Adaptive risk management and lessons learned: post-closure at the “mighty” Sullivan mine

R.A. Peterson  SNC-Lavalin Inc., Canada
S.A. Humphries  SNC-Lavalin Inc., Canada
M.L. Unger  Teck Resources Limited, Canada

Abstract

The Sullivan mine in Kimberley, British Columbia, operated for almost 100 years and was one of the world’s largest producers of lead, zinc and silver. Environmental and risk management controls were initiated in the 1960s, including construction in 1979 of the world’s first high-density sludge treatment plant for treatment of acid rock drainage (ARD) associated with large impoundments of tailings, waste rock, other process wastes and underground mine workings. Large-scale assessment of surface water and groundwater systems were initiated in the 1990s in combination with the implementation of additional mitigation measures to control ARD-related impacts. The Sullivan mine officially closed in 2001, and comprehensive site investigation and risk assessment results were used to develop an adaptive site-wide risk management plan (RMP) that outlines long-term monitoring requirements for groundwater, surface water, vegetation and aquatic biota, with triggers for incremental assessment and mitigation as necessary.

Since closure, predicted improvements in groundwater and surface water quality have been realised; however, in some locations, RMP action levels have been triggered and incremental assessment and mitigation have been required. As an example, action level triggers were reached in surface water at the lower mine yard, where acidic seepage high in metals from shallow groundwater discharges was detected in the adjacent creek. This triggered additional investigation and implementation of interim measures to capture the groundwater as a longer-term solution is being developed. Triggers were also reached in deeper groundwater in the lower mine yard, and monitoring programs have been adapted to these changing conditions. Other challenges have been administrative, resulting from a closure process spanning over a decade and changes to regulatory policies and mine closure requirements during this time. For example, policy changes under the British Columbia Contaminated Sites Regulation (BC CSR) now require protection of aquifers for future drinking water use, which has affected applicable water quality criteria. Soil quality criteria have also changed for a number of exposure pathways following active closure, changing risk assessment assumptions and prompting additional site investigation activities to comply with the criteria under the BC CSR. These evolving physical and administrative conditions, combined with variations in weather and watershed land use, have reinforced the need for closure plans to include appropriate post-closure monitoring, anticipate the potential need to revisit assumptions made during closure planning and set trigger levels for investigating the need to adjust risk management processes.

1 Introduction

The Sullivan underground lead-zinc-silver mine is located in Kimberley, British Columbia, Canada (Figure 1, below). The mine operated for 92 years, from 1909 to 2001, and was one of the world’s largest producers of lead and zinc, producing 8 million and 9 million tonnes, respectively. The Sullivan mine ore body averaged 6% lead, 5.7% zinc and 24.8% iron and consisted mainly of pyrrhotite and pyrite (7:3 ratio) as the most abundant sulphide minerals, with galena and sphalerite as the principal ore minerals. Environmental issues were unknown at the beginning of the mine’s life, but Teck started implementing environmental controls in the 1960s. Reclamation research was initiated in the 1970s, and the world’s first high-density sludge treatment plant was constructed to treat acid rock drainage (ARD).
The mine closed in December 2001 owing to exhaustion of the ore body. The site has undergone decommissioning, reclamation, extensive monitoring, water collection and treatment since 2001 based on a decommissioning and closure plan approved by the Ministry of Energy and Mines. Post-closure monitoring at the site has been conducted using an adaptive risk management plan (RMP) to ensure closure objectives are continually being met. This paper discusses the post-closure management of the site and is a continuation of Humphries et al. (2011).

2 Mine site history, environmental assessment, controls and closure

2.1 Site history and description

Underground mine operations began in 1909, and a small open pit operated for a brief period of time. Production was initially limited because the lead and silver were separated by hand. The zinc contained in the ore was not a desired commodity at the time. In 1920, the Sullivan mine was the first to employ a newly developed differential flotation process for sulphide minerals to produce lead concentrate on a commercial scale. In 1923, a concentrator was constructed at a location remote from the mine site, as large flat surfaces were required for the placement of tailings impoundments. The tailings were rich in iron and sulphur and were used to support subsidiary industrial processes and buildings that operated for a short period of the mine life and included fertiliser, iron and steel plants.

The mine site is located on property owned and operated by Teck Metals Ltd. (Teck) and its predecessors. The mine property was developed in two distinct geographic locations (see Figure 1). The former underground mine and waste rock dumps are located immediately north and west of the City of Kimberley. The concentrator, subsidiary industrial processes and tailings ponds (referred to hereafter as the mill site), are located south of Kimberley, approximately 6 km from the mine. The drainage water treatment plant (DWTP) is located on the St. Mary River approximately 5 km south of the mill.

