MOUNT POLLEY MINE AUGUST 2014 TAILINGS DAM EMBANKMENT BREACH RESPONSE AND APPROACH TO REMEDIATION

Katie McMahen, PAg[1]
Colleen Hughes, EP [2]

[1]Environmental Technician, Mount Polley Mining Corporation, Likely, Canada;
MSc Candidate, Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, Canada

[2]Environmental Coordinator, Mount Polley Mining Corporation, Likely, Canada

ABSTRACT

On August 4, 2014, a foundation failure occurred at the Mount Polley Mine Tailings Storage Facility (TSF), releasing tailings, supernatant, and construction materials into the adjacent Polley Lake and down the Hazeltine Creek corridor into Quesnel Lake, causing erosion and deposition in the creek valley and deposition in Polley and Quesnel Lakes. Mount Polley Mining Corporation's immediate response to the TSF embankment breach included: assessing and managing human health and safety risks; initiating a large-scale environmental monitoring program; and implementing interim sediment and erosion control measures in the Hazeltine Creek corridor. Subsequently, a control-oriented rehabilitation plan was initiated, which included reconstruction of the Hazeltine Creek channel. The next remediation phase, which is currently underway, involves installation of fish habitat features in Hazeltine and Edney Creeks, as well as rehabilitation of riparian and forest ecosystems in the floodplain and upland areas. This reclamation program is guided by results of the Human Health and Ecological Risk Assessment being conducted.

A number of challenges were (and continue to be) met in the TSF embankment breach response process, primarily associated with: external communications; expedient implementation of environment monitoring, construction and rehabilitation programs; and challenging environmental conditions. It is anticipated that long-term monitoring of the receiving environment and rehabilitation works will be required, with continuous improvements being achieved through the adaptive management process that has been necessary to respond to challenges encountered thus far. Strong relationships among Mine representatives, regulators, First Nations and consultants continue to be a key component to moving forward with clarity, and are a precondition of long-term trust.

KEY WORDS

Mine reclamation, tailings spill, emergency response, environmental remediation, rehabilitation, tailings dam embankment breach

INTRODUCTION

The Mount Polley Mine (the "Mine"), operated by Mount Polley Mining Corporation (MPMC; a wholly owned subsidiary of Imperial Metals Corporation [Imperial Metals]), is an open pit copper-gold mine with an underground component that has the capacity to process 22,000 tonnes per day of ore. The Mine is located in the interior of British Columbia (BC), eight kilometres (km) southwest of Likely and 56 km (100 km by road) northeast of Williams Lake, BC (Figure 1).

Clearing of the site and construction of the facility began in 1995, with the mill being commissioned in June 1997. The Mine suspended operations in October 2001 due to low metal prices, then reopened in December 2004 with mill production commencing again in March of 2005.

Early in the morning on August 4, 2014, a breach occurred at the Perimeter Embankment of the Tailings Storage Facility (TSF) due to the failure of an underlying glacial lacustrine layer that was not appropriately characterized or accounted for in engineering designs (Morgenstern et al. 2015). The TSF embankment breach released an estimated 10.6 million cubic metres (Mm^3) of supernatant, 13.8 Mm^3 of tailings slurry (7.3 Mm^3 of tailings solids and 6.5 Mm^3 of interstitial water), and 0.6 Mm^3 of embankment construction materials to the receiving environment. This material flowed into the adjacent Polley Lake, and then down the ~9 km Hazeltine Creek channel to Quesnel Lake, causing ~236 hectares (ha) of varying degrees of erosion and deposition in the creek valley, as well as deposition in Polley and Quesnel Lakes (Miller et al. 2015). An overview of these downstream environments and associated rehabilitation areas is provided in Figure 1. Following the TSF embankment failure, mining and milling operations were suspended, as well as the then-permitted effluent discharge to Hazeltine Creek, and resources were repurposed for remediation work at the TSF, around Polley Lake, and down the Hazeltine Creek corridor to Quesnel Lake.

Rehabilitation and Remediation Approach

MPMC, with support from their consulting team, developed a Rehabilitation and Remediation Strategy to guide post-event environmental monitoring and rehabilitation of terrestrial and aquatic systems. This strategy also addresses requirements of a Pollution Abatement Order (PAO) from the BC Ministry of Environment (MoE) and a *Water Act* Order from the BC Ministry of Forests, Lands and Natural Resources Operations (FLNRO). The Rehabilitation Strategy consists of four (4) phases and is depicted in Figure 2. Phases 1 and 2 have been completed, and Phases 3 and 4 are actively underway. These rehabilitation and remediation works are summarized in the subsequent sections. A review of challenges encountered while conducting these works in an emergency response situation is also presented to provide insight into the associated lessons learned or items for future consideration.

