Teck Metals Ltd.

Pinchi Mine Lake Tailings Storage Facility

2022 Annual Facility Performance Review

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October 2022

October 4, 2022

Teck Metals Ltd.
Kimberley Operations
Bag 2000
Kimberley, British Columbia
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Michelle Unger
Mine Manager

Dear Ms. Unger:

Pinchi Mine Lake Tailings Storage Facility
2022 Annual Facility Performance Review

We are pleased to submit the 2022 Annual Facility Performance Review of the Pinchi Lake Mine Tailings Storage Facility.

Please contact us if you have any questions regarding this report.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Daniel Klassen

Daniel Klassen, P.Eng.
Project Manager

DB/DK:jc

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2022 Annual Facility Performance Review

EXECUTIVE SUMMARY

This report presents the 2022 Annual Facility Performance Review for Teck Metals Ltd.'s (Teck) Pinchi Lake Mine Tailings Storage Facility (TSF) by Klohn Crippen Berger Ltd. (KCB). This report was prepared to fulfill the requirements of a Dam Safety Inspection (DSI) in the Health, Safety and Reclamation Code for Mines in British Columbia (HSRC) (MEM 2016, EMLI 2021). It is also an essential document per the Global Industry Standard on Tailings Management (GISTM) which was released in August 2020. The annual inspection of the TSF facilities was conducted in July 2022 by the Engineer of Record, Daniel Klassen of KCB. Routine inspections were carried out in November 2021 and May 2022 by the Site Surveillance Officer, Mark Pokorski of EcoFor.

This summary section is provided in accordance with the HSRC, and Teck's "Guideline for Tailings and Water Retaining Structures" (Teck 2019).

Summary of Facility Description

Pinchi Lake Mine has been closed since 1975. Teck completed the reclamation/closure works for the TSF in 2011. The TSF and associated water management infrastructure include the following:

- An earthfill tailings embankment: 3 m to 15 m high, approximately 1300 m long.
- A tailings impoundment containing approximately one million cubic metres of tailings. The impoundment is a dry facility with glacial till cover and vegetation on the tailings surface. There is no storage of water in the impoundment.
- A free-flowing, riprap lined open channel Closure Spillway.
- The Ed Creek Diversion Channel, which diverts Ed Creek away from the TSF.

Summary of Key Hazards

KCB understands that Teck's long-term goal for all tailings facilities, where physically possible, is to reach landform status with all potential failure modes that could result in catastrophic release of tailings and/or water being reduced to non-credible. The long-term goal for the Pinchi TSF is to reduce the risk of all potential catastrophic failure modes to be non-credible based on Extreme consequence loading conditions.

Teck, with support from KCB, conducted a credible catastrophic failure mode assessment in April 2022. The assessment considered the three key failure modes for tailings facilities identified in the ICMM Good Practice Guide (ICMM 2021): overtopping, internal erosion and piping, and slope instability. Teck's definition of a "catastrophic" failure is one with a risk to life safety or irreversible impact to a rare or valued ecosystem, social, or cultural heritage element. The conclusion from the assessment was that there are no credible "catastrophic" failure scenarios for the Pinchi TSF based on the available information and current understanding of the site. This conclusion has been submitted for review and finalization by Teck.

A summary of the current conditions is provided below to describe the safeguards that are in place and the justification that these failure modes are well-managed for the Pinchi TSF.

Overtopping:

- There is no permanent pond in the TSF, and the Closure Spillway is designed to convey flood flows passively without developing a large pond in the TSF. A hydrotechnical review of the Closure Spillway found that the freeboard in the TSF during the 1/3 between 1000-year and PMF event is over 4 m (KCB 2022d). The spillway and freeboard are effective controls to manage overtopping risks.

Internal Erosion and Piping:

- The embankment includes three fill zones: local silt-clay and glacial till borrow material, a rockfill zone on the downstream slope, and a transition material between the silt-clay/glacial till and the rockfill. The filter adequacy was reviewed previously, and it was found that the as-built information is insufficient to assess the filter compatibility of these materials (KCB 2015b). However, the majority of the embankment is composed of clayey material with plasticity index greater than 7, which is not susceptible to internal erosion (Fell et al. 2008), and the clayey zone is wide enough that it would not sustain a crack where piping could develop. In addition, there is no water stored in the TSF to generate a gradient or flow to propagate internal erosion to the point of failure if initiated. Based on these considerations, a piping failure of the TSF is considered not credible.

Slope Instability:

- The stability assessment was recently updated based on a revised geological and geotechnical site characterization including some additional laboratory testing (KCB 2022b). The assessment concluded that the TSF meets industry standard factor of safety criteria, consistent with the good performance of the facility since closure in 1975. The condition of the embankment is generally more favourable for stability now than it was during operations due to the draining of the pond and trimming of the embankment crest in some areas. Survey monuments on the embankment crest have not shown ongoing movements.
- The TSF is located in a region of low seismic activity. Simplified deformation analyses were performed as part of the stability assessment (KCB 2022b) and the predicted deformations for the 10,000-year ground motions are less than 0.3 m, which indicates that the embankment and the TSF are expected to perform well under seismic loading.
- The potential for toe erosion to affect embankment stability has been considered, and there are controls in place to address this. Ed Creek Diversion Channel was designed to convey the 1000-year flood event without erosion damage, but gradual weathering and breakage of the riprap has reduced its capacity. A 100 m section of the channel is approximately 10 m from the TSF Embankment, and damage to the riprap during an extreme flood event could initiate gradual erosion of the channel towards the embankment. This is addressed through surveillance and maintenance, and erosion would not be allowed to progress to the point where it could undermine the toe of the embankment. Options for remediating the channel are also being investigated, including replacing the riprap and possibly realigning the channel away from the TSF.

Potential Consequence of Failure

Teck provided the following statement regarding the consequence classification of the facility:

> *Teck are aligned with the most conservative interpretation of the Global Industry Standard on Tailings Management (GISTM) which, in turn, is consistent with their safety culture. Commensurately, Teck has advised that consequence classification is not a part of their tailings management governance and has asked that it not be reported in this AFPR. Instead, Teck will adopt the extreme consequence case design loading for any facility with a credible catastrophic flow failure mode. For facilities without a credible failure mode in terms of a life safety issue, Teck will reduce credible risks to As Low As Reasonably Practicable (ALARP). This consequence case applies for both earthquake and flood scenarios for all tailings facilities, consistent with the GISTM. Adopting this approach meets or exceeds any regulatory requirements, aligns with Teck's goal to eliminate risk for loss of life, and is consistent with the GISTM. This approach is consistent with industry-leading best practices and has an added benefit of providing accurate narratives to communities about the safety of tailings facilities that could impact them and who share Teck's approach of one life is one too many to be at risk. (personal communication, Mar. 14, 2022)*

Evaluations of the Pinchi TSF under extreme loading have been completed and they concluded that the facility can withstand extreme earthquake and flood events without release of tailings, though the spillway may require repairs after passing an extreme flood.

Summary of Key Observations and Significant Changes

There has been no construction or any other significant changes to the TSF or associated water management infrastructure since the 2010/2011 closure works were completed.

There are six vibrating wire piezometers at three locations around the embankment and fourteen survey monuments. Piezometers are read twice per year, and survey monuments were previously measured every ten years, but have since been replaced by InSAR. There were no significant changes in the piezometer readings in 2022, and the quantifiable performance objectives (QPOs) were met. Piezometer readings show seasonal fluctuations between spring and summer/fall. Survey monuments were last read in December 2016, and the readings were below the alert criteria and did not show ongoing movements. There is normally no storage of water in the TSF and no instrumentation for water level or flow monitoring. Based on the TSF performance to date, the instrumentation and reading frequency are considered sufficient for ongoing monitoring of the facility under current conditions (KCB 2022a).

Overall, the TSF Embankment is in good condition with no significant changes observed since 2021, which indicates no changes to stability. A stability assessment of the TSF was performed in 2022, which concluded that the facility meets industry standard static and seismic stability design criteria (KCB 2022b).

OMS Manual and EPRP

The OMS Manual and the Emergency Preparedness and Response Plan (EPRP) for the Pinchi Lake Mine TSF were revised in 2021 and 2020 (Teck 2021, 2020). The EPRP for the TSF is incorporated into the site-wide Mine Emergency Response Plan (MERP). These documents are reviewed annually and updated as needed.

Dam Safety Review

A Dam Safety Review (DSR) of the Pinchi Lake Mine TSF and associated water infrastructure was performed by SRK in 2018 (SRK 2020). There was appropriate engagement and input from the Engineer of Record. The HSRC (MEM 2016, EMLI 2021) requires that all tailings storage facilities undergo a DSR every 5 years at minimum; to comply with the HSRC, the next DSR should be carried out not later than 2023.

Summary of Recommendations

No new issues related to TSF safety were identified during the 2022 AFPR, so there are no new recommendations. Ongoing deficiencies and recommendations from previous years are summarized in the following table. Aligned with the noted good condition of the facility and no observed or computed stability concerns, none of the issues are high priorities. The levels of priority assigned to each item in the table are based on priority ratings developed by Teck (and consistent with HSRC) as follows:

- Priority 1 A high probability or actual TSF safety issue considered immediately dangerous to life, health or the environment, or a significant risk of regulatory enforcement.
- Priority 2 If not corrected could likely result in TSF safety issues leading to injury, environmental impact or significant regulatory enforcement; or a repetitive deficiency that demonstrates a systematic breakdown of procedures.
- Priority 3 Single occurrences of deficiencies or non-conformances that alone would not be expected to result in TSF safety issues.
- Priority 4 Best Management Practice as a suggestion for continuous improvement towards industry best practices that could further reduce potential risks.

As shown in the table, none of the issues are expected to result in a TSF safety issue and are therefore considered “best practice” issues rather than urgent, TSF safety items.

Table ES-1 Summary of Deficiencies and Recommendations

Structure	ID No.	Deficiency or Non-Conformance	Applicable Regulation or OMS Reference	Recommended Action	Priority	Recommended Deadline/Status
Previous Recommendations Ongoing						
TSF	2020-01	The TSF breach assessment performed in 2012 did not assess the credibility of the failure modes considered.	HSRC	A failure modes evaluation should be completed to determine whether there are any credible failure modes, and if so, would they result in uncontrolled release of tailings and water.	3	CLOSED – Evaluation completed and results under review.
Ed Creek Diversion Channel	2020-02	The riprap along the Ed Creek Diversion Channel is undersized and is deteriorating due to weathering	OMS Manual	Select one or two preferred options for upgrading/replacing the existing Ed Creek Diversion Channel that will be advanced to a feasibility level design.	3	In progress – Site investigation planned for Q3 2023 to explore realignment options.
TSF	2020-03	The OMS Manual includes a superseded version of the EPRP as an appendix.	HSRC	The OMS Manual should be updated to reference the Mine Emergency Response Plan.	3	CLOSED – Updated OMS was issued in November 2021.
TSF	2021-01	A small beaver dam (0.8 m high) was observed in the ditch that runs parallel to the toe of the east leg of the TSF Embankment.	OMS Manual	Remove beaver dam from the toe of the east leg of the TSF Embankment to discourage beaver activity in the area.	4	In progress – Beaver dam removal planned for Q3 2022.
TSF	2021-02	Some survey monuments appear to have been removed.	OMS Manual	Check the condition of the survey monuments to confirm which ones are still active.	4	CLOSED – Monitoring of movements will use InSAR (initial results received and are under review), so survey monuments are no longer required.
2022 Recommendations						
No new recommendations						

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CLARIFICATIONS REGARDING THIS REPORT

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the exclusive use of Teck Metals Ltd. (Client) for the specific application to the Pinchi Lake Mine project, and it may not be relied upon by any other party without KCB's written consent.

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1 INTRODUCTION

1.1 Purpose, Scope of Work and Methodology

This report presents the 2022 Annual Facility Performance Review (AFPR) for Teck Metals Ltd.'s Pinchi Lake Mine Tailings Storage Facility (TSF) by Klohn Crippen Berger Ltd. (KCB). This report was prepared to fulfill the requirements of a Dam Safety Inspection (DSI) in the Health, Safety and Reclamation Code for Mines in British Columbia (HSRC) (MEM 2016, EMLI 2021). It is also an essential document per the Global Industry Standard on Tailings Management (GISTM) which was released in August 2020. The following activities were undertaken by KCB:

- Site inspection by Daniel Klassen, P.Eng. (the Engineer of Record) on July 5, 2022 (accompanied by Jason McBain, P.Eng., of Teck).
- Review and update of the list of outstanding recommendations from the previous annual performance reports.
- Review instrumentation and confirm that readings are within acceptable limits.

The inspection was conducted, and this report prepared, in accordance with the Teck Guideline for Tailings and Water Retaining Structures (Teck 2019).

The AFPR is issued before the end of the calendar year, so the period considered for climate data and instrumentation is from September 2021 to August 2022.

1.2 Regulatory Requirements

This inspection report addresses the performance of the TSF and associated water management infrastructure in accordance with the HSRC and the Permit Amendment Approving Closure Plan (Permit No. M-5) dated July 12, 2010.

1.3 Roles and Responsibilities

The HSRC describes and defines responsibilities for several key roles for a TSF (MEM 2016). For Pinchi TSF the following personnel fill these roles:

- Mine Manager: Ms. Michelle Unger of Teck;
- Responsible Tailings Facility Engineer (RTFE) (equivalent to the TSF Qualified Person role defined in the HSRC): Mr. Jason McBain, P.Eng., of Teck; and
- Engineer of Record (EOR): Mr. Daniel Klassen, P.Eng., of KCB.

1.4 Facility Description

The Pinchi Lake Mine is located in central British Columbia on the northern shore of Pinchi Lake approximately 25 km northwest of Fort St. James and 75 km northwest of Vanderhoof. Pinchi Lake is long (23 km) and narrow (ranging from approximately 1000 m to 3250 m wide) and lies at an elevation of approximately 720 metres above sea level (masl). At the mine site, Pinchi Lake is only 1250 m wide. The terrain near the mine site is heavily wooded with rolling hills and generally less than 300 m of relief, although some hills rise to over 1000 masl.

The mine was originally commissioned in the 1940s and operated from 1940 to 1944 during the Second World War. The mine was closed until 1968, when it re-opened and operated from 1968 to 1975. The property was placed on care and maintenance in 1975. Teck substantially completed the mine reclamation and closure works from 2010 to 2012.

A mine site plan and the general arrangement of the TSF are presented in Figures 1.1 and 1.2, respectively. Cross-sections of the TSF Embankment, based on 2012 topography, are shown in Figure 1.3.

The Pinchi Lake Mine TSF was constructed in 1967 and utilized between 1967 and 1975. The TSF is a side-hill impoundment covering approximately 24 ha and contained on three sides by an embankment. Approximately one million cubic metres of tailings are stored in the TSF. The TSF Embankment is approximately 1300 m long, and 3 m to 15 m high. The original embankment was designed and constructed in the late 1960s and was raised in 1975 as shown in the historical drawing presented in Appendix IV. The embankment was originally a homogeneous embankment constructed with local glacial till and upstream slopes of 2.0H:1V near the crest and 2.5H:1V elsewhere, and downstream slopes of 2.0H:1V near the crest and 3.0H:1V elsewhere. When the embankment was raised in 1975, a zone of rockfill was placed on the downstream slope with a transition zone between the glacial till and the rockfill.

Ed Creek originally flowed through the impoundment area as shown in the drawing in Appendix IV (labelled as “Main Creek” and “Ed Main Creek” in the drawing). The creek was diverted to Pinchi Lake via the Ed Creek Diversion Channel, which was constructed on the east side of the TSF (see Figure 1.2).

Water management for the TSF, prior to the implementation of the reclamation/closure works in 2010, comprised a low level decant system supplemented by an open channel Emergency Spillway. The decant box and spillway were located near the west abutment of the TSF Embankment as shown in the drawing in Appendix IV. The decant box and the Emergency Spillway are labelled in the drawing as “new water collection box” and “overflow ditch”, respectively. The decant system and the Emergency Spillway were decommissioned and a Closure Spillway was constructed as part of the closure works completed by Teck in 2010 and 2011.

