of Record (EoR)*" that is planned for release by the end of 2017. The purpose of the guideline is to assist in identifying the roles, responsibilities and accountabilities of the EoR for TSFs, as well as other project participants including the Designer of Record (DoR) where this differs from the TSF EoR, the owner or operator, the regulator, and the third-party reviewer or ITRB.

The guideline will address the responsibilities and range and nature of services that should be included in the scope of service for the DoR, who is the engineer who signs and seals instruments of professional service, and the additional responsibilities and scope of service(s) required for the DoR to accept designation as the TSF EoR. The guideline is intended to clarify the roles and responsibilities of the DoR and the TSF EoR for projects undertaken in the United States. It is typically anticipated that the DoR will become the TSF EoR, providing continued support during TSF operations. The guideline presents concepts that, when consistently applied, have proven extremely beneficial in terms of reducing risk of failure of TSFs.

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