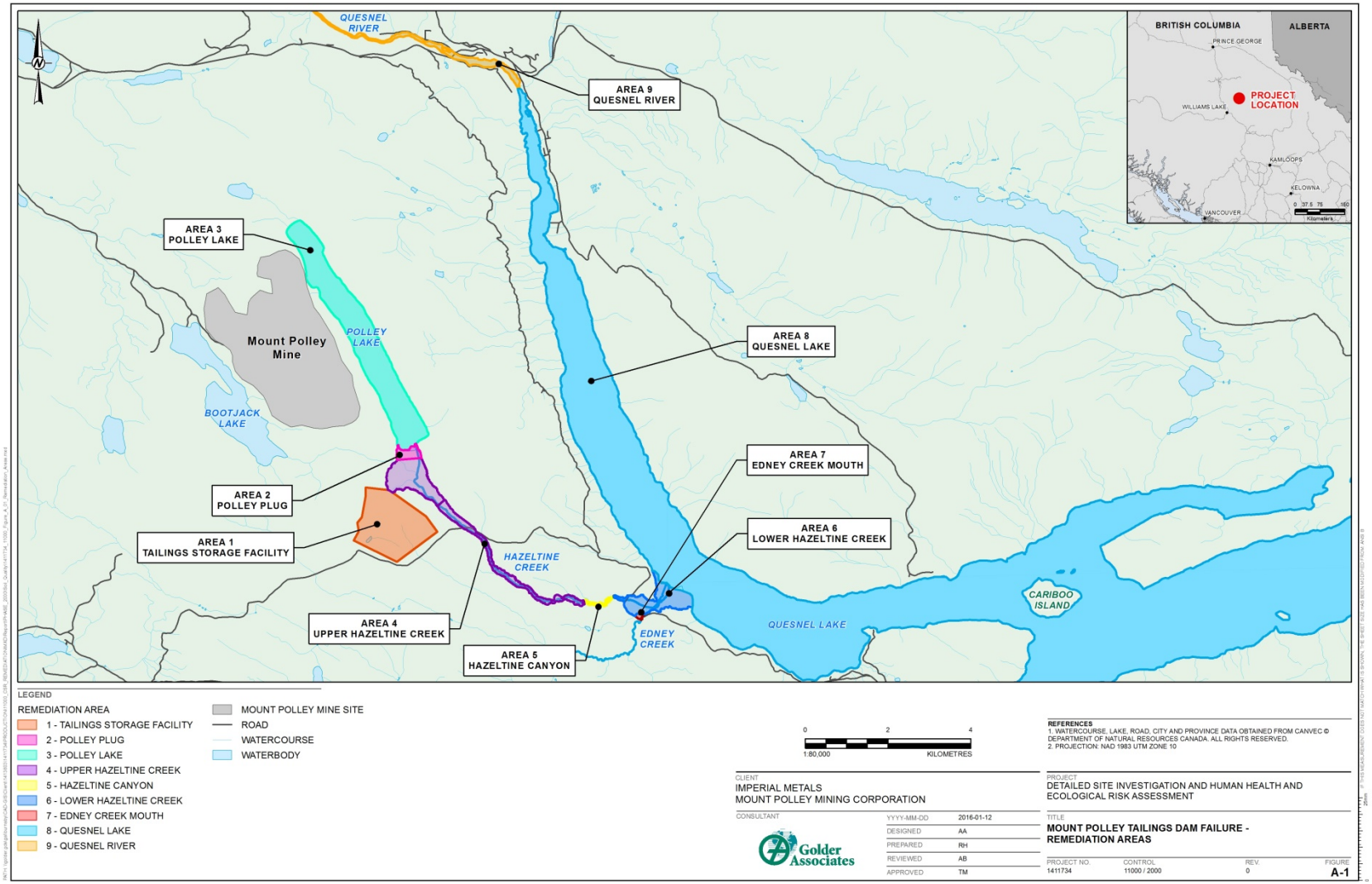

Figure 3 TSF embankment breach remediation areas (reproduced with permission from Zapf-Gilje et al. [2016])

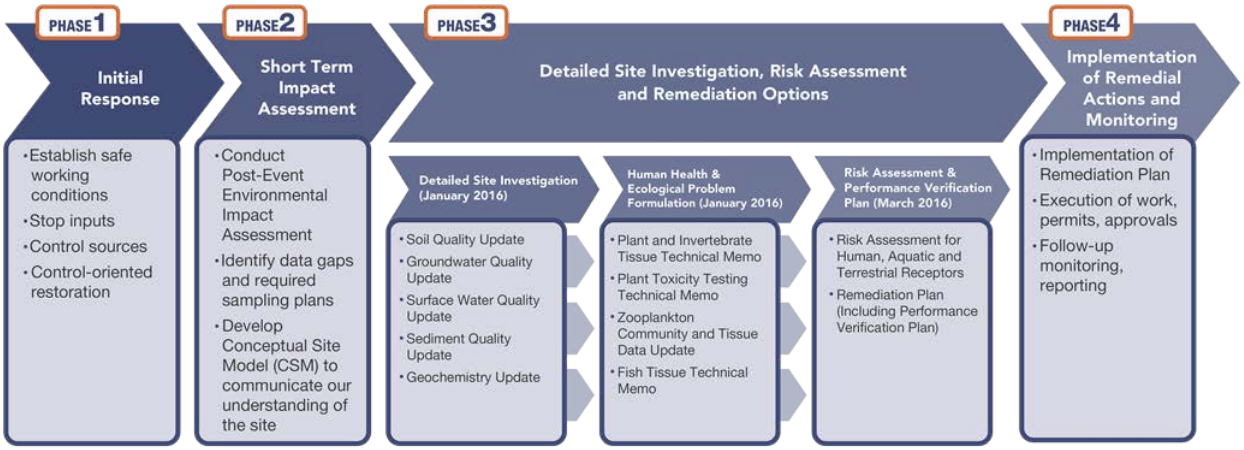

Figure 4 TSF embankment breach Rehabilitation and Remediation Strategy (reproduced with permission from Miller and Zapf-Gilje [2016])

PHASE 1: INITIAL RESPONSE

The initial priority of the emergency response was to address health and safety concerns, including: restriction of public access to impacted downstream areas; cleanup of woody debris on Quesnel Lake, where it presented a vessel navigation hazard; a stability assessment of the "Polley Lake Plug" (an approximately 17 hectare depositional area at the outlet of Polley Lake); and lowering of the artificially high Polley Lake water level, which increased over a metre during the event. Drinking water and fish consumption advisories were issued by the Interior Health Authority for Polley and Quesnel Lakes, however, following water chemistry monitoring, these advisories were subsequently lifted on August 12, 2014, eight (8) days after the TSF embankment breach, with the exception of a small area at the mouth of Hazeltine and Edney Creeks. Despite these advisories being lifted, MPMC organized testing of home water quality and installation of water filtration systems for residents drawing water from Quesnel Lake and the upper Quesnel River.