A facility data sheet that summarizes key information for the TSF is presented in Appendix I.

1.5 Background Information and History

1.5.1 General

The design and construction history, from start-up to closure, is summarized below.

1.5.2 Pre-2010 Construction

The design/construction chronology was as follows:

- 1967 engineering of the facility (Stage 1) by Ripley, Klohn and Leonoff;
- 1967 construction with inspection by Kootenay Engineering and Tara Engineering Laboratories conducting fill placement quality control;
- 1971 inspection letter from Cominco Civil Designer noting settlement (approximately 2 ft) and resulting loss of freeboard - remedial measures were suggested;
- 1974 engineering report by Golder Associates for a 10 ft embankment raise (Stage 2);
- 1975 letter by Golder Associates approving design drawings for a reduced embankment raise of 5 ft;
- 1975 construction of the 5 ft raise;
- 2000 stabilization and rehabilitation of the Ed Creek Diversion Channel;
- 2001 rehabilitation of the Ed Creek Diversion Channel as the riprap and fish habitat were eroded by a large flood wave that resulted from a series of beaver dam failures; and
- 2001 Emergency Spillway excavation to increase flow capacity.

1.5.3 2010 and 2011 Reclamation/Closure Works

The following reclamation/closure works for the TSF were completed by Teck in 2010 and 2011:

- drained the water from the Tailings Impoundment;
- abandoned the Emergency Spillway;
- abandoned the decant system and backfilled the concrete decant inlet box with soil;
- placed and seeded soil cover over the tailings in the TSF;
- trimmed the crest of the western leg of the TSF Embankment for use as cover material for the tailings; and
- constructed the TSF Closure Spillway.

In addition to trimming the TSF embankment crest for the 2010/2011 closure works, Teck developed three borrow areas adjacent to the TSF as a source of cover material for the tailings (see Figure 1.2): Borrow Area A is located downstream of the south leg of the TSF Embankment; and, Borrow Areas B and C are located upstream of the TSF.

The Closure Spillway is located in the area of the former supernatant pond. The spillway invert is set such that water would not be stored in the Tailings Impoundment under normal conditions. Draining of the water from the impoundment and constructing the spillway has converted the TSF into a “dry” facility.

2 SITE ACTIVITIES – FALL 2021 TO SUMMER 2022

The TSF is a closed facility and does not require operational intervention. Scheduled and event driven inspections and maintenance work are carried out on an as-required basis. Requirements for routine inspection and monitoring, and trigger levels for inspection following an extreme event are presented in the Operation, Maintenance and Surveillance (OMS) Manual (Teck 2021).

The Site Surveillance Officer, Mr. Mark Pokorski, carries out inspections of the facility twice per year: one in the spring after freshet, and one in the fall. The 2021 fall inspection was carried out on November 12, 2021, and the 2022 spring inspection was carried out on May 6, 2022. These inspections did not identify any TSF safety issues.

An annual inspection of the TSF is conducted by the Engineer of Record; this inspection occurred on July 5, 2022.

Clearing of vegetation in Ed Creek Diversion Channel was performed in summer/fall 2021.

Water quality sampling was performed on the discharge from the TSF weekly between March 28 and April 25, 2022.

Apart from these routine monitoring and maintenance activities, there were no other site activities over the last year.

3 CLIMATE DATA AND WATER BALANCE DURING 2022

3.1 Climate Data

There is no climate station at the mine site; however, temperature and precipitation data for Fort St. James (Environment Canada climate station no. 1092975, located approximately 25 km southeast of the mine) were reviewed. Table 3.1 compares the recorded monthly temperatures and precipitation from September 1, 2021 to August 31, 2022 with the station's temperature and precipitation normals for 1981 to 2010. The records of temperature and total precipitation (i.e., rainfall + snowfall) from this station are fairly complete, but separate measurements of rain and snow are not available at this or any other nearby stations with recent data. The records show that temperatures and precipitation during the reporting period were generally similar to average conditions.

Table 3.1 Fort St. James (No. 1092975) Temperatures and Precipitation – September 2021 to August 2022 vs. Normal Values

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Year
1981-2010 Normals													
Temperature													
Daily Average (°C)	10.2	4.3	-3.0	-7.8	-9.5	-6.8	-1.8	3.9	9.2	13.4	15.4	14.8	3.5
Daily Maximum (°C)	16.4	9.0	0.6	-3.8	-5.3	-1.7	4.0	9.9	15.6	19.6	21.8	21.7	9.0
Daily Minimum (°C)	3.9	-0.5	-6.5	-11.7	-13.7	-11.8	-7.7	-2.2	2.8	7.2	8.9	7.9	-2.0
Precipitation													
Rainfall (mm)	39.1	38.7	15.7	4.2	4.9	3.6	5.9	18.0	38.2	50.6	50.6	45.0	314.5
Snowfall (cm)	0.2	9.5	28.8	38.4	43.3	26.4	19.8	5.7	0.7	0.0	0.0	0.0	172.7
Precipitation (mm)	39.3	48.1	44.5	42.6	48.1	30.0	25.7	23.7	38.9	50.6	50.6	45.0	487.2
September 2021 – August 2022													
Temperature													
Daily Average (°C)	11.4	4.3	1.0	-14.0	-8.0	-3.2	1.9	2.4	8.1	14.3	17.3	17.9	4.4
Daily Maximum (°C)	16.5	8.9	4.6	-10.0	-3.6	1.1	6.9	7.9	13.3	20.1	22.9	24.3	9.3
Daily Minimum (°C)	6.2	-0.2	-2.6	-17.9	-12.5	-7.5	-3.0	-3.0	2.9	8.5	11.7	11.4	-0.6
Precipitation													
Rainfall (mm)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Snowfall (cm)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Precipitation (mm)	55.2	26.0	38.7	27.2	66.0	18.0	9.5	14.7	32.7	57.1	27.2	49.6	421.9
No. of days of missing data	0	0	0	0	0	0	0	0	0	0	0	3	3

3.2 Water Balance

The HSRC (MEM 2016, EMLI 2021) calls for a water balance review in the annual inspection report. Since the Pinchi Lake Mine TSF is a dry facility, there is no storage of water in the Tailings Impoundment and stormwater inflows are passively released from the impoundment via the Closure Spillway. Based on observations, there has been no indication of water ponding behind the spillway, except in small local depressions in the tailings cover. Because inflow to the impoundment is limited to direct precipitation and stormwater runoff from small catchments upslope of the TSF, an annual water balance review is deemed to be unnecessary. However, a water balance was prepared in 2021 based on average precipitation and temperature from 1998 to 2020 at Fort St. James (Environment Canada climate station no. 1092970 and no. 1092975). Any gaps in data were filled in with data from other nearby Environment Canada climate stations. The water balance is included in Appendix V; the average discharge through the spillway was estimated to be 0.6 L/s.

3.3 Water Quality

The surface water quality discharging from the TSF is monitored annually under effluent permit PE-224. The groundwater quality at Pinchi Lake Mine is monitored under the Contaminated Sites Regulation (B.C. Reg. 375/96). Both surface and groundwater quality are reported by Teck to B.C. Ministry of Environment and B.C. Ministry of Energy, Mines & Petroleum Resources.

4 SITE OBSERVATIONS – JULY 2022

4.1 Visual Inspection

The following areas were inspected during the July 5, 2022 site visit:

- Tailings Storage Facility:
  - Tailings Impoundment (drained and covered with soil);
  - TSF Embankment; and
  - Closure Spillway.
- Borrow Area A Slope;
- Ed Creek:
  - Ed Creek Diversion Channel; and
  - Ed Creek culverts under Pinchi Lake Road.

Weather during the site visit was partly cloudy with sun, brief light showers, and about 20°C. No rain was recorded in Fort St. James on the day of the site visit or in the previous 6 days.

Site observations and recommendations are presented in the following sub-sections and observation locations are identified in Figure 4.1. Selected photographs taken during the inspection are presented in Appendix II, and inspection forms are presented in Appendix III.

4.1.1 Tailings Storage Facility

Tailings Impoundment

- The Tailings Impoundment was observed from the embankment crest, and by walking a path across the soil cover between the east side and the south side of the TSF.
- There was minimal standing water in the Tailings Impoundment at the time of inspection. No water was observed at the entrance to the Closure Spillway (see Photo II-19 in Appendix II). Small, local ponds about 5 cm deep were encountered on the cover (see Photo II-2). There is a drainage channel on the cover that directs flow from east to west towards the Closure Spillway, and there was standing water in the channel in some locations, but no flow was observed (see Photo II-3).
- The soil cover on the tailings is covered in grass (Photos II-1 to II-3, II-8, and II-10). No signs of erosion, large ponds, or deformation of the cover were observed.

TSF Embankment

- The embankment crest, and upstream and downstream slopes of the TSF Embankment appeared to be in good condition (Photos II-4 to II-17).

- No cracks were observed on the embankment crest. Longitudinal cracks were previously observed on the crest of the southwest leg of the TSF Embankment in 2015, 2017, 2018, and 2019, but these were not visible at the time of the inspection (and not observed in the fall 2021 or spring 2022 inspections). The cracks are likely surficial features related to drying of the embankment crest surface and are not a TSF safety concern.
- The embankment slopes were covered with grasses and small shrubs. The most significant vegetation was observed on the downstream slope of the east leg, near the northeast corner of the TSF, where many bushes are higher than 2 m (see Photo II-4). The southwest and east legs have a few plants higher than 1.5 m but most of the vegetation is much shorter than that (see Photos II-13 to II-17). This does not present an immediate concern for embankment safety but note that the vegetation management plan recommends clearing vegetation higher than 1.5 m from the embankment slopes (Spectrum 2017).
- A pond was observed in the trees near the toe of the east leg of the TSF Embankment (see Figure 1.2 for location; Photo II-5) as in previous inspections. This pond is located near a drainage channel that was shown on historical drawings of the TSF (see Appendix IV) and labelled "runoff channel." The channel ran parallel to the main Ed Creek channel, and apparently once joined up with Ed Creek just inside the TSF. The pond appears to collect local runoff, and it drains through a channel to the south and through a culvert into Ed Creek Diversion Channel. The pond level was slightly higher than was observed during inspections prior to 2021 due to the beaver dam noted below.
- A small beaver dam (0.8 m high) was observed in the channel south of the pond described above (see Location 5 in Figure 4.1, Photo II-44). Although this beaver dam is not currently an embankment safety issue, removal is recommended to discourage beaver activity in the area, and there is an open recommendation (2021-01) to remove it. The spring routine inspection (EcoFor 2022) notes the presence of a second smaller beaver dam about 20 m downstream in the same channel, but the vegetation in the channel at the time of the AFPR site visit was too dense to observe the second beaver dam. Based on the coordinates provided in the spring inspection, the second beaver dam should be located within the vegetation shown in Photo II-43.
- Apart from the pond noted above, the ground at the downstream toe of the embankment was dry and no ponded water or seepage were observed.

Closure Spillway

- There was no flow or standing water in the Closure Spillway channel; there was a 30 cm deep pond at the downstream end of the riprap (Photo II-23).
- The riprap along the entire Closure Spillway channel appeared to be in good condition (Photos II-18 to II-22). The spillway has likely not experienced any high flood discharges since it was constructed. Vegetation growth in the channel was minimal, with only a few small shrubs (Photo II-22).

- The Outlet Channel was observed at the culvert crossing on the road adjacent to the Emergency Spills Lagoon (Photos II-24 to II-26). New flow stations (each including a staff gauge and an ABS riser pipe with level logger inside) have been installed near the culvert inlet and outlet. The culvert inlet was wet but there was no flow into the culvert, and the staff gauge was obscured by vegetation so could not be read. There is local ponding but no flow at the culvert outlet, with a depth of 14 cm measured at the outlet and the staff gauge also reading 14 cm. The middle reach upstream of the culvert and the lower reach downstream of the culvert are both filled with vegetation reaching over 2 m height, and there is vegetation directly in front of the culvert inlet. The Outlet Channel and culvert are not related to TSF safety but clearing of the vegetation may be prudent to reduce the need for maintenance and repairs to the channel and the road after a large storm event. The vegetation management plan (Spectrum 2017) recommends clearing the vegetation in the outlet channel every 2 years or prior to the vegetation exceeding 1.5 m height.

4.1.2 Borrow Area A Slope

- Borrow Area A is located near the south leg of the TSF Embankment. The slope, which is about 10 m downstream of the toe, appeared to be in good condition (Photos II-27, II-28 and II-30).
- Cracks were observed on the slope from 2013 to 2017 (Location 1 in Figure4.1) and 2020 (Location 2 in Figure 4.1). Measurements of crack movements were taken from 2015 to 2018 using metal rods installed on either side of the cracks (Photo II-28), but these measurements showed no ongoing movements and were discontinued in 2019. The cracks are no longer visible due to vegetation growth and are not a TSF safety concern. Nevertheless, this area will continue to be monitored during routine inspections as per the OMS Manual.
- The toe of the borrow area slope was generally dry, with one area of wet ground observed in the northeast corner (Location 3 in Figure 4.1; Photo II-29); similar wet areas have been observed since 2011, and they are believed to be associated with groundwater unrelated to the TSF.

4.1.3 Ed Creek

Ed Creek Diversion Channel

- Vegetation in Ed Creek Diversion Channel was cleared in 2021, but the grass in the base of the channel has since regrown to around 1.5 m height (Photo II-34).
- Previous AFPR reports have noted that the riprap along some areas of the Ed Creek Diversion Channel is weathering and breaking up (Photo II-36). The condition of the riprap appeared similar to previous inspections. Degradation of the riprap is discussed further in Section 5.4.
- The riprap along a small section of the channel (Location 4 in Figure 4.1; Photo II-35), where a depression had formed in the riprap surface, was replaced in 2014. This riprap appeared to be in good condition.

- The 460 mm diameter HDPE culvert on the north bank of the Ed Creek Diversion Channel had vegetation growing in front of the inlet (see Figure 1.2 for culvert location, and Photos II-41 and II-42). This is not a TSF safety concern. There was no flow in the culvert and the ditch upstream was dry.

Ed Creek Culverts Under Pinchi Lake Road

- There are two culverts on Ed Creek under Pinchi Lake Road approximately 300 m east of the mine gate (see Figure 1.2 for location and refer to Photos II-45 to II-48). Flow was observed in both culverts, with water depths of 5 cm at the east (left) culvert inlet and 2 cm at the west (right) culvert inlet.
- There was no vegetation immediately in front of the culvert inlets. However, bushes are growing within 0.5 m of the west (right) culvert inlet. This is not an immediate concern, but these bushes could be cleared as preventative maintenance during routine site vegetation clearing.

4.2 Instrumentation Review

4.2.1 Piezometers

There are six vibrating wire piezometers at three locations around the embankment (four piezometers at the toe, two at the crest) as shown in Figure 1.2; these piezometers are read twice per year at minimum. Quantifiable Performance Objectives (QPOs) for the piezometers are defined as threshold piezometric elevations, and these are given in Appendix VI. Based on the TSF performance to date, the piezometers and reading frequency are considered sufficient for ongoing monitoring of the facility under current conditions (KCB 2022a).

Piezometer readings taken in fall 2021 and spring 2022 are included in Table 4.1, and threshold values are shown for comparison. The readings are all below the threshold values. The readings show that the phreatic surface is 1 m to 3 m below ground at the toe of the embankment, and 9 m below the crest at the highest embankment section. Piezometer readings are shown as elevations versus time in Figure 4.2. The readings in the piezometers at the embankment toe (DH16-01-VWP1,2 and DH16-03-VWP1,2) show seasonal fluctuations up to 2 m, with higher readings in the spring and lower readings in the fall. The piezometers installed below the embankment crest (DH16-02-VWP1,2) have shown less variation in the readings after an initial period of stabilization following installation. The piezometers at the toe of the west leg (DH16-01-VWP1,2) showed an upward gradient of up to 0.2, while the other piezometers showed negligible gradients.