Figure 1 Key map of Sullivan mine site

A total of 9.75 million metric tonnes of waste rock was generated and placed at four locations at the mine site, the north and south waste dumps along the Mark Creek Valley in the lower mine yard (LMY) and the No. 1 Shaft waste dump and the open pit waste dump located above the city centre.

The Sullivan concentrator produced waste by-products of tailings and float rock, a coarse by-product from ore separation through heavy media production (i.e. flotation process). Float rock was generated from 1947 until closure, with 4.3 million metric tonnes stockpiled at the concentrator. The tailings ponds were located
immediately adjacent to the southeast side of the concentrator. Approximately 122 million metric tonnes of mill tailings averaging 0.6% lead, 0.6% zinc and 27% iron were produced over the life of the mine.

Ammonium phosphate fertiliser was produced between 1953 and 1987 using iron concentrate from the concentrator and ammonia and phosphate rock from other producers. The fertiliser process resulted in residual wastes including 7.0 million metric tonnes of phosphogypsum and 3.4 million tonnes of iron oxide. The gypsum was initially discharged into the St. Mary River but later placed into storage ponds to minimise the impact on receiving waters. The impoundments for the gypsum were constructed further east of the iron calcine ponds and south of the concentrator tailings ponds. The stockpiled iron calcine was sold for cement manufacturing until 2011.

Figure 2  Sullivan plans showing waste impoundments, surface topography and inferred surface water and groundwater flow paths

2.2  Early environmental controls

ARD is the main environmental concern in the former mine workings, waste rock piles and tailings impoundments. Acidic water with high concentrations of metals and sulphate has been found in both surface
and subsurface waters. High metals concentrations in soil and vegetation exists around the mine site. Fertiliser plant by-products are also sources of fluoride and sulphate in groundwater and soils.

Programs to address environmental concerns were initiated in the late 1960s and focused on reduction of waste discharge directly to watercourses and reclamation of waste disposal areas on land. A research program was initiated in 1972 to develop revegetation technology to return waste disposal sites and disturbed land to productive rangeland. In 1979, Teck commissioned the DWTP to treat collected acidic waters from the mine, tailings decant water from the concentrator and seepage water collected downgradient of the tailings and gypsum ponds.

The DWTP is a high-density sludge treatment process that uses lime to neutralise acidic water and precipitate heavy metals in the form of hydroxides in an iron sludge. The effluent from the plant is discharged into the St. Mary River, and the sludge is retained in a holding pond. The treatment plant is highly effective, lowering total metal concentrations in influent by over 98% prior to discharge. The DWTP treatment plant operates under an effluent permit from the BC Ministry of Environment.

![Figure 3](image-url)  
**Figure 3** Drainage water treatment plant located on the St. Mary River

### 2.3 Environmental assessment and groundwater modelling

Although site investigations were undertaken during mine operation, large-scale environmental assessment in the form of comprehensive soil, groundwater, surface water and sediment investigations commenced in the early 1990s, approximately coinciding with closure. Based on these investigations, a hydrogeological and geochemical conceptual model was developed to allow predictions of post-closure groundwater and surface water concentrations. A risk assessment for human and ecological (terrestrial and aquatic) receptors (HHERA) was completed, which included biota collection and analyses.

Surface water and groundwater flow patterns in the area have been shaped by till/bedrock topography caused by large permeability differences between till/bedrock and other, more permeable surficial deposits. The majority of groundwater flow occurs through sand and gravel deposits within and above the till and generally follows buried sub-basins defined by the till/bedrock topography. Groundwater flow in the mine area is generally divided into four discrete drainages that discharge into three different creeks. In some areas, such as the LMY, significant heterogeneity in proximate source materials has required detailed investigation to obtain an adequate understanding of local conditions. For the mill site and surrounding area, extensive characterisation and delineation of the bedrock/till topography identified eight distinct groundwater flow paths that ultimately discharge to the St. Mary River (Figure 2).

At the mill site, groundwater travel times to receiving water bodies are relatively long; thus, geochemical modelling was undertaken to predict geochemical evolution of ARD-impacted groundwater along flow paths 2, 4 and 6. The model predicted it would take between 150 to 480 years to consume the carbonate aquifer buffering capacity between the waste impoundments from the mill site and the St. Mary River, the main
downgradient aquatic receiving body (Humphries et al., 2011). Results from the modelling were used to predict future concentrations of parameters of concern that may affect aquatic receptors in support of the HHERA, as well as to provide a broad timeframe for the prioritisation and implementation of mitigation measures. The draft RMP, described below, was based on the HHERA.