A secondary, but concurrent, priority was to contain the approximately 80% of tailings that remained in the TSF, and to control erosion of deposited dam outwash materials and areas exposed by scouring into Quesnel Lake. As such, a number of source control-oriented measures were also implemented over the subsequent months, which are summarized in Table 1.

While environmental impact assessment and monitoring of the downstream receiving environment commenced immediately after the event, a large-scale environmental monitoring program was formalized in the weeks following the TSF embankment breach, which is described in more detail under Phase 2.

MPMC received formal confirmation from provincial government that Phase 1 had been completed on July 29, 2015 (MoE 2015).

Table 1. A summary of the initial response actions to the TSF embankment breach and milestone completion dates

Initial Response Action	Completion Date
Modifications and upgrades to the Mine water collection and conveyance system were carried out to "reverse" the water management system, such that Mine contact water was directed to, and stored in the Springer Pit; the Springer Pit was the primary active mining pit prior to the TSF embankment breach and was repurposed to store Mine contact water.	September 4, 2014 (including collection of outflow from the breach location)
Construction of ~2.6 M tonne temporary rockfill containment berm across the breach location to control tailings solids mobilization (safety and source control measure).	October 10, 2014
The Perimeter Embankment breach was repaired in the winter of 2014-2015 (following failure investigations and permitting) to manage freshet flows and as a permanent source control measure. Engineering and construction monitoring services were provided by Golder Associates Ltd. (Golder; Figure 3).	May 3, 2015
Helicopter application of annual grass seeds along the length of the Hazeltine Creek corridor and on exposed tailings on the TSF surface as part of wind and water erosion control measures.	September 13, 2014
Construction of two (2) sediment control ponds designed by SNC Lavalin Inc. in lower Hazeltine Creek to settle larger (> 10 µm) particulates eroded from Hazeltine Creek, thereby reducing turbid discharge to Quesnel Lake during stream stabilization work (Figure 3). Rigorous archaeological study followed by construction commenced in early October 2014.	December 12, 2015
A field-engineered stream rehabilitation project was initiated in the ~9 km Hazeltine Creek channel and in the lower ~1km of Edney Creek. Construction involved removal of tailings, excavation down to competent till, and channel armouring with low sulfur, non-acid generating run-of-mine waste rock (Figure 3; Bronsro et al. 2016). This construction was the primary strategy for controlling erosion and downstream sediment transport to Quesnel Lake.	May 12, 2015 ("clear" water May 13, 2015)

PHASE 2: SHORT-TERM IMPACT ASSESSMENT

Following the TSF embankment breach, a comprehensive environmental monitoring program was implemented concurrently with Phase 1. The objective of this phase of the program was to assess physical, chemical, and biological effects in the first six (6) to eight (8) months following the TSF embankment breach. The program included assessment of water quality, sediment quality, aquatic toxicology, fish and fish habitat, geochemistry, limnology (including a volume mass balance of erosion and deposition, and development of a hydrodynamic model for Quesnel Lake), hydrology, geomorphology, soil quality, and terrestrial wildlife and vegetation. The results are presented in a Post-Event Environmental Impact Assessment Report (PEEIAR; Miller et al. 2015).

PHASE 3: DETAILED SITE INVESTIGATION, RISK ASSESSMENT, AND REMEDIATION OPERATIONS

The initial results presented in the PEEIAR (Miller et al. 2015) provided a basis for initiation of a Human Health and Ecological Risk Assessment (HHERA) required by a MoE PAO amendment. The PEEIAR identified: the primary contaminants of concern; areas where additional or confirmatory monitoring was required to assess potential long-term impacts; and potential exposure pathways for humans and ecological receptors, allowing development of a Conceptual Site Exposure Model. It also identified receptor exposure conditions by characterizing the elemental composition of various media (soil, sediment, water, biota tissue) and the potential for impacts by metals through toxicity testing and geochemical investigations (Kennedy and Day 2015).

Ongoing monitoring and targeted investigations continued following the PEEIAR submission, and a Detailed Site Investigation and Human Health and Ecological Problem Formulation were prepared in January 2016 (Zapf-Gilje et al. 2016). Findings from this monitoring were also presented in a PEEIAR Update Report (Miller and Zapf-Gilje 2016). The final HHERA is scheduled to be submitted to MoE by November 30, 2016.

While the purpose of this paper is to discuss rehabilitation works, development of rehabilitation plans (and ultimately a final Remediation Plan) relies on findings from environmental monitoring and the HHERA. Environmental monitoring results to date consistently indicate that impacts from the TSF embankment breach are primarily physical (Miller and Zapf-Gilje 2016, Zapf-Gilje et al. 2016). Despite numeric exceedances of environmental quality benchmarks, or background levels which in some instances naturally exceed guidelines, in some media (soil and sediment), geochemical investigations (Kennedy and Day 2015) and associated chemistry and toxicity monitoring (Stecko et al. 2015, Miller and Zapf-Gilje 2016 and technical reports referenced therein) indicate that these materials are non-acid generating and have low bioavailability and leaching potential. Based on this work, the main components of rehabilitation work necessary to mitigate or manage impacts are as follows:

- **Erosion:** The exposed tailings and eroded native materials can contribute to elevated levels of particulates and associated metals in downstream water bodies; removal and/or stabilization (recontouring, revegetation, etc.) of these materials is the primary control strategy.
- **Tailings Constraints to Vegetation Growth:** Following the TSF embankment breach, a "halo" zone along the Hazeltine Creek corridor was formed where tailings were deposited on the forest floor, but no erosion or vegetation removal occurred. In spring 2015, an unanticipated die off of trees in this zone occurred because the saturated, fine-textured tailings mixture created anaerobic conditions in the root zone. In the spring, as trees flushed following dormancy, anaerobic conditions persisted in the subsurface soils, and trees were not able to uptake water due to the decayed state of their roots from the physical smothering effect (Miller and Simard 2015). This indicates that improvements to the physical structure of deposited materials,such as increasing organic matter content or mixing with buried native soil materials, are required to support vegetation growth. In addition, chemistry data show poor nutrient conditions in the deposited tailings and native material (dominantly till) exposed by the scouring event. Thus, soil amendments and/or a revegetation plan to rebuild soil nutrient status through primary succession will

be necessary; rehabilitation of the soil biological community lost through scour or onset of anaerobic conditions will be necessary to support this nutrient cycling.