Prior to the 2010/2011 closure works, a piezometer located 10 m from DH16-02-VWP1,2 showed typical readings of around El. 733.5 m, which is 0.7 m higher than the May 6, 2022 reading. This suggests the piezometric levels in the embankment have gone down compared to the condition before the pond was drained.

Table 4.1 Fall 2021 and Spring 2022 Piezometer Readings

Piezometer ID	Piezometric Elevation (m)			Depth Below Ground (m)	
	Threshold Value	Nov. 12, 2021	May 6, 2022	Nov. 12, 2021	May 6, 2022
DH16-01-VWP1	736.1	733.3	735.1	2.8	1.0
DH16-01-VWP2	736.1	733.5	734.2	2.6	1.9
DH16-02-VWP1	738.5	732.5	732.6	9.5	9.4
DH16-02-VWP2	738.5	732.8	732.8	9.2	9.2
DH16-03-VWP1	737.0	735.1	735.2	2.8	2.7
DH16-03-VWP2	737.0	735.0	735.1	2.9	2.8

4.2.2 Flow and Water Level Measurements

Since there is no pond, there is no flow measurement or water level instrumentation at the TSF. Prior to decommissioning, flow from the decant system was measured. Since 2011, water is released through the Closure Spillway but, given that the spillway channel is lined with large riprap, most of the low flows pass through the riprap, making it difficult to measure flow.

4.2.3 Survey Monuments

Survey monuments were installed on the TSF Embankment crest in 1998; however, some monuments were destroyed over the years. New survey monuments were installed in June 2014. The locations of the 2014 monuments and the surviving 1998 monuments are shown in Figure 1.2. QPOs for the survey monuments are provided in Appendix VI.

Readings were last taken in December 2016, and the readings met the QPOs and did not show ongoing movements (KCB 2017).

Some survey monuments have been noted missing in recent years, and there is an outstanding recommendation (2021-02) to check the condition of the monuments to confirm which are still active. KCB understands that Teck intends to transition to monitoring movements with InSAR beginning later in 2022, so the survey monuments will become obsolete soon. In light of this, the recommendation about the survey monuments has been closed. Initial InSAR data was received in October 2022 and was under review at the time of writing.

5 TSF SAFETY ASSESSMENT

5.1 Dam Safety Review

A Dam Safety Review (DSR) of the Pinchi Lake Mine TSF and associated water infrastructure was performed by SRK in 2018 (SRK 2020). There was appropriate engagement and input from the Engineer of Record.

The HSRC (MEM 2016, EMLI 2021) requires that all tailings storage facilities undergo a DSR every 5 years at minimum. To comply with the HSRC, the next DSR should be carried no later than 2023.

5.2 Failure Modes Review

KCB understands that Teck's long-term goal for all tailings facilities, where physically possible, is to reach landform status with all potential failure modes that could result in catastrophic release of tailings and/or water being reduced to non-credible. The long-term goal for the Pinchi TSF is to reduce the risk of all potential catastrophic failure modes to be non-credible based on Extreme consequence loading conditions.

Teck, with support from KCB, conducted a credible catastrophic failure mode assessment in April 2022. The assessment considered the three key failure modes for tailings facilities identified in the ICMM Good Practice Guide (ICMM 2021): overtopping, internal erosion and piping, and slope instability. Teck's definition of a "catastrophic" failure is one with a risk to life safety or irreversible impact to a rare or valued ecosystem, social, or cultural heritage element. The conclusion from the assessment was that there are no credible "catastrophic" failure scenarios for the Pinchi TSF based on the available information and current understanding of the site. This conclusion has been submitted for review and finalization by Teck.

A summary of the current conditions is provided below to describe the safeguards that are in place and the justification that these failure modes are well-managed for the Pinchi TSF.

Overtopping:

- There is no permanent pond in the TSF, and the Closure Spillway is designed to convey flood flows passively without developing a large pond in the TSF. A hydrotechnical review of the Closure Spillway found that the freeboard in the TSF during the 1/3 between 1000-year and PMF event is over 4 m (KCB 2022d). The spillway and freeboard are effective controls to manage overtopping risks.

Internal Erosion and Piping:

- The embankment includes three fill zones: local silt-clay and glacial till borrow material, a rockfill zone on the downstream slope, and a transition material between the silt-clay/glacial till and the rockfill. The filter adequacy was reviewed previously, and it was found that the as-built information is insufficient to assess the filter compatibility of these materials (KCB 2015b). However, the majority of the embankment is composed of clayey material with plasticity index greater than 7, which is not susceptible to internal erosion (Fell et al. 2008), and the clayey zone is wide enough that it would not sustain a crack where piping could develop. In addition, there is no water stored in the TSF to generate a gradient or flow to propagate internal erosion to the point of failure if initiated. Based on these considerations, a piping failure of the TSF is considered not credible.

Slope Instability:

- The stability assessment was recently updated based on a revised geological and geotechnical site characterization including some additional laboratory testing (KCB 2022b). The assessment concluded that the TSF meets industry standard factor of safety criteria, consistent with the good performance of the facility since closure in 1975. The condition of the embankment is generally more favourable for stability now than it was during operations due to the draining of the pond and trimming of the embankment crest in some areas. Survey monuments on the embankment crest have not shown ongoing movements (Section 4.2.3).
- The geological and geotechnical characterization of the TSF is summarized in the stability assessment (KCB 2022b). The key foundation unit is a lacustrine clay which was characterized based on drilling and laboratory testing, and appropriately conservative assumptions about the extent, thickness, and strength parameters were made for modelling this unit to account for uncertainty. The site characterization is believed to be sufficiently detailed for this facility. The stability assessment described above examined slip surfaces through the lacustrine clay and found that stability criteria were met.
- The TSF is located in a region of low seismic activity, and the estimated seismic ground motions are small, with a peak ground acceleration (PGA) of 0.09 g for the 10,000-year return period for Site Class B/C[1] (KCB 2020) and 0.14 g for Site Class D (KCB 2022b). Simplified deformation analyses were performed as part of the stability assessment (KCB 2022b) and the predicted deformations for the 10,000-year ground motions range from less than 0.1 m to 0.3 m, which indicates that the embankment and the TSF are expected to perform well under seismic loading. The strengths adopted in this assessment were reduced to account for potential liquefaction of the tailings and cyclic softening of the foundation clay.
- There are no significant erosion features on the crest or slopes of the embankment. Surface runoff from the impoundment drains towards the closure spillway and will not erode the embankment surface. The embankment surface is vegetated and well protected against surface erosion. The downstream slope of the embankment includes coarse rockfill, so any erosion channels that form would be self-armouring and unlikely to rapidly erode through the embankment.
- The potential for toe erosion to affect embankment stability has been considered, and there are controls in place to address this. Ed Creek Diversion Channel was designed to convey the 1000-year flood event without erosion damage, but gradual weathering and breakage of the riprap has reduced its capacity. A 100 m section of the channel is approximately 10 m from

[1] Site classes are as defined in Table 4.1.8.4-B of the National Building Code of Canada 2020

the TSF Embankment, and damage to the riprap during an extreme flood event could initiate gradual erosion of the channel towards the embankment. This is addressed through surveillance and maintenance, and erosion would not be allowed to progress to the point where it could undermine the toe of the embankment. Options for remediating the channel are also being investigated, including replacing the riprap and possibly realigning the channel away from the TSF.

5.3 Potential Consequence of Failure

Teck provided the following statement regarding the consequence classification of the facility:

> *Teck are aligned with the most conservative interpretation of the Global Industry Standard on Tailings Management (GISTM) which, in turn, is consistent with their safety culture. Commensurately, Teck has advised that consequence classification is not a part of their tailings management governance and has asked that it not be reported in this AFPR. Instead, Teck will adopt the extreme consequence case design loading for any facility with a credible catastrophic flow failure mode. For facilities without a credible failure mode in terms of a life safety issue, Teck will reduce credible risks to As Low As Reasonably Practicable (ALARP). This consequence case applies for both earthquake and flood scenarios for all tailings facilities, consistent with the GISTM. Adopting this approach meets or exceeds any regulatory requirements, aligns with Teck's goal to eliminate risk for loss of life, and is consistent with the GISTM. This approach is consistent with industry-leading best practices and has an added benefit of providing accurate narratives to communities about the safety of tailings facilities that could impact them and who share Teck's approach of one life is one too many to be at risk. (personal communication, Mar. 14, 2022)*

Evaluations of the Pinchi TSF under extreme loading have been completed, as described in Section 5.4. These evaluations concluded that the facility can withstand extreme earthquake and flood events without release of tailings, though the spillway may require repairs after passing an extreme flood.

5.4 Physical Performance

5.4.1 Geotechnical Performance

The embankment has performed adequately for over 40 years, and there is no record of slumping or instability since operations ceased in 1975. The closure works in 2010 and 2011 included changes that improved the stability of the embankment, including:

- draining the pond, resulting in a decrease in phreatic levels within the embankment (as discussed in Section 4.2.1); and
- trimming the crest of the west leg of the TSF Embankment, resulting in a reduction in driving forces for potential failure surfaces in that area.

Geological and geotechnical site characterization were completed by KCB, based on available drilling and laboratory testing data of the dam fills and the foundation materials, between 2016 and 2022, to inform an updated stability assessment (KCB 2022b). The assessment considered the 10,000-year earthquake ground motions for Passive Care Closure, in accordance with the GISTM. The results of the assessment show that the TSF meets industry standard factor of safety criteria for static and seismic loading, and the estimated seismic deformation from the 10,000-year earthquake ground motions is 0.3 m or less (which the embankment can accommodate) (KCB 2022b).

5.4.2 Hydrotechnical Performance

Closure Spillway

The Closure Spillway is a free-flowing riprap-lined open channel, which passively releases water from the TSF. There is no storage of water in the TSF. The spillway is lined with large riprap and non-flood flows pass through the riprap with very little, if any, flow over the riprap surface. To the best of our knowledge, the Closure Spillway has not been subjected to any large flood flows since it was constructed in 2010.

The Closure Spillway was designed to route the 24-hour 1000-year rainfall plus 100-year snowmelt event (KCB 2009), which was adequate to meet the CDA (2007) criteria. In 2022, KCB reassessed the capacity of the spillway against the GISTM Passive Care Closure criteria (10,000-year design event). However, CDA (2013) recommends against extrapolating flood statistics for return periods longer than 1,000 years, as the results can be unreliable. Therefore, a design flood event of 1/3 between the 1000-year event and the Probable Maximum Flood (PMF) was used in the assessment, which exceeds the estimated 10,000-year event.

The assessment concluded that the spillway can convey the higher design flows without overtopping, but the spillway channel riprap downstream of the embankment toe would likely be damaged in the process (KCB 2022d). An assessment of the potential erosion during this design flood event concluded that erosion initiated at the embankment toe would be very unlikely to progress past the dam centreline, and thus would not result in a release of tailings (KCB 2022d).

Ed Creek Diversion Channel

Ed Creek Diversion Channel was designed to convey the 1000-year flood event without erosion damage. The right bank of the channel near the TSF Embankment was also designed to contain the PMF with some erosion damage. Observations of the riprap since the original construction in 2000 have shown that the riprap is gradually weathering and breaking down. Test pits in 2014 confirmed that the in-place riprap is undersized compared to the original design (KCB 2015a). Observations show that the degradation of the riprap is happening slowly, and the channel could still convey large flood flows, though not to the level of the original design. There is the potential for an extreme flood event to initiate erosion of the channel. A 100 m section of the channel is located approximately 10 m from the TSF Embankment, and erosion in this area, if left unchecked, could eventually erode the glacial till soils in the right bank and undermine the embankment toe (KCB 2022c). The channel is inspected twice per year and after large precipitation events, so this risk is appropriately managed through surveillance and maintenance that are carried out as per the OMS Manual. However, a long-term solution is for Teck to re-establish erosion protection, as was first recommended in 2014. A site investigation is planned for 2023 to explore the possibility of realigning the diversion channel away from the TSF.

Vegetation Control

Vegetation should be cleared periodically from the water conveyance structures including the Closure Spillway, Ed Creek Diversion Channel, and ditches or they will not operate to design capacity. This is covered under the vegetation management plan (Spectrum 2017).

5.5 Operational Performance

The Pinchi Lake Mine TSF has been closed for about 45 years and, as indicated in Section 2, there are no operational requirements.

5.6 OMS Manual and EPRP Review

The OMS Manual and the Emergency Preparedness and Response Plan (EPRP) for the Pinchi Lake Mine TSF were revised in 2021 and 2020 (Teck 2021, 2020). The EPRP for the TSF is incorporated into the site-wide Mine Emergency Response Plan (MERP). These documents are reviewed annually and updated as needed.

6 CONCLUSIONS AND RECOMMENDATIONS

No new issues related to TSF safety were identified during the 2022 AFPR, so there are no new recommendations. Ongoing deficiencies and recommendations from previous years are summarized in Table 6.1. The priorities assigned to each item in Table 6.1 are based on priority ratings developed by Teck (and consistent with HSRC) as follows:

- Priority 1 A high probability or actual TSF safety issue considered immediately dangerous to life, health or the environment, or a significant risk of regulatory enforcement.
- Priority 2 If not corrected could likely result in TSF safety issues leading to injury, environmental impact or significant regulatory enforcement; or a repetitive deficiency that demonstrates a systematic breakdown of procedures.
- Priority 3 Single occurrences of deficiencies or non-conformances that alone would not be expected to result in TSF safety issues.
- Priority 4 Best Management Practice as a suggestion for continuous improvement towards industry best practices that could further reduce potential risks.

Notwithstanding the deteriorating riprap in the Ed Creek Diversion Channel, which has both an interim and longer-term remedial plan, the Pinchi Lake Mine TSF appears to be in good condition and there are no major concerns related to TSF safety.

Inspections were carried out in November 2021 and May 2022 by the Site Surveillance Officer, and in July 2022 by the Engineer of Record.

There were no threshold exceedances in the piezometers in 2022.

The riprap along the Ed Creek Diversion Channel is undersized and is gradually weathering and breaking down. This has reduced the capacity of the channel to convey large flood flows without erosion damage compared to the original design. Part of the channel is located approximately 10 m from the TSF Embankment, and erosion in this area, if left unchecked, could eventually erode the glacial till soils in the right bank and undermine the embankment toe. The channel is inspected twice per year and after large precipitation events, so this risk is appropriately managed through surveillance and maintenance that are carried out as per the OMS Manual.

Climate data from the nearest climate station from September 1, 2021 to August 31, 2022 showed that temperature and precipitation were generally similar to average conditions (based on 1981 to 2010 climate normals). Since the water balance is based on annual average climate data, there is no water storage in the TSF, and inflows are limited to direct precipitation and stormwater runoff from upslope, updating the water balance on an annual basis is deemed to be unnecessary.

The OMS Manual was updated by Teck in 2021 (Teck 2021). The EPRP is incorporated into the site-wide Mine Emergency Response Plan (MERP) (Teck 2020).