2.4 Closure

The Decommissioning and Closure plan was finalised and approved in 2001. General closure activities included building demolition, remediation of hydrocarbon contaminated soils, removal of hazardous materials, filling of the open pit, closure of landfills, and revegetation of the site. The mine openings were closed and sealed, and mine subsidence areas were fenced to prevent public and wildlife access. Signage and fencing were installed to prevent trespassing.

A major aspect of site decommissioning and closure was to minimise the amount of water contacting mine waste and to protect groundwater and surface watercourses. As such, soil cover systems and water interception measures were installed. The soil covers at the site include an engineered complex cover for the tailings waste impoundments and a simple soil cover for the waste dumps and plant sites. The engineered soil cover system for the tailings waste impoundments was designed based on nearly two decades of research and investigation using locally available materials at sites representative of those to be reclaimed (Gardiner et al., 1997). In total, 1,000 hectares of mine-disturbed areas were reclaimed.

Teck developed a long-term water management strategy at both the former mine and the former mill sites to reduce downgradient loading of contaminants associated with historical activities and comply with applicable regulations. The strategy consists of a variety of mitigation measures, a number of which include hydraulic interception for treatment at the DWTP. The hydraulic interception measures were installed based on the comprehensive environmental assessment work conducted and generally include deep groundwater aquifer wells and a network of trenches and ditches with associated sumps and pumps installed to intercept shallow groundwater. The trenches and ditches are typically keyed into a low permeability feature (i.e. till/bedrock) downgradient of the source areas. An example of the construction and final trench in the James Creek catchment is shown in Figure 4.

![Figure 4 Construction (left) and completion (right) of the diversion trench keyed into till in the James Creek catchment](image)

Approximately 24 km of pipeline and 30 aquifer pumps collect contaminated seepage water. The seepage water is stored in a large surface water reservoir referred to as the ARD pond, which has enough capacity to allow the DWTP to operate biannual campaigns. An underground mine dewatering system was also
constructed to store and collect ARD water generated from the mine workings. This water is also treated on a biannual basis. The DWTP will continue to operate as required.

3 Risk management plan development

3.1 Regulatory setting

In 1991, at the request of the BC Ministry of Energy and Mines, Teck developed a comprehensive decommissioning and closure plan and presented it to a public forum for review. The review participants, forming the Sullivan Public Liaison Committee (SPLC), included government agencies, local union representatives, city councillors, members of the public and the local environmental society.

Based on the requirements of the Mines Act, the closure plan focused on the effects of ARD from waste rock dumps and waste impoundments. The BC Environmental Management Act defines the mine workings and waste areas as “core” areas and other areas, including industrial facilities and ancillary operations such as maintenance shops and mills, as “non-core” areas. Independent environmental studies for the demolition of buildings and remediation of non-core areas were initiated in 1995. As the studies progressed, it became clear that the potential impacts of metals as a result of mining and non-mining activities also needed to be investigated (Higgins et al., 2004). To adequately determine whether post-closure conditions were acceptable and properly managed in the long term, Teck adopted a risk assessment/risk management approach. This approach was taken in consultation with regulators and the SPLC, as the Sullivan mine was the first in BC to use a risk assessment approach for closure. The risk assessment process began in 2001 and was concurrent with the final reclamation phases of the site. The reclamation permit was amended in 2004 with endorsement from regulators and the SPLC; one of the conditions was approval of an environmental risk assessment by the BC Ministry of Environment. The draft risk assessment and RMP were submitted in 2005/2006.

Since submittal of the draft risk assessment and RMP, there have been a number of changes in regulatory policy and therefore regulatory end points (goalposts) that have affected ongoing management. For example, an added protocol in the BC Contaminated Sites Regulation (CSR) resulted in the need to consider protection of groundwater for future drinking water purposes in areas with no current or planned use. The new protocol resulted in ongoing consultation with the BC Ministry of Environment as to how to manage areas where drinking water standards may be exceeded. In addition, risk assessment techniques and therefore policies have also advanced since submittal; associated CSR requirements include new methods for the application of land use standards and evaluation of terrestrial receptors, changes to technical guidance related to site investigation and aquatic assessment (including addition of new methods of assessment), and changes to numerical toxicity reference values (TRVs).