- **Vegetation:** Revegetation of areas where scouring occurred and areas where trees were logged from the dead halo zone is necessary for erosion control and rehabilitation of the structure and function of the riparian and forest ecosystems.
- **Fish Habitat:** Fish habitat along the length of Hazeltine Creek and in lower Edney Creek was lost during the debris flow and is being rehabilitated to provide stream habitat functions.

PHASE 4: IMPLEMENTATION OF REMEDIAL ACTIONS AND MONITORING

The final Remediation Plan will be informed by outcomes of the HHERA and associated approvals for management of spilled tailings, but initial rehabilitation work has been implemented concurrently with Phases 2 and 3. Rehabilitation works completed to date are summarized below. The intent of these sections is to present an overview of the approach to rehabilitation, and provide a background for discussing challenges and lessons learned, as opposed to a comprehensive description of rehabilitation prescriptions.

Aquatic Ecosystems

Following construction of the mean annual flood channel and floodplain for the Hazeltine and Edney Creek channels (Phase 1), the next step is to install fish habitat features in the constructed channel. A Habitat Objectives Working Group, with representatives from MPMC and their consultants, First Nations, the MoE, FLNRO, and Fisheries and Oceans Canada (DFO), was formed by MPMC to define rehabilitation goals and provide input into the design work, with a focus on the fisheries protection provisions of the *Fisheries Act.*

The Habitat Objectives Working Group met frequently in 2015-2016 working toward consensus on the development of a framework to evaluate habitat remediation efforts. This framework included the identification of the ecological units to be considered, and the methods and metrics to use to assess productivity. The final metrics for each unit included whether or not the species affected were considered to be Commercial, Recreational, or Aboriginal (CRA) fisheries, the ecological functions of the unit (e.g., spawning, rearing, over wintering, or migration), the pathway of effect (e.g., sediment deposition, scour, change in water quality), the magnitude of effect (high, medium, or low), the duration (e.g., Polley Lake >2 years), the productivity component, whether there was baseline information available, and the potential indicators (e.g., fish population age structure). As an example, lower Edney Creek had a long list of CRA fish, the function was mostly spawning, it ranked high for magnitude, the duration was low, there were limited baseline data, and the indicators include relative abundance (catch per unit effort) for some species and evidence of habitat utilization for others. This information and monitoring results will inform the final requirements for balancing possible effects on the fishery for a given duration of time.

The lower ~800 metre (m) reach of Edney Creek into which Hazeltine Creek flowed prior to the TSF embankment breach was prioritized; the channel reconstruction completed during Phase 1 occurred in a separate flow path from Hazeltine Creek to allow continued fish passage to the upstream, unimpacted, watershed. The design of the fish habitat integrated three specific channel meander patterns, each of which is associated with features of the overall creek channel (lower flood plain, mean annual flood plain, and low flow channel). In July and August 2015, water was diverted from the lower reach of the Edney Creek channel and fish habitat features were installed based on whether the area was considered to be spawning or rearing habitat (Figure 3). The spawning habitat includes gravel platforms associated with rock weirs to facilitate scour of the ponds. The channel is complexed using boulders, logs, and tree tops to provide in-stream and

over stream cover for fish. The creek is designed so that interaction of flows with the features described will sustain and create runs, riffles and small ponds in the low flow channel. Habitat construction is detailed in Bronsro et al. (2016). Features have been stable through the first annual freshet flows, and fish use in the newly constructed habitat has being observed and documented by MPMC.

The work in Edney Creek has provided useful experience, and early data show successful outcomes. The process (Bronsro et al. 2016) of stream construction in Hazeltine Creek will largely follow the process used for Edney Creek, although the specifics will reflect the habitat objectives determined through the consultative process outlined above. To facilitate channel construction, a weir structure was installed at the outflow of Polley Lake, at the start of the Hazeltine Creek channel, to allow reduction of flow rates during construction. Fish fences were also installed to prevent fish from entering the system during active construction and prior to completion of fish habitat reconstruction. At of the time of writing, the installation of habitat features into the foundational channel is in progress within the first ~1,000 m of Hazeltine Creek.

Terrestrial Ecosystems

The goal for rehabilitation of the terrestrial environments impacted by the TSF embankment breach is to reclaim the structure and function of the terrestrial habitat along the Hazeltine Creek channel to a useful and productive condition. Rehabilitation work completed to date is described below for the different disturbance types created by the event.

Depositional Zone (upper Hazeltine Creek corridor): The "Polley Lake Plug" area immediately downstream of the TSF contains the thickest deposits of outwash materials (up to ~3.5 m deep in some areas; Miller et al. 2015). Work to date has focussed on removal of tailings in areas immediately adjacent to the Hazeltine Creek channel to reduce creek sedimentation. Rehabilitation plans for this area are in progress, and will be based on longer-term tailings management decisions related to outcomes of the HHERA, improved understanding of tailings constraints for vegetation growth, and evaluation of reclamation methods.