Table 6.1 Summary of Deficiencies and Recommendations

Structure	ID No.	Deficiency or Non-Conformance	Applicable Regulation or OMS Reference	Recommended Action	Priority	Recommended Deadline/Status
Previous Recommendations Ongoing						
TSF	2020-01	The TSF breach assessment performed in 2012 did not assess the credibility of the failure modes considered.	HSRC	A failure modes evaluation should be completed to determine whether there are any credible failure modes, and if so, would they result in uncontrolled release of tailings and water.	3	CLOSED – Evaluation completed and results under review.
Ed Creek Diversion Channel	2020-02	The riprap along the Ed Creek Diversion Channel is undersized and is deteriorating due to weathering	OMS Manual	Select one or two preferred options for upgrading/replacing the existing Ed Creek Diversion Channel that will be advanced to a feasibility level design.	3	In progress – Site investigation planned for Q3 2023 to explore realignment options.
TSF	2020-03	The OMS Manual includes a superseded version of the EPRP as an appendix.	HSRC	The OMS Manual should be updated to reference the Mine Emergency Response Plan.	3	CLOSED – Updated OMS was issued in November 2021.
TSF	2021-01	A small beaver dam (0.8 m high) was observed in the ditch that runs parallel to the toe of the east leg of the TSF Embankment.	OMS Manual	Remove beaver dam from the toe of the east leg of the TSF Embankment to discourage beaver activity in the area.	4	In progress – Beaver dam removal planned for Q3 2022.
TSF	2021-02	Some survey monuments appear to have been removed.	OMS Manual	Check the condition of the survey monuments to confirm which ones are still active.	4	CLOSED – Monitoring of movements will use InSAR (initial results received and are under review), so survey monuments are no longer required.
2022 Recommendations						
No new recommendations						

7 CLOSING

We thank you for the opportunity to work on this project. Should you have any questions, please contact the undersigned.

Yours truly,

KLOHN CRIPPEN BERGER LTD.
B.C. Permit to Practice No. 1000171

PROFESSIONAL
PROVINCE OF
D. R. KLASSEN
39699
BRITISH COLUMBIA
ENGINEER

Daniel Klassen Oct. 4, 2022

Daniel Klassen, P.Eng.
Geotechnical Engineer

DB/DK:db

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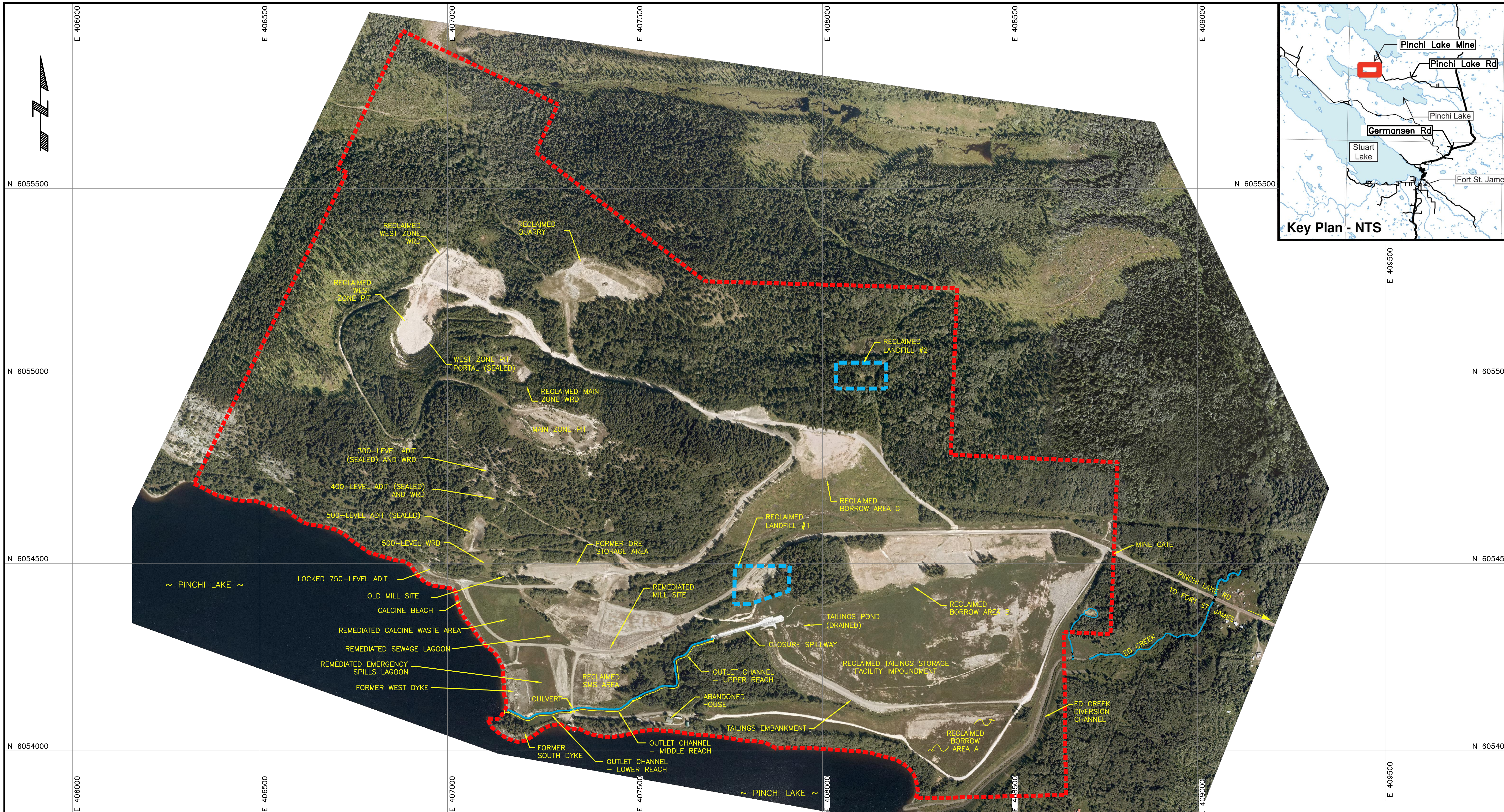
FIGURES



TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCTOBER 2022

LEGEND

PROPERTY BOUNDARY

WRD — WASTE ROCK DUMP

NOTES

1. ORTHOPHOTO IMAGE TAKEN IN 2013 (PROVIDED BY TECK).
2. COORDINATES ARE UTM ZONE 10, NAD83.

NOT FOR CONSTRUCTION

CLIENT: Teck

Klohn Crippen Berger

PROJECT: PINCHI LAKE MINE TSF 2022 ANNUAL FACILITY PERFORMANCE REVIEW

TITLE: MINE SITE PLAN

PROJECT No.: M07728 A38

FIG. No.: 1.1

KCB-R-MLB

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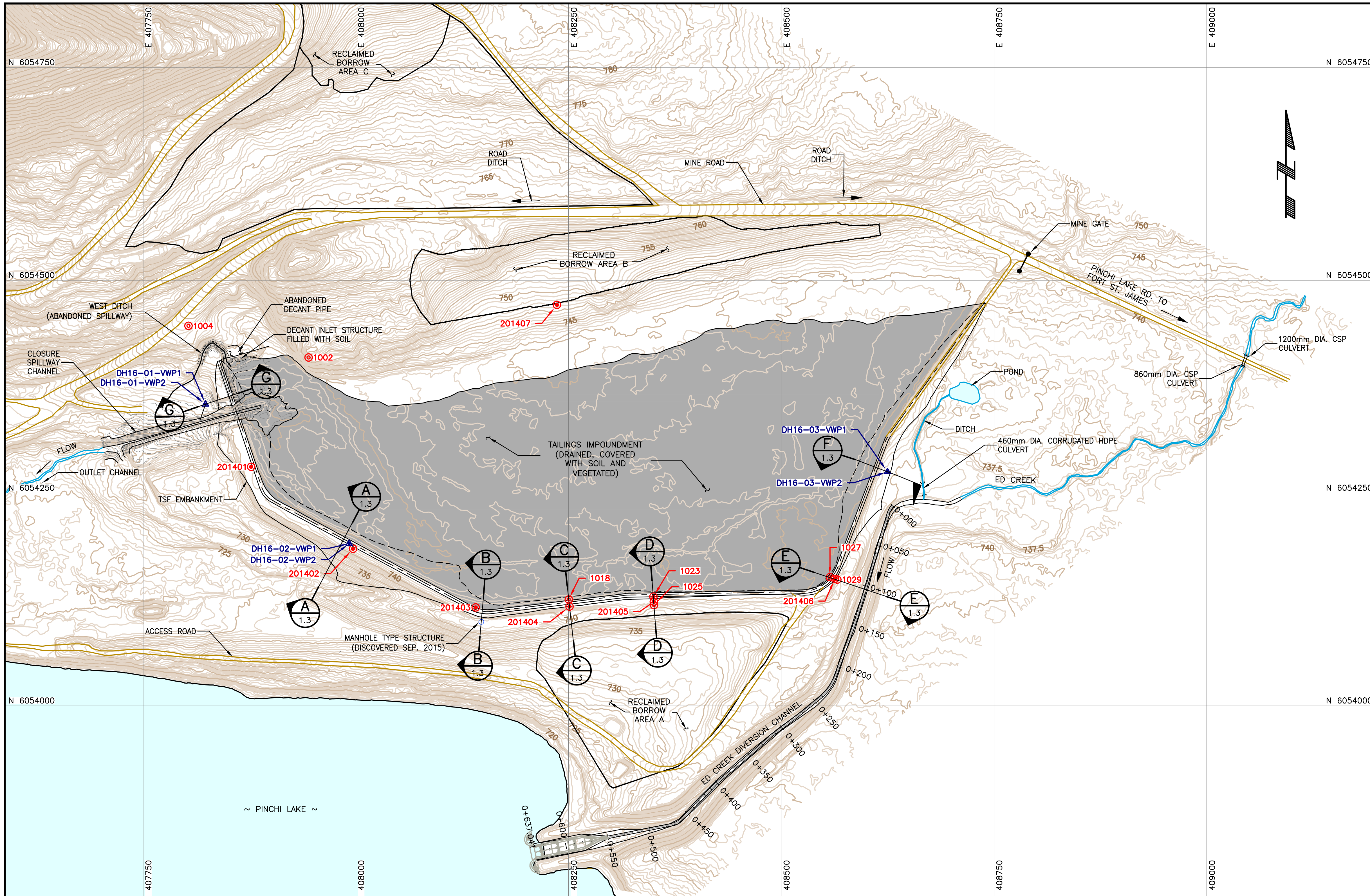

LEGEND

- 1998 SURVEY MONUMENT
- 2014 SURVEY MONUMENT
- 2016 VIBRATING WIRE PIEZOMETER

NOTES

1. GENERAL SITE TOPOGRAPHY IS BASED ON SEPTEMBER 2012 LIDAR SURVEY BY McELHANNEY ENGINEERING. TOPOGRAPHY FOR SPILLWAY CHANNEL IS BASED ON JUNE 2011 GROUND SURVEY.
2. COORDINATES ARE NAD83, UTM ZONE 10.

NOT FOR CONTRUCTION

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCTOBER 2022

SCALE 0 100 m

REFERENCE DRAWINGS:
CHAINAGE FOR ED CREEK DIVERSION CHANNEL IS FROM KLOHN CRIPPEN DWG No. D-6101.

CLIENT: Teck

Klohn Crippen Berger

PROJECT: PINCHI LAKE MINE TSF
2022 ANNUAL FACILITY PERFORMANCE REVIEW

TITLE: TAILINGS STORAGE FACILITY PLAN

PROJECT No.	FIG. No.
M07728 A38	1.2

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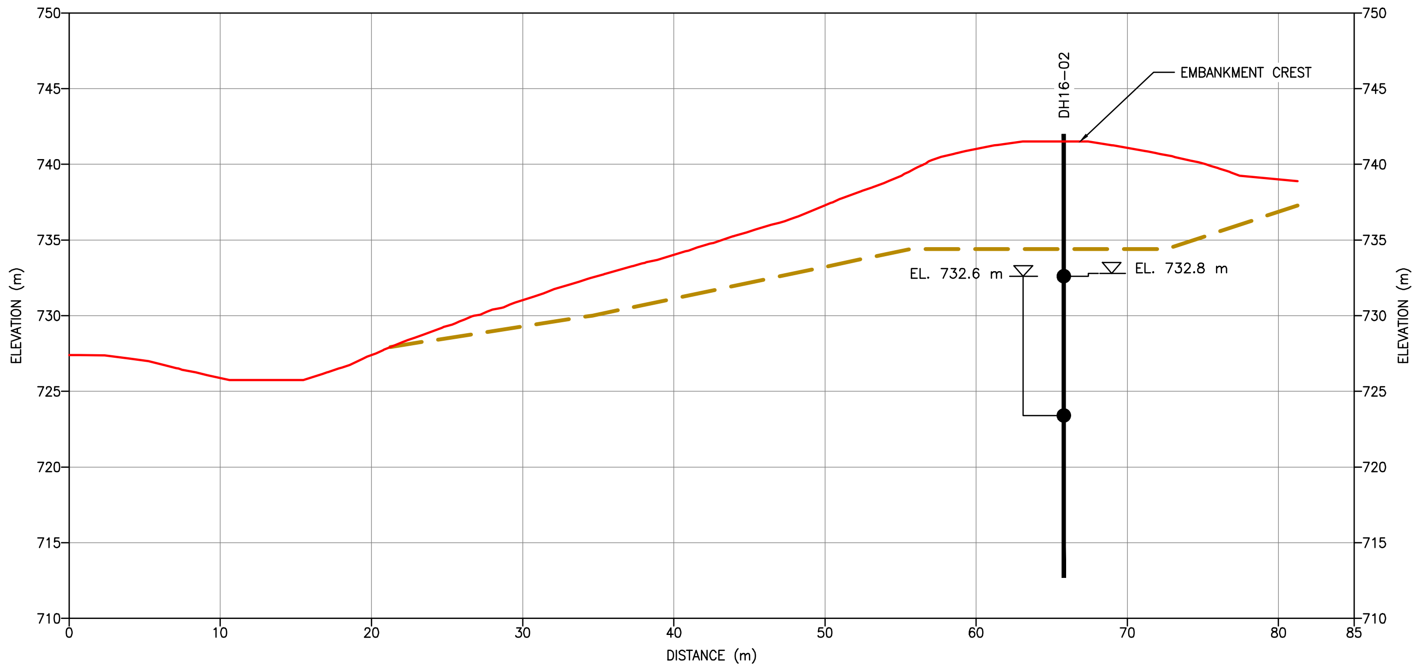
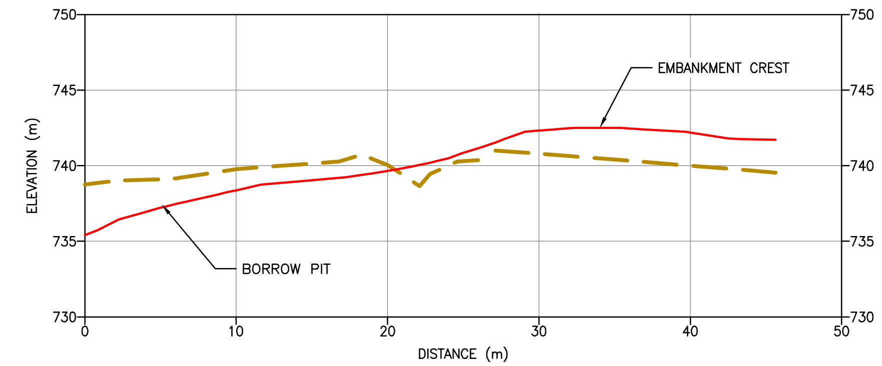
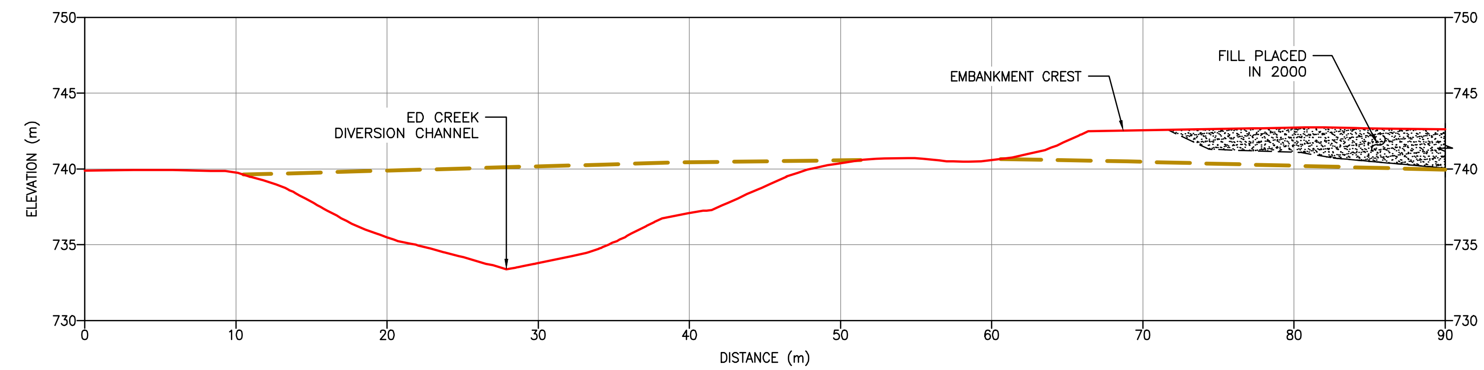