3.2 Risk management plan

The RMP is the primary tool used to guide the long-term environmental management of the site. The purpose of the RMP is twofold: (1) to ensure that future activities do not pose unacceptable risks to persons spending time at the site or to the environment, and (2) to monitor and manage environmental conditions at the site. The first was achieved by establishing a framework for action that will be taken should certain “triggers” for surface water quality, groundwater quality, vegetation performance and receiving environment testing be exceeded. The second purpose was achieved by linking the RMP to requirements of the Sullivan reclamation permit issued under the BC Mines Act.

The RMP for water quality is generally structured around the protection of aquatic life based on results from the HHERA. The hydrogeological and geochemical conceptual model identified different timeframes for aquatic life exposure; as such, the RMP is structured differently for groundwater intrinsically linked to receiving water bodies. For groundwater in site 1, flow paths 7 and 8 at site 2 and receiving water bodies at both sites, the triggers are based on numerical criteria developed from regulatory criteria and/or risk-based benchmarks established in the HHERA. For groundwater in site 2, where contaminant migration is expected
to occur over longer timeframes, the RMP is designed to track the evolution of groundwater quality and obtain the information needed to plan further mitigative action and/or obtain the data needed to demonstrate that breakthrough is unlikely.

The RMP is ongoing and is managed by Teck. The RMP is a result of requirements for closure and involves a component of regulator consultation. However, the BC Ministry of Environment has not officially approved the RMP because at the time it was submitted, the process fell outside of the Ministry’s typical administrative procedures and the risk assessment was not finalised. Additional discussion is presented in Section 4.

3.2.1 Monitoring programs

The monitoring program at Sullivan includes 69 groundwater sites, 18 surface water sites, benthos monitoring sites and a number of vegetation sites as part of the RMP. As can be expected on a site with a number of sizable contaminant sources spread over a large mountainous area with complex geology, hydrogeology and hydrology, trends at these monitoring stations vary based on the preferential groundwater flow paths. However, water quality improvements from mitigation measures have been observed at a number of locations and are consistent with the hydrogeological and geochemical conceptual models established during the site characterisation work (Humphries et al., 2011).

3.2.2 Triggers for action

The triggers are based on the hydrogeological and geochemical conceptual site model and HHERA developed for the site and differ depending on the timeframe in which groundwater will potentially impact receiving water. For site 1, flow paths 7 and 8 at site 2, and receiving water, the surface and groundwater quality triggers are based on exceedances of regulatory standards, maximum concentrations within five years and/or rising trends over three years, which would trigger additional investigation or corrective action. For groundwater in site 2, the trigger for mitigative action or additional studies is based on regular review of historical trends every six years. As the site 2 dataset accumulates, it will be continually evaluated as detailed in the RMP, and incremental assessment and/or mitigative action will be taken to achieve risk-based objectives. These monitoring plans, trigger and actions are shown graphically in Figure 5.
Figure 5  Simplified flow charts depicting general monitoring plans, triggers and actions

4  Post-closure adaptive management and lessons learned

The Sullivan mine will require perpetual monitoring and maintenance related to the existing sources at the site and operation of the DWTP. Since closure, the RMP and related ongoing management have had to take an adaptive approach to address both changes in regulatory policy and triggers for action from monitoring; these are described below.

4.1  Adapting to policy changes

As described in Section 3, a number of changes in regulatory policy have occurred that were neither anticipated nor incorporated into the RMP. This has created a need for further consultation with the BC
Ministry of Environment and additional assessment requirements outside of the RMP, and may ultimately have implications for the RMP. The evolution of guidance and regulations over the span of a decade post-closure has highlighted the need for an adaptive approach to generate certainty in end points (goalposts), and allow for improved timing of regulatory approvals, resource allocation and planning.

4.2 Monitoring results and RMP actions triggered

Surface and groundwater monitoring have occurred across the site for decades, allowing for trends in water quality to be measured before, during and after the closure process. Groundwater concentrations of key contaminants (i.e. sulphate and dissolved metals) at several sampling stations downgradient from site 1 sources, such as the No. 1 Shaft waste dump and the open pit waste dump, have been decreasing over time. Concentrations in receiving environments downgradient of these sources, including Lois Creek, have also exhibited decreasing trends supporting the water quality improvement predictions associated with the mitigation and closure activities. Groundwater and surface monitoring results from locations in the LMY intended to assess potential impacts related to the north and south waste dumps also indicate improving quality and confirm interception system performance; however, in recent years, concentrations of elevated zinc and other indicator parameters have been identified in Mark Creek and have triggered further assessment beyond the routine RMP monitoring, as discussed further below.