Halo Zone (upper and lower Hazeltine Creek corridor): Removal of dead trees with smothered roots, and repurposing of those trees for fish habitat and terrestrial rehabilitation work has occurred. Trees that were still alive were left in place, and some trees were left as "stubbed" stumps, where safe to do so, as habitat for birds. Methods for rehabilitation of these areas following tree removal are being evaluated, including tailings removal or mounding of the tailings to improve above-ground/below-ground oxygen and drainage pathways, and to expose the underlying mineral soil. No additional actions beyond monitoring are currently being undertaken in any areas where tailings deposition was shallow and trees survived.

Scour Zone (Middle Hazeltine Creek corridor): In areas where scouring was the primary impact, most of the exposed cutbanks have been recontoured, often requiring push back of the undisturbed forest to achieve an appropriate slope angle for safety and erosion control. Where that pushback has occurred, the forest soil was placed over the recontoured area to provide additional organic matter, seed sources, and active soil biota to enhance rehabilitation. Site preparation (mounding) and application of woody debris recovered from the debris flow is

ongoing to reduce erosion, as well as to create wildlife habitat and improved plant microsites (Figure 3). The woody debris also acts as a source of seed and long-term soil carbon. Revegetation to date has focused on the floodplain areas to reduce potential erosion into the channel. Willow (*Salix* spp.) wattles and live stakes and black cottonwood (*Populus trichocarpa*) wattles collected from site have been installed using bioengineering techniques (Figure 3). Black twinberry (*Lonicera involucrata*), red-osier dogwood (*Cornus stolonifera*), and prickly rose (*Rosa acicularis*) nursery seedlings have also been planted along one side of the floodplain, maintaining the other side for access to construct fish habitat features in the future. Planting of Sitka alder (*Alnus viridis*) seedlings grown from seed collected on site is planned for fall 2016 in areas between the floodplain and forest edge. Future revegetation of upland areas is anticipated to include additional early successional species, with seeds collected from Mine site where possible. These native species have been selected based on their role in primary succession in the region and projected ability to survive in the available habitats. The selected species are anticipated to be fast growing (and shade out invasive species), easily propagated, and produce leaf litter (and in the case of alder, fix nitrogen) to begin building soil. While primary succession in the region is typically dominated by shrubs, a light application (30 kg/ha) of a native blend of grasses and forbes is being applied to provide additional erosion control and organic matter inputs. Figure 3 presents photos of rehabilitation work in this area.

Depositional Zone (lower Hazeltine Creek corridor): The deposited tailings and eroded native materials at the mouth of the Hazeltine Creek channel were not as deep as in the "Polley Lake Plug" near upper Hazeltine Creek (0.15 to 1.5 m). Tailings were, for the most part, removed, in particular from the channel and floodplain areas. Wood chips produced from trees recovered from Quesnel Lake were available and applied in spring 2015 to reduce erosion, hold moisture and eventually to provide organic carbon as they decompose. These chips were mixed and mounded in 2016, along with larger site preparation work across the area to expose mineral soil for planting and natural plant ingress. This site preparation work included mounding and application of woody debris as described for the Scour Zone above. Planting of the floodplain and revegetation of upland areas is ongoing as described in Scour Zone section above. The time series photographs in Figure 4 shows progression of reclamation in this area.

Figure 5 Rehabilitation works photos: A. TSF Perimeter Embankment breach repair cut-off wall and buttress; B. Hazeltine Creek channel reconstruction; C. Lower Hazeltine Creek sedimentation ponds; D. Edney Creek fish habitat features; E. Hazeltine Creek floodplain revegetation; F. Terrestrial reclamation site preparation and woody debris application

Figure 6 Lower Hazeltine Creek rehabilitation timeline; top to bottom: November 2014, June 2015, August 2016

CHALLENGES ENCOUNTERED

Through the process of conducting environmental monitoring, emergency mitigation measures and rehabilitation works in response to a large-scale environmental incident, many challenges have, as expected, been encountered. A number of these challenges are described below, along with MPMC's approaches for managing these challenges, to shed light on associated lessons learned, recommendations, or items for future consideration.

External Communication

Public Communication: The need to present accurate information to the public and communicate the large-scale response works actively occurring was an important element of the TSF embankment breach response. Public relations activities were previously incorporated into the roles of MPMC technical staff, but the increased need to disseminate information and meet with interested parties necessitated additional support. Support from Imperials Metals public relations staff and hiring of a new Chief Scientific Officer position, as well as development of a lead consulting role for an individual with experience in emergency response communications, aided in filling this gap.

While speculation and the presence of incorrect information in the news and social media streams were rampant, MPMC and Imperial Metals focussed on presenting factual information, as opposed to responding to defamatory or provocative statements. Further, information dissemination was focussed on local communities that could potentially be affected by environmental impacts or economic impacts associated with suspension of Mine operations, such as layoffs, rather than on responding to far-field or antagonistic interests.

A number of new lines of communication were implemented (or existing methods significantly increased in frequency) including: open public meetings held regularly in Likely and Williams

Lake, as well as for the Williams Lake Indian Band and Xat'sull First Nation; online publication and mailing out of Community Update Bulletins; updates on the Imperial Metals website (including copies of weekly reports to the MoE); news releases; media interviews; and monthly submissions to the Likely Matters newsletter starting in late 2015. Communication material was made available in the form of summarized and interpreted data, photographs, update reports and brief videos that explained the approach and showed the work being carried out. Consulting support on information presentation methods, including visuals, along with careful selection of presenters and ensuring that they communicated at a level appropriate for the general public were important considerations. The use of unmanned Aerial Vehicles (drones) proved to be highly effective (cost and functionality), as they could provide abundant photo and video material at a scale that was ideal for the physical works. The importance of distributing accurate and timely content for media and public very early in such an event is a lesson learned and highly recommended for others in similar situations.