SECTION A 1.2



SECTION D 1.2

EMBANKMENT HEIGHT AND SLOPE			OVERALL SLOPE (NOTE 2)
SECTION	EMBANKMENT HEIGHT (m)	SLOPE OF D/S FACE	
A	14.0	2.7H:1V	2.7H:1V
B	2.5	2.7H:1V	2.4H:1V
C	1.8	2.3H:1V	4.5H:1V
D	1.5	2.0H:1V	4.3H:1V
E	1.8	4.3H:1V	4.3H:1V
F	4.7	1.9H:1V	1.9H:1V
G	4.0	2.9H:1V	2.9H:1V



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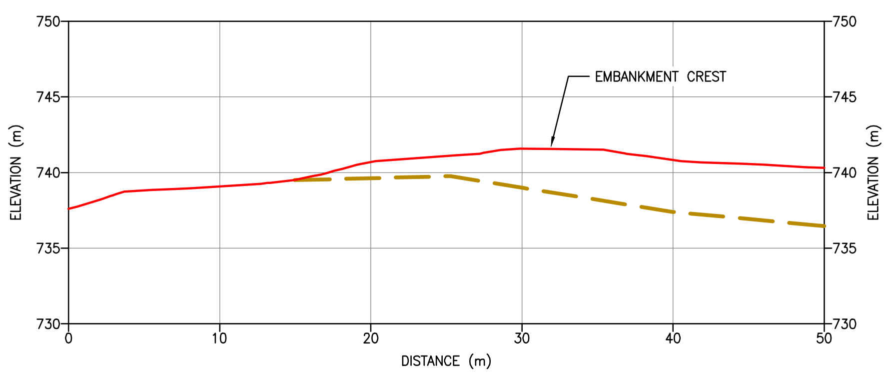

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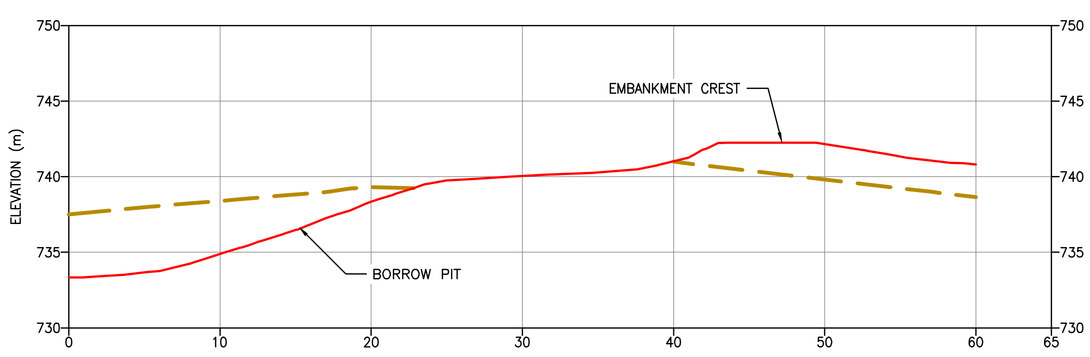
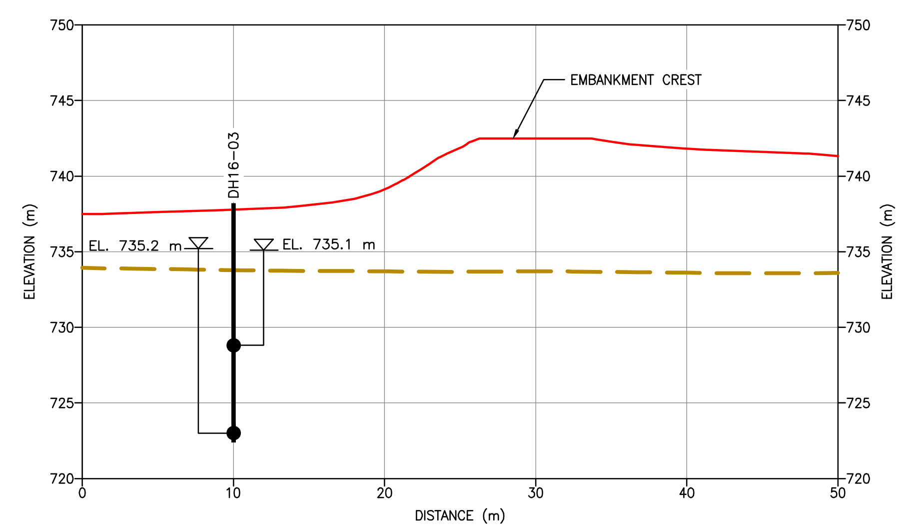
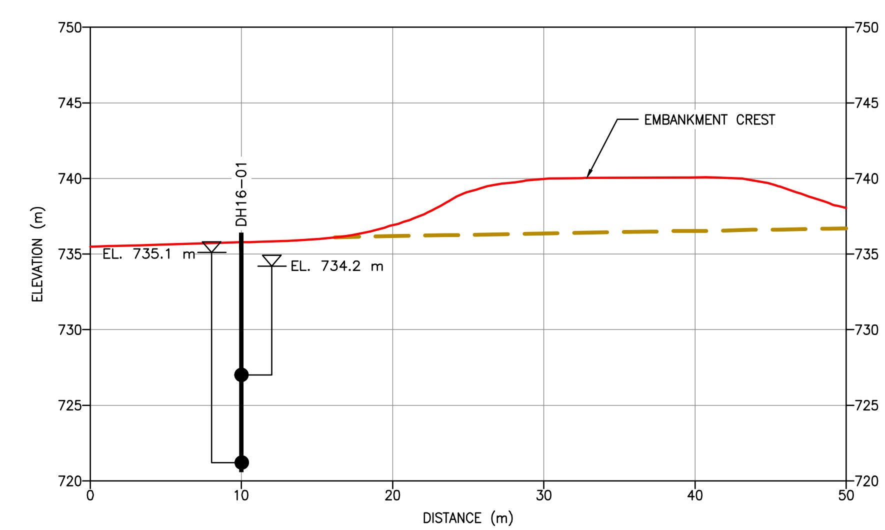


SECTION C 1.2



SECTION F 1.2



SECTION G 1.2

LEGEND:

- PIEZOMETER TIP/SCREEN
- 732.6 m MAY 06, 2022 READING (m)
- ORIGINAL GROUND SURFACE PRE-1967
- GROUND SURFACE AFTER 2010/11 RECLAMATION/CLOSURE WORKS (SEP. 2012 LIDAR SURVEY)

NOTES:

1. ORIGINAL GROUND SURFACE HAS BEEN EXTRACTED FROM DWG. PLM-D-3, REV.1 AND IS APPROXIMATE.
2. OVERALL SLOPE IS MEASURED FROM DOWNSTREAM EDGE OF EMBANKMENT CREST TO TOE OF NATURAL GROUND SLOPE (SECTIONS A, B, F AND G), TOE OF BORROW PIT SLOPE (SECTIONS C AND D) OR BASE OF ED CREEK DIVERSION CHANNEL (SECTION E).

NOT FOR CONSTRUCTION

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED OCTOBER 2022

SCALE 0 10 m

CLIENT: Teck

Klohn Crippen Berger

PROJECT: PINCHI LAKE MINE TSF 2022 ANNUAL FACILITY PERFORMANCE REVIEW

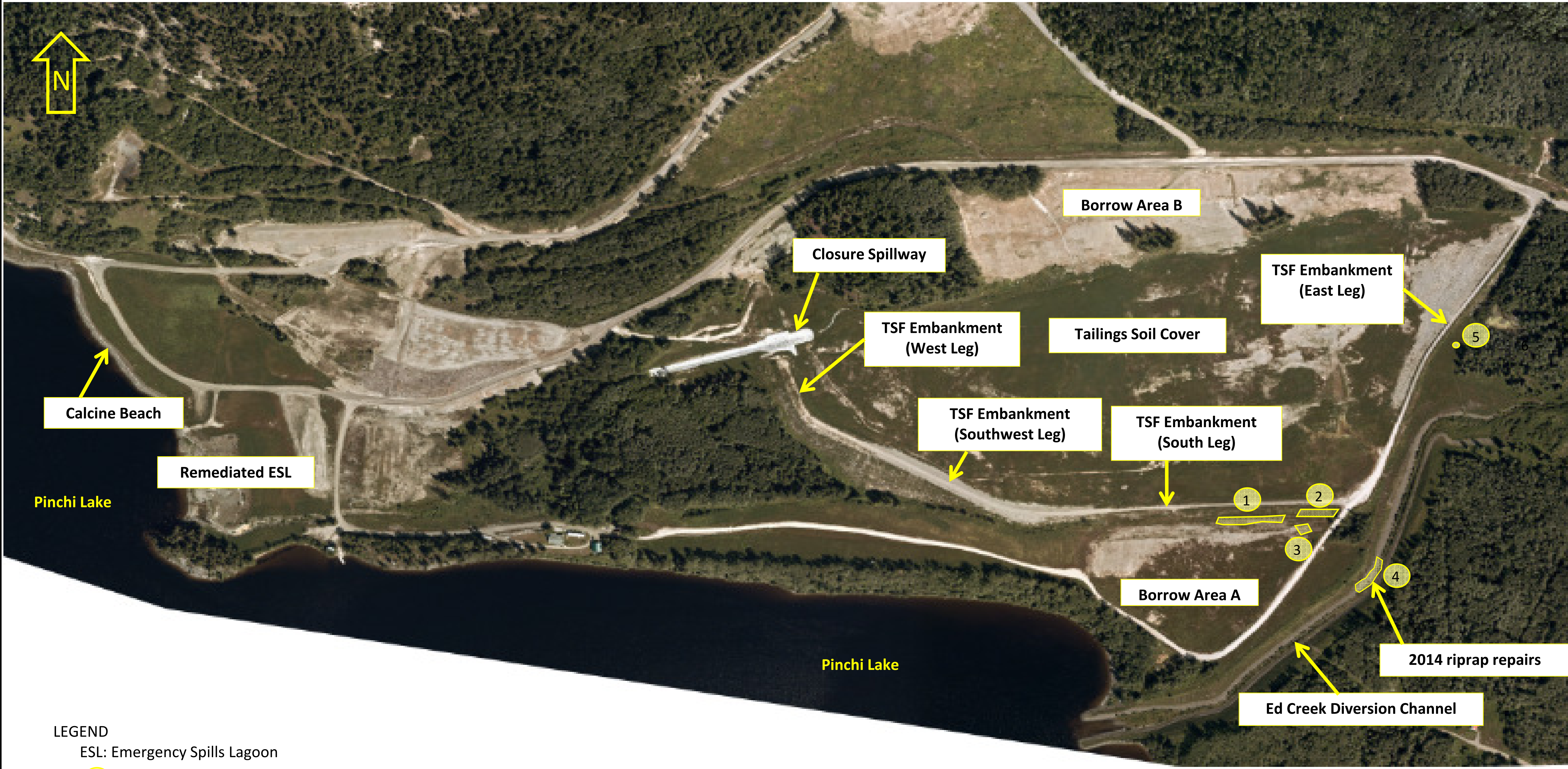
TITLE: TAILINGS STORAGE FACILITY EMBANKMENT CROSS SECTIONS

PROJECT No. M07728 A38

FIG. No. 1.3

KCB-R-MLB

Time: 13:45:13
Date: 10/3/2022
Scale: 1:2.5849(PS)
Drawing File: Z:\M\VCR\M07728A38-TML-Pinchi Lake 2022 Services\400 Drawings\CAD\05-FIGURES\2022 Annual Facility Performance Review\Fig1.3 - Sections.dwg (dhu)
Xref File(s):
Image File(s): Teckcominco-color-logo



LEGEND

ESL: Emergency Spills Lagoon

3 Observation Location

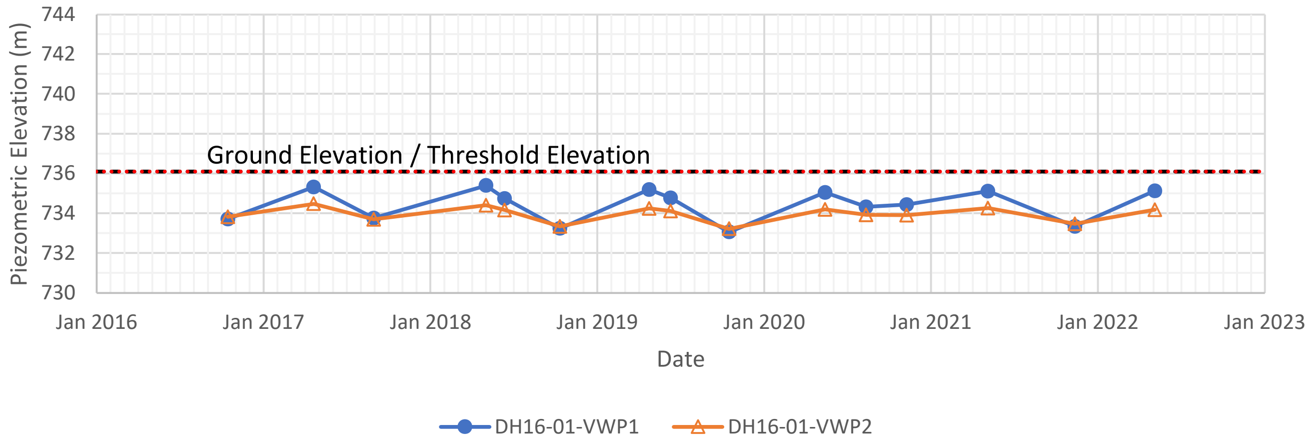
Not to Scale

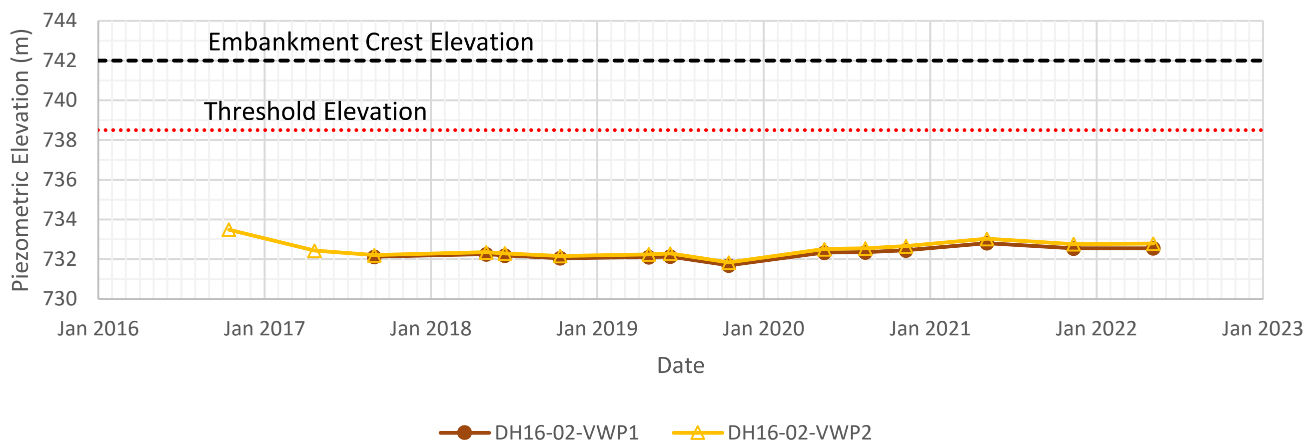
NOTES:

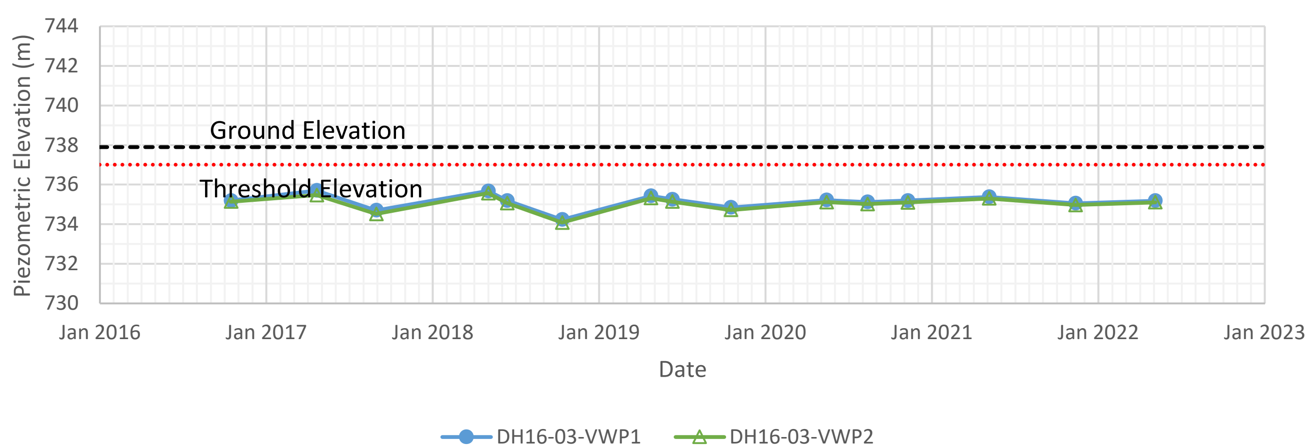
1. All Locations shown are approximate.