At site 2, monitoring results also support the predicted improvements in many areas, including reductions in water levels in source areas attributed to water diversion and cover systems, and improved chemistry in select groundwater and receiving water monitoring locations. In locations where improvements are not expected (e.g. some source areas), chemistry and hydrogeological conditions are compared to modelling predictions to assess potential requirements for supplemental mitigation as necessary.

4.2.1 Actions triggered

In recent years, RMP action levels have been triggered in some locations, and incremental assessment and mitigation have been required. Action level triggers were reached in Mark Creek surface water at the LMY, where acidic seepage high in metals from shallow groundwater discharges was detected in the creek. This discovery occurred through visual observations rather than by analysing quantitative results from RMP monitoring and comparison to trigger concentrations. The seepage was discovered in an area where sand drains were installed to direct shallow groundwater to the deeper aquifer for hydraulic interception and treatment during periods of higher groundwater levels. Since the sand drains were installed, there have been changes upslope of the waste dump, including the clearing of large forested areas for residential and ski hill development, which may have resulted in additional groundwater inputs above the waste dump. Changes to surface and groundwater flow regimes, along with different patterns of precipitation and temperature (key factors identified as contributing to seepage), were conditions not anticipated during mitigation planning and are outside of Teck’s control. Additional investigation was triggered by the seepage discovery and included implementation of benthic invertebrate and surface water monitoring programs outlined in the RMP.

Detailed groundwater investigations were initiated alongside weekly surface water monitoring to gain further understanding of the seepage mechanisms and seasonal groundwater/surface patterns and interactions, and to identify long-term solutions. Results from the investigations were used to identify and trigger implementation of interim mitigation measures, including a series of shallow collection wells and dewatering pumps to capture the groundwater, while a longer-term solution is being developed. Results of the investigation work were used to refine the RMP monitoring program, which has been adapted to assess new areas of concern and the effectiveness of temporary mitigation features. The RMP monitoring program revisions have included the addition of new sample collection points in the creek and for groundwater, as well as incorporating visual inspections of the creek and monitoring pump operation to maximise performance.

Action levels were also reached in deeper groundwater in the LMY, which trigged additional sampling and geochemical review of historical and recent groundwater conditions. Monitoring programs have been adapted to include more detailed review of select areas of the LMY ahead of planned comprehensive review.
in the RMP. Additional mitigation is not considered necessary, as the trigger levels in groundwater are attributed to variability in flow rather than a factor requiring further mitigation at this time. No receiving water monitoring locations in groundwater discharge areas have exhibited changes in quality that would require additional deeper groundwater mitigation.

4.2.2 Additional actions triggered
Additional mitigation actions unrelated to RMP triggers are based on desire to enhance environmental performance and reduce uncertainty and risk for the long term. In general, the seepage collection pumps and associated collection infrastructure have been well maintained, and long-time employees and contractors have a good working knowledge of the systems. This results in a consistent approach to management of the systems and opportunities to preserve infrastructure; however, supplemental actions have been implemented for continual improvement and to address gaps in the systems. These initiatives have included developing an updated site-wide water balance for post-closure conditions, improving monitoring instrumentation, enhancing seepage collection maintenance programs and a variety of supplemental investigation and mitigation activities to improve water collection and treatment efficiency. Water quality and general site conditions continue to evolve; as such, diligence and regular review of operational and RMP activities are required to ensure appropriate assessment and mitigation activities, and an early warning system to detect potential issues, are in place. Similarly, as water quality is improving in many areas, reductions in RMP monitoring efforts and frequency in these locations will be warranted and will be proposed during RMP update processes. In addition to non-climate-related conditions, potential effects related to climate change must be considered; these pose challenges based on the uncertainty of how, and to what extent, conditions will change in the future.

4.3 Lessons learned
More than a decade of post-closure experience has provided valuable insight for future management of the Sullivan. Following are several key lessons learned through closure.

- **Build adaptive plans for the long-term**
  Where long-term monitoring and risk management is required, management plans should incorporate adaptive features that clearly outline how change will be handled. This includes processes for identifying when and why updates might be required, how updates will be managed, who will be responsible for executing and reviewing changes to the plan, and what performance indicators could be managed to assess adequacy of change. Where plans include monitoring and maintenance activities, triggers for action and for reducing monitoring requirements should be clearly outlined to ensure programs are representative and sensible for the long term. In addition, triggers may require regular review and adjustment to ensure adequate management of risks. Site managers should be flexible and expect to change the plan as lessons are learned and conditions change.