Regulatory, First Nations and Key Stakeholder Communication: In addition to increased public communication, the following new avenues for MPMC to receive feedback and direction from relevant regulators, First Nations and other key communities of interest were implemented by the regulators tasked with responding to the TSF embankment breach, with the goal of addressing all aspects of the response:

- A daily call with Emergency Management BC and the Cariboo Regional District Emergency Operations Centre included representatives from the MoE, the Ministry of Energy and Mines (MEM), FLNRO, DFO, First Nations, and local stakeholders. These calls changed to include only the provincial government agencies and the DFO when the state of local emergency was revoked in late August 2014. The frequency then decreased to bi-weekly, weekly and then to semi-weekly in the fall of 2015.
- A committee supplemental to the Joint Implementation Committee, which was formed under the Participation Agreements held between MPMC, the Williams Lake Indian Band and the Xat'sull First Nation, was formed to focus on TSF embankment breach-related items.
- An Environmental Working Group (EWG) was established by the MoE, the Williams Lake Indian Band and the Xat'sull First Nation to facilitate environmental technical discussions. Formation of this group was an outcome of a Letter of Understanding signed between the Williams Lake Indian Band, Xat'sull First Nation and the Province of BC in August 2014.
- A Government to Government Technical Working Group also established under the Letter of Understanding for joint review of MPMC deliverables and submissions by the MoE, the Williams Lake Indian Band and the Xat'sull First Nation (MPMC not a member).
- A Government to Government Senior Officials Committee was also established under the Letter of Understanding. This committee receives reports from the EWG and is composed of representatives from local First Nations and the MoE, the MEM, and the BC Ministry of Aboriginal Relations and Reconciliation (MARR) to oversee all of the TSF embankment breach response activities (MPMC not a member).

- The Principles Table, which consists of the Chiefs of the local First Nations and the BC Ministers of Environment, Energy and Mines, and Aboriginal Relations and Reconciliation (MPMC not a member).
- A Science Panel formed by MoE to bring together technical representatives from primarily academic bodies.
- A Habitat Objectives Working Group (previously described).

These groups provided a venue for prioritizing risks and evaluating associated remediation measures, incorporating the priorities of the various parties. This was particularly important for management actions where all available options were associated with drawbacks. For example, one immediate impact of the TSF embankment breach was an artificially increased water level in Polley Lake, and there were concerns about the geotechnical stability of the deposited tailings material at the end of the lake relative to its potential to hold this water back. For safety purposes, a decision was made that dewatering Polley Lake to Hazeltine Creek around the "Polley Lake Plug" using pumps was a necessary action; however, this resulted in increased flow rates in the Hazeltine Creek, and consequently increased sedimentation. A second longer-term example is balancing the need for short-term environmental protection and the desire to conduct rehabilitation works in a timely manner, with the timeline for receiving final results of the HHERA, which may influence rehabilitation methods.

Frequent meetings of the aforementioned groups also helped facilitate review of the various components of the response program. The review process was complex, involving a number of parties and highly technical components, which necessitated the involvement of, and site visits by, third party Qualified Professionals and other consultants contracted by regulators, First Nations, and MPMC. These response-oriented groups provided beneficial input and perspectives on response actions, and help to expedite timelines such that measures could be implemented without delay for environmental protection purposes. For example, local information on the importance of interior coho salmon (*Oncorhynchus kisutch*) in Edney Creek was incorporated into fish habitat rehabilitation planning. Similarly, these meetings provided venues for managing the increased scrutiny of activities occurring at the Mine, and enabling communication to facilitate rebuilding of trust following the TSF embankment breach.

Expedient development of the groups described above encompassing regulators, First Nations, and communities of interest, however, resulted in overlaps and intensive scheduling constraints for all parties. Over time, the frequency of meetings for these various groups has decreased, with some redundant groups being dissolved. Transition back to regular structures for communication, including Implementation Committee Meetings held with the Williams Lake Indian Band and Xat'sull First Nation under existing Participation Agreements, Public Liaison Committee Meetings, and the Mine Development Review Committee has shown the effectiveness of these established systems and highlights their usefulness, which can translate to emergency response communications. Similarly, the transition to incorporating the response program into day-to-day operations had been occurring simultaneously. It is anticipated that the result will be more efficient regulation and coordination of environmental management activities, and a more holistic approach that allows for identification of any gaps and consideration of cumulative effects.

<u>Expedient Implementation of Response Programs</u>

Access to Impacted Areas: The primary concern following the TSF embankment breach was public and worker safety, specifically in impacted areas downstream. Initially, until geotechnical investigations could be conducted, there was uncertainty about the stability of material deposited at the outflow of Polley Lake (the "Polley Lake Plug") relative to the artificially increased water level in the lake. Despite the desire to conduct investigations and monitoring, access restrictions were put in place for the public, regulators, and MPMC personnel. Notwithstanding other responsibilities to act, the paramountcy of life and safety protection in the hierarchy of actions cannot be disputed. There were no lives lost as a result of this dam breach, and health and safety management was rigorously adhered to throughout the response. By late August 2014, safe access was verified by through geotechnical investigations and specific protocols were in place to manage hazards. At this time, MPMC facilitated access for agency staff and research scientists (i.e., those with a need to access the area). As safety improved, MPMC provided tours for the local community and area First Nations members.

Technical Human Resources: To support response work, substantial additional and specialized resources were hired under contract to supplement the Mine staff technical and operational resources. To handle the need to orient and manage a number of new and existing consultants, MPMC reserved Mine staff to coordinate the various monitoring programs and consulting teams, provide site-specific knowledge, manage day-to-day logistics and review deliverables (as opposed to carrying out the field programs). A major focus was management of the substantial datasets being generated, such that MPMC retained all data on site in a form useable for ongoing and future analyses. Despite this, requirements for reporting and meeting with regulators still exceeded MPMC's internal capacity. Short-term support and leadership was provided from senior environmental staff from another Imperial Metals operation, but in the longer-term, formation of a lead consulting position for an individual with experience in responding to environmental incidents was found to be effective in helping liaise with regulators, First Nations and stakeholders, as well as coordinate the response program at a high level. This role decreased over time as emergency needs were addressed and response programs developed.