TO BE READ WITH KCB REPORT DATED: OCTOBER 2022

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC, AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT, AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS, OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.	CLIENT Teck Klohn Crippen Berger	PROJECT PINCHI LAKE MINE TSF 2022 ANNUAL FACILITY PERFORMANCE REVIEW TITLE JULY 2022 OBSERVATION LOCATIONS PROJECT No. M07728A38	FIG No. 4.1







TO BE READ WITH KCB REPORT DATED: OCTOBER 2022

CLIENT: Teck

Klohn Crippen Berger

PROJECT: PINCHI LAKE MINE TSF - 2022 ANNUAL FACILITY PERFORMANCE REVIEW

TITLE: PIEZOMETER READINGS

PROJECT No. M07728A38

FIG No. 4.2

APPENDIX I

Facility Data Sheet

Appendix I
Facility Data Sheet

PINCHI LAKE MINE TSF EMBANKMENT

PHYSICAL DESCRIPTION

Embankment Type	Earthfill
Maximum Embankment Height	15 m
Embankment Length	1300 m
Embankment Crest Width	6 m to 8 m May be wider in some areas.
Impoundment Area	21 ha (surface area of covered tailings)
Volume of Tailings	1 million m^3 approximate
Reservoir Capacity	This is a "dry" tailings impoundment. There is no storage of water and the impoundment is normally dry. Storage capacity between the spillway invert (El. 735.25 m) and the minimum embankment crest (El. 740.2 m) is 29,600 m^3.
Spillway Capacity	Spillway has capacity to route 1/3 between 1,000-year and PMF with > 4 m freeboard in the impoundment, and 0.5 m in the spillway channel. However, riprap from the embankment toe to the downstream end of the channel is undersized for the IDF and may be damaged. Estimated peak spillway discharge = 7 m^3/s
Catchment Area	55 ha
Access to Embankment	Vehicle access to the mine from Fort St. James is 25 km north along Germansen Road, and then 20 km west along Pinchi Lake Road. Both roads are gravel surfaced. The access road into the mine site is gated and locked. The mine site can also be reached by water over Pinchi Lake. The lake usually has ice cover from November to mid-April.

APPENDIX II

July 2022 Photographs

Appendix II
July 2022 Photographs

Photo II-1 Tailings Impoundment – Looking west from ~60 m west of TSF Embankment East Leg

Photo II-2 Tailings Impoundment – Shallow local ponding on soil cover

Photo II-3 Tailings Impoundment – Looking south along drainage channel in cover, ~70 m west of TSF Embankment East Leg. Note standing water

Photo II-4 TSF Embankment – East leg, looking south. Note vegetation

Photo II-5 TSF Embankment – Pond near toe of east leg

Photo II-6 TSF Embankment – East leg looking south

Photo II-7 TSF Embankment – East leg, looking north

Photo II-8 TSF Embankment – East leg, looking west at the covered tailings surface

Photo II-9 TSF Embankment – South leg, looking east

Photo II-10 TSF Embankment – South leg, looking north at the covered tailings surface

Photo II-11 TSF Embankment – South leg, looking west

Photo II-12 TSF Embankment – Southwest leg, looking northwest along the crest

Photo II-13 TSF Embankment – Southwest leg, looking southeast along downstream slope

Photo II-14 TSF Embankment – Southwest leg, looking downstream from the crest

Photo II-15 TSF Embankment – Southwest leg, looking northwest along the downstream slope

Photo II-16 TSF Embankment – West leg, looking north along downstream slope

Photo II-17 TSF Embankment – West leg, looking south along downstream slope

Photo II-18 Closure Spillway – Inlet apron

Photo II-19 Closure Spillway – Spillway inlet (dry)

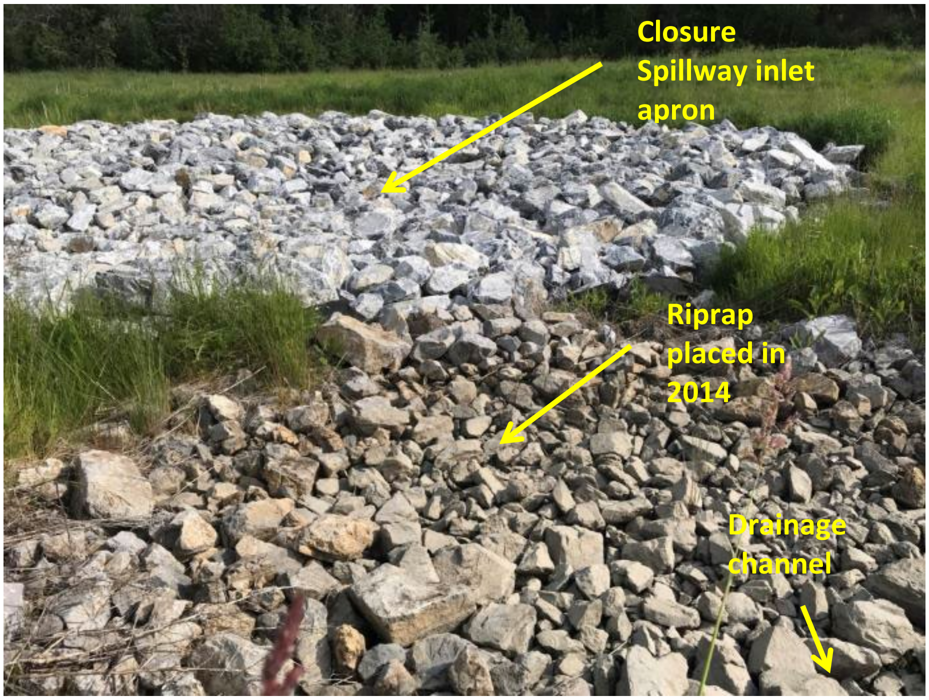


Photo II-20 Spillway inlet looking downstream

Photo II-21 Closure Spillway – looking downstream from embankment crest

Photo II-22 Closure Spillway – looking downstream

Photo II-23 Closure spillway – Pond at downstream end of riprap

Photo II-24 Outlet Channel – Middle Reach, looking upstream from road between the South of Mill Site (SMS) and Emergency Spills Lagoon (ESL) areas

Photo II-25 Outlet Channel – Culvert inlet and flow monitoring station

Photo II-26 Outlet Channel – Culvert outlet and flow monitoring station

Photo II-27 Borrow Area A – Looking east along the slope

Photo II-28 Borrow Area A – crack monitoring rod location 203

Photo II-29 Borrow Area A – Wet ground in northeast corner

Photo II-30 Borrow Area A – Looking northwest towards slope from access road along east side

Photo II-31 Ed Creek Diversion Channel – Looking downstream at outlet at Pinchi Lake

Photo II-32 Ed Creek Diversion Channel – looking downstream towards outlet

Photo II-33 Ed Creek Diversion Channel – looking downstream from between second and third bends

Photo II-34 Ed Creek Diversion Channel – Vegetation in channel, looking upstream from between second and third bends

Photo II-35 Ed Creek Diversion Channel – looking upstream from near second bend. Light coloured area of riprap was replaced in 2014 and is in good condition

Photo II-36 Ed Creek Diversion Channel – Riprap on right bank, showing weathering and breakage

Photo II-37 Ed Creek Diversion Channel – looking downstream from between first and second bends

Photo II-38 Ed Creek Diversion Channel – looking upstream from between first and second bends

Photo II-39 Ed Creek Diversion Channel – Looking downstream from near first bend

Photo II-40 Outlet of 460 mm culvert on north bank of Ed Creek Diversion Channel

Photo II-41 Inlet of 460 mm culvert on north bank of Ed Creek Diversion Channel. Note vegetation near the inlet

Photo II-42 Ed Creek Diversion Channel – Ditch upstream of culvert inlet and Ed Creek Diversion Channel

Photo II-43 Ditch north of Ed Creek Diversion Channel, looking south. Ditch is filled with vegetation

Photo II-44 Beaver dam and pond near East Leg toe, looking north

Photo II-45 Inlet of Ed Creek culverts under Pinchi Lake Road

Photo II-46 Flow monitoring station immediately upstream of Pinchi Lake Road culverts

Photo II-47 Looking upstream from inlet of Ed Creek culverts under Pinchi Lake Road

Photo II-48 Outlet of Ed Creek culverts under Pinchi Lake Road

APPENDIX III

July 2022 Inspection Forms

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

TSF EMBANKMENT AND TAILINGS IMPOUNDMENT

Date: July 5, 2022 Inspected By: D. Klassen

Time: 8:30 am to 11:30 am Pond Water Level: No pond

Weather: Partly cloudy, 20°

Is there any apparent ….	Yes	No	Comments
Cracks			
• Embankment cracks on the embankment crest?		X	
○ Enlargement of cracks or new cracks in SW leg and S leg of embankment (first observed in 2015)?		X	Not visible, see comment 1
• Embankment cracks on the u/s slope?		X	
• Embankment cracks on the d/s slope?		X	
Vegetation Growth and Debris			
• Excessive tree or shrub growth on embankment?		X	Plants > 2 m high on east leg d/s slope, but not excessive
• Debris in tailings impoundment?		X	
Other Structural Problem			
• Settlement or erosion on the embankment crest?		X	
• Slough, slides, bulges or erosion on u/s slope of embankment?		X	
• Slough, slides, bulges or erosion on d/s slope of embankment?		X	
• Sinkhole on embankment crest?		X	
• Sinkhole on u/s slope of embankment?		X	
• Sinkhole on d/s slope of embankment?		X	
• Sinkhole in tailings pond till cover?		X	
• Erosion of flow channels in tailings pond till cover?		X	
Ponding / Seepage			
• Evidence of water ponding on embankment crest?		X	
• Wet areas or seepage on d/s slope or toe of embankment?		X	
• Evidence of water ponding at d/s toe of embankment?	X		See comment 2 below
• Wet areas or seepage along d/s abutments?		X	
Animal Activity			
• Rodent burrows in embankment?		X	
• Beaver dam in Tailings Pond?		X	Beaver activity noted downstream of east leg toe, see note 3.

Additional comments:

1. Cracks have been observed in this area for several years and are believed to been formed by loosening and drying of the soil as part of the reclamation and seeding and are not considered to be a TSF safety issue. These cracks were not visible during the 2022 inspection.
2. A pond is located near the toe of the east leg of the embankment, which drains to the south through a culvert into Ed Creek Diversion Channel. This pond has been observed in previous inspections and appears to be related to local runoff. The pond level was higher than normal due to the beaver embankment described in note 3. No other ponds were observed near the embankment toe.
3. A beaver embankment is present downstream of the east leg of the embankment, in a ditch that leads from the pond area at the embankment toe south towards the culvert at the right bank of Ed Creek Diversion Channel (see Figure 4.1 in the main text for location). The embankment is 80 cm high.

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

CLOSURE SPILLWAY

Date: _July 5, 2022_______ Inspected By: _D. Klassen______________

Time: _9:30 AM________________

Weather: Partly cloudy, 20°____________________

Is the spillway flowing? ____No____________(yes / no) If yes, give approx. flow depth: _______ mm

Is the flow above the riprap? ___No_________(yes / no) If yes, give approx. flow depth above riprap: _______ mm

Is there any apparent	**Yes**	**No**	**Comments**
Vegetation Growth and Debris			
• Excessive tree or shrub growth along the channel?		X	A few small shrubs
• Debris in the channel?		X	
Riprap			
• Displaced or broken down riprap in channel bottom?		X	
• Displaced or broken down riprap along the right bank?		X	
• Displaced or broken down riprap along the left bank?		X	
Erosion, cracks, slough, slides or bulges			
• Along the bottom of channel?		X	
• Along the right bank of channel?		X	
○ Any signs of recent movement of slump on right bank?		X	
• Along the left bank of channel?		X	
Seepage			
• Seepage into the channel from right side slope?		X	
• Seepage into the channel from left side slope?		X	
Animal Activity			
• Beaver embankment in spillway channel?		X	
• Any other animal activity?		X	

NOTE: left and right banks are looking downstream along the channel.

Additional comments:

30 cm deep pond at the downstream end of the spillway. No flow.

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

OUTLET CHANNEL

Date: July 5, 2022 ________ Inspected By: D. Klassen __________

Time: 12:00 PM _______________

Weather: Partly cloudy, 20° ____________________

Is there flow in the channel? No __________ (yes / no)

Give location of flow: ________________________________ Give approx. flow depth: ______ mm

Is there any apparent …..	Yes	No	Comments
Middle Reach (along reclaimed SMS area)*			
• Debris in the channel?		X	
• Erosion in the channel?		X	
• Beaver activity in channel?		X	
Culvert under road between SMS and ESL			
• Blockage of culvert inlet or outlet?	X		See note 1
• Structural damage or deformation of culvert pipe?		X	
• Displaced or broken-down riprap?		X	
Lower Reach (along former Emergency Spills Lagoon)*			
• Excessive tree or shrub growth in the channel?		X	
• Debris in the channel?		X	
• Erosion in the channel?		X	
• Displaced or broken-down riprap in channel?		X	
• Beaver activity in channel?		X	

*NOTE: Middle Reach of Outlet Channel is the flow route along the reclaimed South of Mill Site (SMS) area, from the edge of the trees to the culvert under the road between the SMS and the remediated Emergency Spills Lagoon (ESL). Lower Reach extends from the culvert to Pinchi Lake. Upper Reach is densely vegetated and is not inspected.

Additional comments:

1. There is vegetation growing at the culvert inlet, but there is no flow or ponding at the inlet. Water is ponding locally at the culvert outlet, 14 cm deep.