- **Confirm goalposts wherever possible**
  As regulation and protocol for closure-related activities can change over the course of closure processes, there is potential to have to repeat or update work and documentation to meet current requirements. Wherever possible and reasonable, the regulatory/environmental requirements (i.e. the goalposts for the work) should be confirmed with and accepted by appropriate agencies. This may also include less formal agreements on various approaches, where confirming an understanding of regulatory acceptance is warranted to ensure disruptions such as changes in personnel or changes in regulatory oversight are managed practically.

- **Anticipate and prepare for changes**
  Conditions at any given site, as well as in the surrounding area, will change over time and can include positive change (e.g. realisation of predicted improvements in water quality) and negative change (e.g. changes at neighbouring sites with adverse affects for the site). Conditions may also not appear as they seem, and
complexity and heterogeneity pose additional challenges for managing large sites that cover a wide area with variable climatic, geological and ecological conditions. Managers should anticipate potential changes during closure planning, including worst-case scenarios, and consider how these may be managed or even avoided if consequences are negative. Site managers planning for change benefit from a combination of creativity, technical knowledge and experience at the site and in the surrounding area.

- **Consistent maintenance is required to preserve infrastructure and ensure efficiency**

A solid understanding of site infrastructure and a robust, well informed maintenance program will help ensure infrastructure performance and durability over the long term, and help maintain operational costs. At the Sullivan mine, the consistency related to long-term employees and contractors intimately familiar with the site infrastructure was beneficial leading up to closure and has continued to be so.

- **Visual inspections detect issues**

Visual observations made by site personnel and contractors have identified issues at the Sullivan mine that warranted further investigation and/or implementation of corrective measures. Some issues might not have been detected through routine monitoring based on their scale, or because the location is not monitored as part of the RMP or other site monitoring. Issues have been detected through observations made by long-term employees; less experienced or less attentive employees might not have identified a potential problem. An alert and experienced eye can help identify and address issues in a timely manner, and, in general, visual inspections are relatively easy and inexpensive.

- **Improve continuously**

Site knowledge will build over the course of mine operation and through closure, and both minor and major adjustments will be identified that can benefit the site, and site managers, for the long term. New perspectives, new information, new technologies and lessons learned will become available through any post-closure period. This provides great opportunity for continual improvement, and site managers should take advantage of these lessons wherever possible to enhance environmental, regulatory and financial performance.

## 5 Conclusions

The “mighty” Sullivan mine in Kimberley, BC, operated for almost 100 years and was one of the world’s largest producers of lead, zinc and silver. Environmental and risk management controls were initiated in the 1960s to address ARD issues associated with large impoundments of tailings, waste rock, other process wastes and underground mine workings, and included construction of the world’s first high-density sludge water treatment plant. The Sullivan mine officially closed in 2001, and comprehensive site investigation and risk assessment results were used to develop an adaptive site-wide RMP that outlines long-term monitoring requirements for groundwater, surface water, vegetation and aquatic biota, with triggers for incremental assessment and mitigation as necessary. Stakeholders involved with closure planning included the SPLC, government agencies, local union representatives, city councillors, the public, and the local environmental society.

An important aspect of risk management at the Sullivan mine is Teck’s long-term water management strategy, which includes a wide array of hydraulic interception and storage features to reduce loadings of contaminants from the mine and mill sites. Since closure, predicted improvements in groundwater and surface water quality have been realised; however, RMP action levels have been triggered in some locations, and incremental assessment and mitigation have been required. Action has also been triggered as a result of visual observations and monitoring activities outside of the RMP. Changes in site conditions, as well as changes in surrounding land use and climate, have posed challenges for site management and have required adjustments to the RMP. Other challenges have been administrative, resulting from a closure process spanning more than a decade and changes to regulatory policies and mine closure requirements during this time. These evolving physical and administrative conditions, combined with variations in weather and watershed land use, have reinforced the need for closure plans to include appropriate post-closure
monitoring, anticipate the potential need to revisit assumptions made during closure planning and set trigger levels for investigating the need for adjustments to risk management processes. Lessons learned through the post-closure process include the importance of building an adaptive plan, confirming regulatory expectations and anticipating and preparing for changes; the benefits of a consistent maintenance program and experienced staff; and the importance of making visual inspections and taking advantage of opportunities for continual improvement.

References