One exception to this approach is that MPMC was largely responsible for conducting the water quality monitoring program. This was a targeted area where MPMC field expertise was most applicable. Because water continues to be one of the most frequently monitored matrices, this also allows for efficient use of resources by minimizing costs associated with external field technicians, and leverages the Mine's logistical capabilities. In support of this, Mine employees in technical roles were repurposed to provide support with field work and data management. Further field and construction support was also sourced from local First Nations, which facilitated their direct involvement in post-TSF embankment breach monitoring and rehabilitation programs.

Financial Security and Employee Retention: An ~350 employee mining operation represents a significant payroll and the ability of any company to respond to a major event requires careful planning of fiscal and human resources to sustain the necessary response actions, particularly in a market where base metals prices were down. While it was necessary to lay off staff due to suspended operations, the Mine and its consultants made efforts to accommodate as many of the employees in the response work. Such fiscal sustainability and retention of human capital necessitated planning to allow restart of the operation, even if only in a limited capacity. The

response program continued to be a major focus and was resourced through employees not engaged in the limited restart operation and through contracted services. Following a permitting process, restricted operations at partial capacity resumed in August 2015, with tailings deposition occurring in an open pit (the Springer Pit). While viable reserves still exist at the bottom of the Springer Pit, this was the only feasible option for short-term restricted operations. Subsequent approvals received in June 2016 authorized full operations to resume, with tailings being deposited in the repaired TSF. Resumed operations have facilitated re-hiring of employees and much of the current remedial work is resourced through contracted services.

No Breaks from "Mother Nature" – Water Management during the Response

Seasonal and environmental conditions had to be accounted for in planning environmental impact studies, and in the execution of rehabilitation and source control work. Freshet was the primary challenge, both with the planning and preventative measures required in advance of freshet, as well as the management of atypical multiple "freshet" events that occurred.

Creek Rehabilitation during "Freshets": Work in the Hazeltine Creek corridor was scheduled to occur during the winter months when water sources into the creek are normally frozen, simplifying water management and access requirements. However, winter climatic conditions in 2014-2015 and 2015-2016 where atypical, with multiple rain and "spring thaw" events occurring throughout the winter. Frequent melting hindered road construction, maintenance and access necessary for Hazeltine Creek corridor rehabilitation. These melt events also required stream diversion around active construction areas, which considerably increased the workload and complexity of the work, and in some cases required suspension of stream work. Adaptive management of work locations to balance weather conditions, prioritize tasks or focus on out-of-creek activities, such as advance construction material transport to strategic locations, was necessary. The Hazeltine Creek channel rehabilitation works Environmental Management Plan and associated full-time environmental monitors were a key component of managing risk to the receiving environment in the creek channel during runoff conditions.

Freshet Preparations – Hazeltine Creek Flows: Similarly, the ability to decrease freshet flows in Hazeltine Creek to reduce erosion,so flows did not exceed the mean annual flood channel or exacerbate erosion in areas where channel reconstruction was not yet complete, was identified as a necessary measure. Further, the ability to manage flow rates in the Hazeltine Creek corridor is also of benefit in allowing flows to be reduced during sensitive periods of creek reconstruction. This resulted in prompt design, permitting, and installation of a weir structure at the outlet of Polley Lake prior to freshet 2015.

Freshet Preparations – Site Water Management: To manage the spring freshet, water balance projections indicated that contingency temporary water storage in the TSF,prior to being pumped to the Springer Pit, may be necessary for high return period events. This required permitting and construction of a repair in the location of the TSF embankment breach, following investigation activities, during winter 2014-2015. The TSF was previously constructed with a till core; however, this type of construction cannot be carried out in freezing conditions and is further constrained during precipitation (i.e., rain) events. Given this, a cut-off wall, using cutter-soil mixer technology, was selected as an appropriate technology to repair the breach area to provide

temporary surplus water storage in advance of freshet 2015. Construction occurred 24 hours per day, seven (7) days per week through the winter months. Completing this geotechnically complex and unique project on an expedited timeline was, in the end, not required for the low return period freshet that occurred in 2015, but allocation of resources to this construction was a necessary preventative measure.

Short-Term Site Water Management: Because of the Mine's positive water balance, an effluent discharge is necessary for the Mine regardless of whether mining and milling operations are active. Given the loss of the permitted discharge to Hazeltine Creek, and the finite capacity of onsite water storage (i.e., the Springer Pit), the time period for permitting was constrained. This necessitated initiation of a water management plan permitting process concurrently with implementation of response works. Options analyses revealed diverging opinions from First Nations, regulators and stakeholders regarding water discharge alternatives, and a staged approach was applied to develop and authorize an implementable plan within the time constraints noted above. A short-term solution was selected, with discharge to Quesnel Lake using the reconstructed Hazeltine Creek channel as a conveyance channel. Primary considerations for selection of this short-term water management plan included that it: was technically feasible and implementable under the time constraints noted above; would cause only minor delays, if any, to creek rehabilitation works; was less resource intensive relative to other, longer-term options (although procurement and commissioning of a water treatment plant as well as installation of dual diffusers at depth in Quesnel Lake was still required); did not preclude any of the potential long-term solutions; and met all regulatory requirements to be protective of the receiving environment. This staged approach (i.e., the short-term authorization) was a common method used by the regulators following the TSF embankment failure, with permit conditions in place to ensure long-term steps are taken, but allowing flexibility, improved consultation and more detailed design work to be completed.