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

ROAD DITCH ABOVE TAILINGS IMPOUNDMENT

Date: July 5, 2022 Inspected By: D. Klassen

Time: 11:45 AM

Weather: Partly cloudy, 20°C

Is there flow in the channel? No (yes / no)

Give location of flow: ______________________________ Give approx. flow depth: ______ mm

Is there any apparent …..	Yes	No	Comments
Road Ditch			
• Excessive tree or shrub growth in the channel?	X		Trees growing in ditch near bottom of hill close to the mine gate
• Debris in the channel?		X	
• Erosion in the channel?		X	
• Beaver activity in the channel?		X	

Additional comments:

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

BORROW AREA A

Date: July 5, 2022 Inspected By: D. Klassen

Time: 10:15 AM

Weather: Partly cloudy, 20°C

Is there any apparent …..	Yes	No	Comments
Cracks			
• Cracks on ground between borrow pit and toe of embankment?		X	
• Cracks on borrow pit slope?		X	Obscured by vegetation
Other Structural Problems			
• Sloughs, slides, bulges or erosion on borrow pit slope?		X	
Ponding / Seepage			
• Wet areas or seepage on borrow pit slope?		X	
• Wet areas or seepage at toe of borrow pit slope?	X		See comment 1 below
• Evidence of water ponding within borrow area?		X	
Animal Activity			
• Rodent burrows in borrow pit slope?		X	

Additional comments:

1. One area of wet ground in the northeast corner, but no ponds or flowing water.

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

ED CREEK DIVERSION CHANNEL

Date: July 5, 2022 Inspected By: D. Klassen

Time: 10:45 AM

Weather: Partly cloudy, one brief rain shower, 20°C

Is there flow in the channel? Yes (yes / no)

Give location of flow: Base of channel Give approx. flow depth: 200 mm

Is there any apparent	**Yes**	**No**	**Comments**
Vegetation Growth and Debris			
• Excessive tree or shrub growth along the channel?		X	See comment 1 below
• Debris in the channel?		X	
Riprap			
• Displaced or broken down riprap in channel bottom?	X		See comment 2 below
• Displaced or broken down riprap along the right bank?	X		See comment 2 below
• Displaced or broken down riprap along the left bank?	X		See comment 2 below
Erosion, cracks, slough, slides or bulges			
• Along the bottom of channel?		X	
• Along the right bank of channel?		X	
• Along the left bank of channel?		X	
Seepage			
• Seepage into the channel from right side slope?		X	
• Seepage into the channel from left side slope?		X	
Animal Activity			
• Beaver embankment in spillway channel?		X	
• Any other animal activity?		X	

NOTE: left and right banks are looking downstream along the channel.

Additional comments:

1. Vegetation was observed throughout the base of the channel, including tall grasses up to 1.5 m height.
2. As noted during previous inspections, riprap along entire diversion channel is deteriorating. Visual inspection suggested there were no significant changes from the condition in recent years.

Pinchi Lake Mine Tailings Storage Facility
Inspection Checklist

ED CREEK CULVERTS AT PINCHI LAKE ROAD

Date: July 5, 2022

Inspected By: D. Klassen

Time: 8:00 AM

Weather: Partly cloudy, 20°C

Is there flow in the culverts? Yes (yes / no)

Give approx. water depth in channel at culvert inlet: 50 mm

Is there any apparent …..	Yes	No	Comments
Culverts Under Pinchi Lake Road			
• Excessive tree or shrub growth at inlet or outlet?		X	See comment 2 below
• Blockage of culvert inlets or outlets?		X	
• Structural damage or deformation of culvert pipe?		X	
• Erosion in channel u/s or d/s of culvert?		X	
• Beaver activity in Ed Creek u/s or d/s of culvert?		X	

Additional comments:

1. Water depth at culvert inlet is for east culvert. West culvert has an approximate water depth of 20 mm.
2. Bushes growing near west culvert inlet; some branches within 0.5 m of the inlet, but not blocking it.

APPENDIX IV

1975 Embankment Drawing

Job No.	J-PLO.003
Drawing No.	PLM D 514
Revision	0
Reference	PLM-P-37, TAILINGS DISPOSAL
Drawn by	K. FRICKE JAN. 14/75
Checked by	J.E. PRIME FEB/4/75
	Engineering TRAIL, B.C.
Function	MINES
Activity	PINCHI LAKE MERCURY
Section	TAILINGS DAM EXTENSION - 1975
Job	PLAN & SECTIONS
Scale	AS NOTED
Drawing No.	PLM D 514 0

APPENDIX V

Water Balance

Klohn Crippen Berger

Teck Metals Ltd.

Pinchi Lake Mine Tailings Storage Facility

2020 Water Balance

BEST MANAGED COMPANIES CANADA Platinum member

ISO 9001 14001 45001

M07728A37.730

August 2022

August 26, 2022

Teck Metals Ltd.
Kimberley Operations
Bag 2000
Kimberley, British Columbia
V1A 3E1

Ms. Michelle Unger
Mine Manager

Dear Ms. Unger:

Pinchi Lake Mine Tailings Storage Facility
2020 Water Balance

We are pleased to submit the 2020 Water Balance Report for the Pinchi Lake Mine Tailings Storage Facility.

Please contact us if you have any questions regarding this report.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Daniel Klassen

Daniel Klassen, P.Eng.
Project Manager

NW/SC:jc

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Teck Metals Ltd.

Pinchi Lake Mine Tailings Storage Facility

2020 Water Balance

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CLARIFICATIONS REGARDING THIS REPORT

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2. The observations, findings and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.
3. The report is based on information provided to KCB by the Client or by other parties on behalf of the client (Client-supplied information). KCB has not verified the correctness or accuracy of such information and makes no representations regarding its correctness or accuracy. KCB shall not be responsible to the Client for the consequences of any error or omission contained in Client-supplied information.
4. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.

1 INTRODUCTION

This letter summarizes an update to the water balance completed by Klohn Crippen Berger Ltd. (KCB) for the Pinchi Lake Mine Tailings Storage Facility (TSF) to reflect the 2020 water year. A GoldSim Player file of the water balance accompanies this letter. The Pinchi Lake Mine TSF is located in central British Columbia, on the north side of Pinchi Lake, at an elevation of approximately 750 m. No tailings have been deposited in the TSF since 1975 and closure reclamation works were completed in 2011.

The previous water balance for the TSF (KCB 2019) was completed in GoldSim, incorporating climate data from 1998 to 2017, and summarized results for the 2017 water year. The objectives of this water balance model are to comply with regulatory requirements, and to demonstrate the current understanding of flows into and out of the TSF under normal conditions.

The following updates to this model were made for the 2020 water balance:

- Climate data from 2018, 2019 and 2020 were included in the model, and the 2020 water balance is reported.
- Minor updates to the hydrology module of the GoldSim model to be consistent with KCB's internal standards.
- Modifications to the model to meet Teck's internal guidelines for water balance models (Teck 2018) that include, but are not limited to, the following:
  - a water balance schematic;
  - future climate scenario;
  - a technical reference manual for the model, including the hydrology module (see Appendix I); and
  - a GoldSim Player file with user Dashboards provided to Teck.

2 METHODOLOGY

2.1 Model

The previous TSF water balance (KCB 2019) was completed with an older version of KCB's in-house GoldSim hydrology module. Updates to the hydrology module were made to enhance the soil moisture accounting and snowmelt calculations. Since these changes were minor, the previously-calibrated model parameters remain unchanged. Appendix I contains a user manual for the GoldSim model and a technical reference manual for the hydrology components.

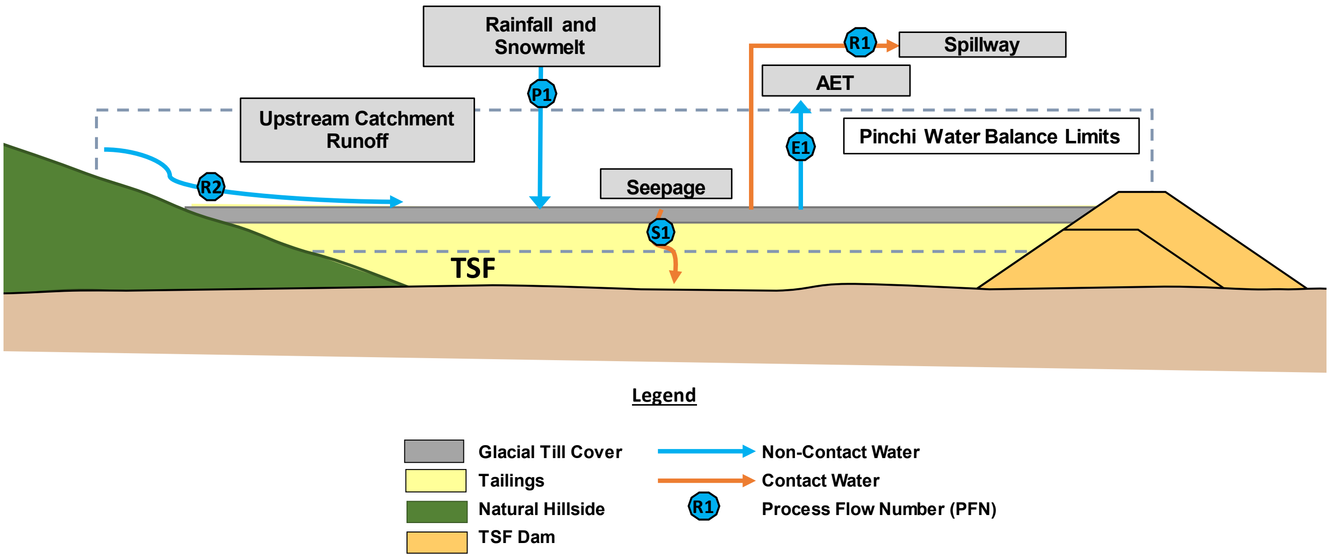
As in the previous TSF water balance (KCB 2019), there are two scenarios modelled to reflect the pre- and post-covering of the TSF. The pre-cover scenario included a small (0.4 ha) pond near the outlet of the TSF where water levels and discharge through a decant structure had been measured since 1997. The last year of measurement at the TSF outlet occurred in 2008, just prior to reclamation and closure of the TSF that saw: the pond drained; the decant structure and emergency spillway replaced with the current riprap closure spillway; and the tailings covered with glacial till and vegetated.

The water balance was modelled in GoldSim as two catchment areas, the TSF impoundment and upstream area, reporting to the closure spillway. Snow accumulation and snowmelt were estimated using daily precipitation and temperature data. Snow accumulation was validated using regional snow course data. Runoff, seepage loss, and evaporation loss in the catchment were estimated using a soil moisture accounting (SMA) model. A SMA model uses daily precipitation, temperature, soil moisture, and soil permeability of a catchment to estimate the amount of water that enters, is stored in, and leaves the catchment. The surface soil storage and seepage rate were calibrated to water level and flow measurements taken in 2007 and 2008 (assuming the small pond present in 2008), or the "pre-cover scenario".

The GoldSim model was then updated to reflect current closure conditions, or the "post-cover scenario", by removing the free water pond and increasing soil storage to account for the vegetated glacial till closure cover. The "post-cover" model was run using the past 23 years of climate data (1998 to 2020) to estimate monthly average flows. Modelled runoff volumes in April and May were compared to runoff volumes that were estimated by interpolating between spot flow measurements in 2011 and 2012 to provide a level of confidence in the results; however, there is not enough data to calibrate the post-cover scenario.

A schematic of the "post-cover" TSF water balance is shown on Figure 2.1. Process Flow Numbers (PFNs) are used to report the water balance results (see Section 3). The water balance focuses on the TSF cover with the objective of estimating runoff and net percolation of water into the tailings.

Figure 2.1 TSF 'Post-Cover' Water Balance Schematic

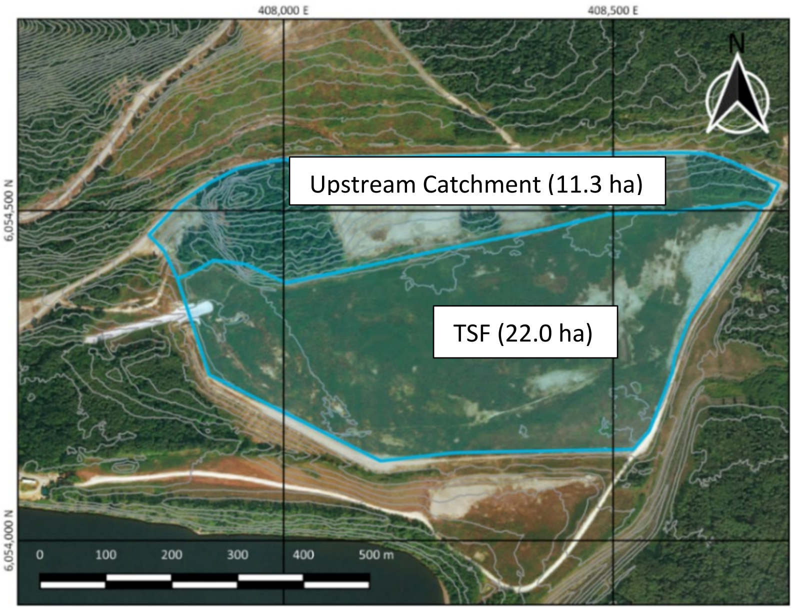


2.2 Input Data

2.2.1 Catchment Areas

Approximately 22.0 ha of tailings area and 11.3 ha of upstream catchment report to the closure spillway (Figure 2.2). The upstream catchment assumes the ditch beside the access road operates during normal conditions. Note that this upstream catchment area is less than what was used in the assessment of the TSF spillway capacity because that assessment assumed the road upstream of the TSF is breached during the Inflow Design Flood (IDF).

Figure 2.2 TSF Water Balance Catchment Areas



2.2.2 Climate

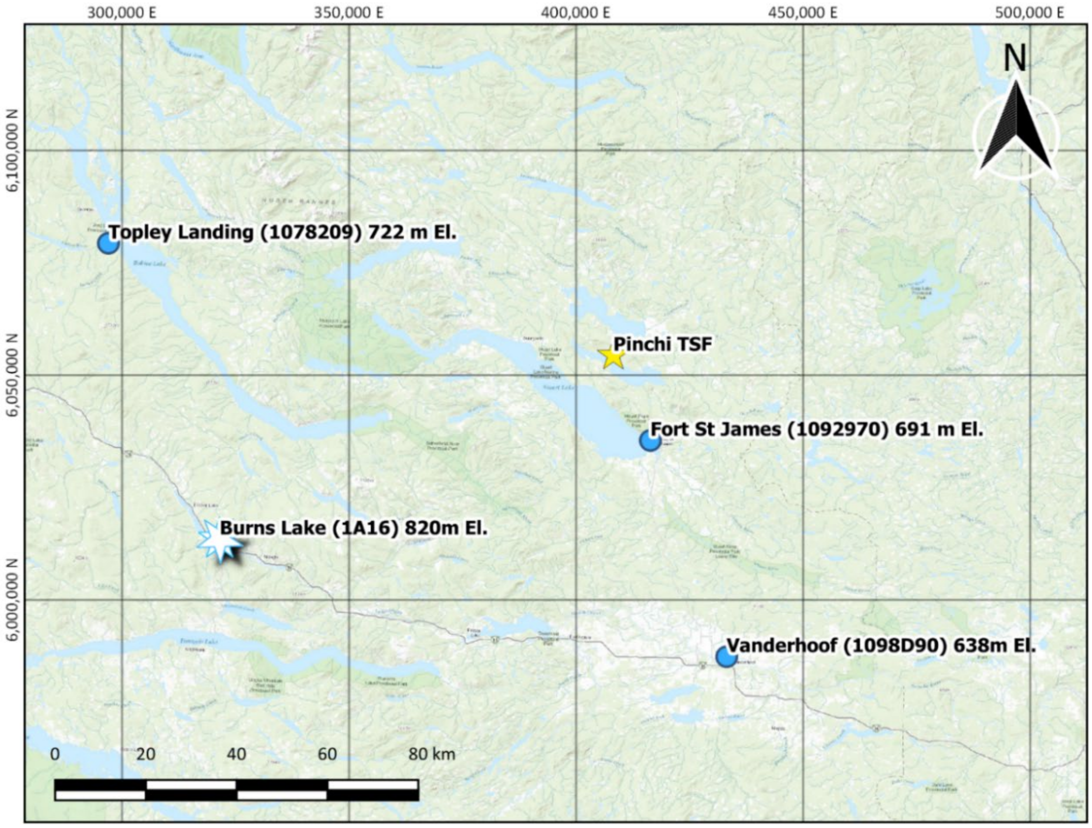
Regional Environment Canada climate stations with parameters of interest, along with period of record and elevation, are listed in Table 2.1 and shown on Figure 2.3.