Lessons Learned

As remediation and rehabilitation proceed, it is anticipated that new challenges will continue to emerge. Key methods for managing these challenges will incorporate approaches that have been found to be effective to date, including:

- Application of a phased approach to the response, prioritizing human health and safety, followed by source control, then rehabilitation.
- Early and frequent distribution of factual media content to prevent erroneous narratives (e.g., "toxic tailings" – testing shows that they are not) in the public domain.
- Routine, transparent communication with regulators, First Nations and public stakeholders.
- Retaining of supplemental technical and experienced human resources, including consultants and contractors.
- Management of fiscal resources to support rehabilitation works, support the local economy, and maintain MPMC's status as a viable mining operation. This includes continued production to generate revenue that can sustain the viability of rehabilitation works.

- Implementation of an adaptive management response framework, based on results from monitoring and observations, including those from regulators and the public, as well as planning exercises.
- Application of a staged approach to meeting long-term objectives to allow for: improved consultation and incorporation of regulator, First Nations and stakeholder input; flexibility to incorporate adaptive management responses; and increased timelines for technical design and construction project components.

Despite all of these challenges encountered in the rehabilitation processes, it is worth highlighting some positive items related to the event. Most importantly, no injuries or fatalities occurred as a result of, or during the response to, the TSF embankment breach. Secondly, the geochemistry of the deposit and tailings at the Mine are not acid generating. and, compared to many other mines, have low levels of metal leaching (Kennedy and Day 2015). Finally, the rehabilitation works have been able to involve local contractors as well as First Nation businesses (e.g., Xat'sull General Partner Ltd.) and joint ventures (e.g., Lake Excavating Ltd. and Peterson Contracting Ltd.) through earth works, revegetation, and environmental monitoring contracts. These experienced contractors made themselves readily available for emergency response projects, and not only was their work beneficial, but their direct involvement enhanced transparency and capacity building, helping to rebuild trust, which was admittedly impaired following the TSF embankment breach. These mutually beneficial partnerships have helped support the continued viability of established Participation Agreements in place between MPMC, the Williams Lake Indian Band, and the Xat'sull First Nation.

CONCLUSION

Next steps for the Mine will involve completion of fish habitat rehabilitation in the Hazeltine Creek channel, along with ongoing recontouring, site preparation and revegetation of terrestrial areas. Concurrently, permitting and implementation of a long-term water management system that does not involve conveyance utilizing the Hazeltine Creek channel is underway.

Rehabilitation of areas impacted by the tailings dam embankment breach will be a long process, but in the approximately two (2) years since the event, significant progress has been made, as described in this paper. It is anticipated that long-term monitoring of the receiving environment and rehabilitation works will be required, with continuous improvements being achieved through the adaptive management process that has been necessary to respond to challenges met thus far along the road to rehabilitation. Strong relationships among the MPMC team, regulators, First Nations, and consultants continue to be a key component to moving forward with clarity and are a precondition of long-term trust.

ACKNOWLEDGEMENTS

The authors would like to thank Luke Moger (MPMC), Dr. 'Lyn Anglin (Imperial Metals), Sophie Hsia (Imperial Metals), Brian Kynoch (Imperial Metals), and Lee Nikl (Golder) for their valuable comments. Thanks also to Golder for allowing reproduction of figures from their reports.

REFERENCES

Bronsro, A., Ogilve, J., Adams, M., and Nikl, L. 2016. River rehabilitation following a dam breach. Proceedings from the BC Technical and Research Committee on Reclamation Symposium, September 19-22, 2016.

Kennedy, C. and Day, S. 2015. Mount Polley Mine Tailings Dam Failure: Update on Geochemical Characterization of Spilled Tailings. Prepared for Mount Polley Mining Corporation.

MoE (BC Ministry of Environment). 2015. Mount Polley Mine Tailings Breach: Environmental Mitigation and Remediation Progress Report: End of Phase I Retrieved August 8, 2016 from http://www.env.gov.bc.ca/epd/mount-polley/pdf/20150729/2015ENVphase-one-progress-report.pdf

Morgenstern, N.R., Vick, S.G., and Van Zyl, D. 2015. Independent Expert Engineering Investigation and Review Plan Report on Mount Polley Tailings Storage Facility Breach. Province of British Columbia. Retrieved August 8, 2016 from https://www.mountpolleyreviewpanel.ca/final-report

Miller, T. and Simard, S. 2015. Forest conditions and die back in areas of thicker tailings deposition. Prepared for Mount Polley Mining Corporation. Report Number 1411734-947-TM-Rev2-11000.

Miller, T., Zapf-Gilje, R., and Nikl, L. 2015. Mount Polley Mining Corporation Post Event Environmental Impact Assessment Report – Key Findings Report. Retrieved August 8, 2016 from https://www.imperialmetals.com/our-operations-and-projects/operations/mount-polley-mine/mount-polley-updates/tsf-breach-information-resources

Miller, T. and Zapf-Gilje, R. 2016. Mount Polley Mine Tailings Storage Facility, Perimeter Embankment Breach Update Report; Post-Event Environmental Impact Assessment. Prepared for Mount Polley Mining Corporation. Report Number 1411734-124-R-Rev0-10000.

Stecko, P., Russel, C., Batchelar, K., Wiramanaden, C., and White, M. 2015. Mount Polley Tailings Dam Failure Sediment Quality Impact Characterization. Prepared for Mount Polley Mining Corporation.

Zapf-Gilje, E., Bruemmer, A., Zapf-Gilje, R., and Miller, T. 2016. Mount Polley Rehabilitation and Remediation Strategy Detailed Site Investigation Mount Polley Tailings Tam Failure Mount Polley, BC. Prepared for Mount Polley Mining Corporation. Report Number 1411734-114-R-Rev0-11000.