Snowpack and snowmelt are estimated based on precipitation and temperature data; however, measurements of snowpack are needed to validate these estimates. Snow course is measured in the spring at Burns Lake, 100 km southwest of site, at an elevation of 820 m, similar to Pinchi Lake Mine TSF (750 m).

Table 2.1 Regional Climate Stations

Station Name	Station ID	Period of Record	Elevation (m)	Distance from Site	Parameters of Interest
Fort St. James	1092970	1895 to 2019	691	20 km southeast	Precipitation, Temperature
Fort St. James Auto	1092975	2013 to 2021	688	20 km southeast	Precipitation, Temperature
Vanderhoof	1098D90	1980 to 2021	638	70 km southeast	Precipitation, Temperature
Topley Landing	1078209	1962 to 2017	722	115 km northeast	Precipitation, Temperature
Burns Lake	1A16	1970 to 2021	820	100 km southwest	Snow Course

Figure 2.3 Regional Climate Station Locations



Note:

1. Fort St. James and Fort St James Auto stations are in the same location on this map.

Precipitation and temperature are inputs to the TSF water balance. These parameters were taken first from the Fort St. James station due to its proximity to site, with gaps filled in with data from Vanderhoof and Topley Landing as required. To account for the TSF being at a higher elevation, precipitation data from these stations was increased by 3%[1] and temperature data was decreased by 0.3°C[2].

Potential evapotranspiration (PET) is calculated using the Hargreaves evaporation equation (Hargreaves and Samani 1985), with inputs of daily temperature data and an assigned crop coefficient, see Appendix I for details. For the TSF this crop coefficient was calibrated to match observed runoff. Actual evapotranspiration (AET) losses from the pond and catchment are then calculated based on PET and water availability.

Monthly averages of the 1998 to 2020 climate data inputs used in the GoldSim model are presented in Table 2.2.

[1] Based on an increase of 5% per 100 m elevation gain suggested by Quick (2005).
[2] Based on a decrease of 0.65°C per 100 m elevation gain, which is the average lapse rate defined for the International Standard Atmosphere.

Table 2.2 1998 to 2020 Monthly Climate Averages

Period	Precipitation (mm)	Rain[1] (mm)	Snow[1] (mm SWE)	PET[2] (mm)
January	45	3	43	1
February	29	2	27	2
March	26	8	18	17
April	24	20	4	55
May	38	37	0	97
June	46	46	0	111
July	51	51	0	117
August	41	41	0	101
September	40	40	0	57
October	51	39	12	23
November	43	14	29	4
December	40	3	37	1
Annual Totals	472	302	170	588
Percent of Precipitation	100%	64%	36%	

Notes:

1. Snowfall is calculated from precipitation data below 1°C. It is presented in units of snow water equivalent (SWE).
2. PET is calculated using the Hargreaves equation for daily evaporation and an assigned crop coefficient.

2.2.3 Surface Storage

Based on the recorded data, discharge from the TSF spillway normally occurs only during freshet indicating that there is enough surface depression, vegetation and upper soil moisture storage to contain most rain events. An initial estimate of these storages for the pre-cover model calibration (i.e., 2007/2008 condition) was 80 mm, broken down as follows:

- 5 mm of canopy storage (before the closure cover was installed).
- 65 mm of soil moisture storage in a dry antecedent moisture condition (AMC) based on:
  - 0.221 water content at wilting point (i.e., dry antecedent condition);
  - 0.430 water content at saturation point (porosity); and
  - 300 mm thick surface soil layer involved in evapotranspiration processes, associated with a silty-clay soil type.
- 10 mm of surface depression storage, assumed on a permeable surface and mild grade.

Using the measured data from spring freshet events to calibrate the pre-cover GoldSim model, the total moisture storage for the TSF was estimated to be 90 mm (Section 2.2), compared to the initial estimate of 80 mm. A 90 mm storage is equivalent to a curve number of 74 under the Soil Conservation Service (SCS) TR-55 hydrology model, which is reasonable for a flat and permeable area.

For the post-cover water balance, surface storage was increased to 110 mm to account for the vegetated glacial till cover. This is approximately consistent with an SCS curve number of 70. The pre- and post-cover soil property estimates are provided in Table 2.3. The wilting point and field capacity values are used to determine when the water content of the surface soil becomes too dry for further evapotranspiration and percolation into the tailings. When the water content is below the field capacity, percolation into the tailings stops. When the water content is below the wilting point, evapotranspiration stops. These processes are described more in Appendix I.

Table 2.3 Pre- and Post-Cover Modeled Soil Properties

Soil Properties	Pre-Cover Scenario	Post-Cover Scenario
Canopy Storage	5 mm	15 mm
Depression Storage	10 mm	30 mm
Wilting Point	0.221	0.221
Field Capacity	0.321	0.321
Porosity	0.430	0.430
Soil Depth	300 mm	300 mm

2.2.4 Seepage Rate

Seepage is estimated as the amount of precipitation and/or snowmelt percolating into the tailings and reporting somewhere downstream of the spillway. Percolation occurs in the model only while the surface of the TSF has a moisture content above field capacity, and the percolation rate is capped at the saturated hydraulic conductivity of the tailings. In the 2009 and 2019 water balances (KCB 2009; KCB 2019), a saturated hydraulic conductivity of 1×10^{-8} m/s, or approximately 1 mm/day, was used for the tailings. This value was not revised during pre-cover model calibration. The glacial till closure cover is assumed to have a hydraulic conductivity similar to the tailings, so no change to this value was made for the post-cover scenario.

2.3 Pre-Cover Scenario Calibration

The model was calibrated for the pre-cover scenario by adjusting watershed storage, seepage, temperature index (TIPM), and evaporation input parameters to fit measured pond level and flow data. Modelled snow accumulation was compared to measured values at Burns Lake, but no snowmelt parameters were adjusted. Selection of the period for model calibration was based on periods where there were concurrent data sets for pond level, discharge measurements in the TSF, and snow course measurements (at Burns Lake). This level of information was only available for the pre-cover scenario in 2007 and 2008. Results of the model calibration are presented in Figure 2.4.

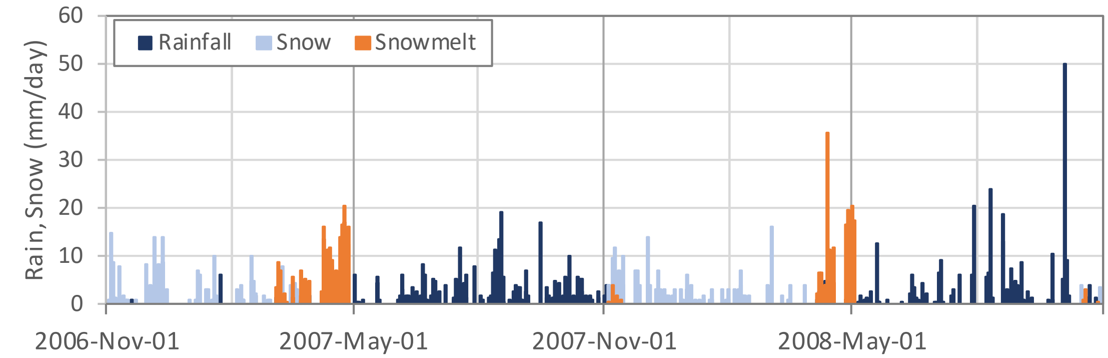
The estimated snow accumulation snow water equivalent (SWE) from the calibrated water balance model is comparable to the snow course SWE measurements at Burns Lake in 2007 and 2008. Burns Lake is at a similar elevation to the TSF, so no elevation correction was required. The temperature index parameter (TIPM), as part of the updated GoldSim model in the SNOW-17 subsection (see Appendix I), was increased from 0.5 to 0.9 to best align with the discharge results.

The estimated water level and TSF discharges from the calibrated water balance model closely correlate to the measured data in 2007 and 2008. The model predicted some discharge in late fall in both years when measurements were not taken; however, these volumes were small compared to the freshet discharge volumes.

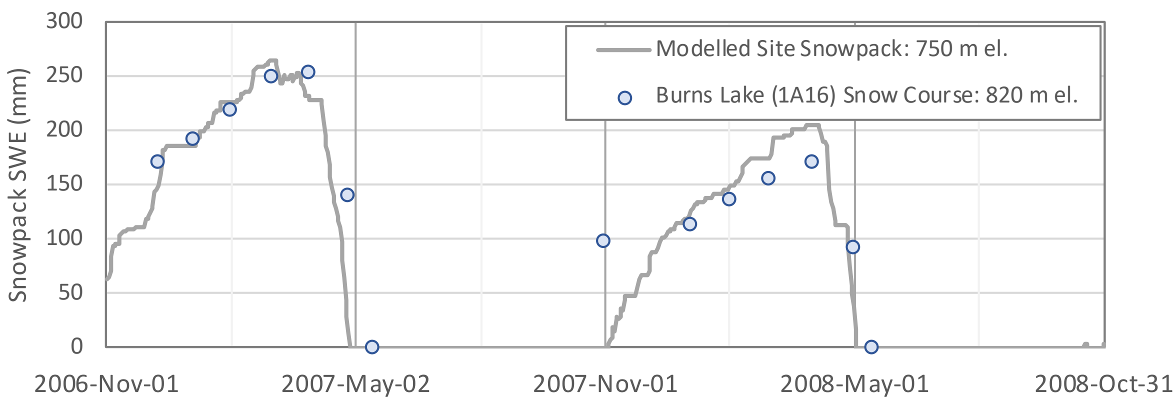
The results described above and shown in Figure 2.4 indicate that the calibrated water balance model provides a reasonable representation of the hydrologic performance of the TSF.

Figure 2.4 Pre-Cover Model Calibration using 2007 and 2008 Data

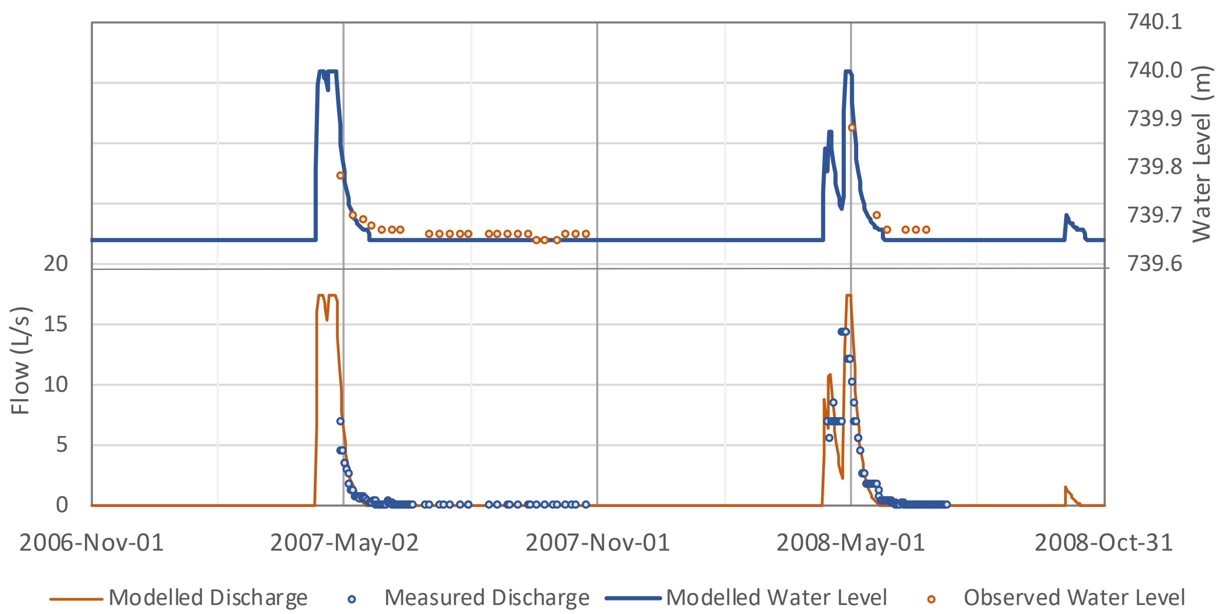
Climate Inputs



Snowpack



Pond Level and Discharge Calibration



2.4 Post-Cover Scenario Validation

The post-cover scenario was validated[3] using flow rates measured[4] approximately 450 m downstream of the TSF spillway. In 2011 and 2012, flows were measured five and four times, respectively. In 2013 to 2019, flows were measured either once or twice a year. Due to the higher number of measurements in 2011 and 2012, this period was selected for validation of the post-cover scenario model. Flow measurements and the associated runoff volume estimated for April-May in 2011 and 2012 are compared with modelled April-May runoff volumes in Table 2.4.

Table 2.4 Post-Cover Model Validation using 2011 and 2012 Data

Parameter	2011	2012
Flow Measurement 1	3.2 L/s on April 19	11.8 L/s on April 23
Flow Measurement 2	9.4 L/s on April 26	9.2 L/s on April 30
Flow Measurement 3	7.3 L/s on May 3	3.6 L/s on May 7
Flow Measurement 4	3.2 L/s on May 10	0.9 L/s on May 14
Flow Measurement 5	0 L/s on May 17	n/a
Measured April-May Runoff Total[1]	10,500 m^3	11,000 m^3
Modelled April-May Runoff Total	10,100 m^3	12,700 m^3

Note:

1. Total April-May runoff volumes were estimated based on the measured flow rates and estimated flow durations.

The modelled and measured runoff values for April-May 2011 and 2012 are within 12% of each other. This comparison indicates that the post-closure scenario model is a reasonable representation of the conditions and that no further calibration of the model is needed.

2.5 2020 Updates

Four manual flow measurements were completed in 2020 as part of the tailings spring effluent monitoring. These flow measurements were not used to calibrate/validate the model, which was completed prior to 2020 (KCB 2019). Table 2.4 compares measured flow to modelled flow on these dates. Both the model and flow measurements indicate relatively high flows occurring on April 19, 2020. However, the model flows consistently underpredicted measured flows. Some, or all, of this discrepancy may be due to a somewhat larger catchment area reporting to the flow measurement site than the TSF spillway.

[3] Validation included comparing modelled April and May runoff volumes for the post-cover scenario to measured data in 2011 and 2012, without the adjustment of any input parameters.
[4] Collected by Ecofor in April and May between 2011 and 2019.

Table 2.5 2020 Measured to Modelled Spillway Discharge

Date	Measured Discharge 450 m Downstream of TSF Spillway (L/s)	Modelled Discharge through TSF Spillway (L/s)
2020-04-19	188	61
2020-04-27	12.1	0
2020-05-03	2	0
2020-05-12	1.7	0

3 RESULTS

The estimated average monthly TSF water balance[5] results reflecting the current post-cover closure conditions, with no free water pond and a vegetated glacial till cover, are summarized in Table 3.1. Results for the 2020 water year are shown in Table 3.2 and summarized in Figure 3.1.

An estimated 9% of direct precipitation on the TSF is lost to seepage, while 77% is lost to AET on an average annual basis. Average spillway discharge is the remaining 14% of direct precipitation on the TSF plus runoff from the upstream catchment.

Table 3.1 Average 1998-2020 TSF Water Balance Results

Period	TSF Inflows		TSF Outflows and Storage			
	P1	R2	E1	S1	R1	Change in Storage[1] (m^3)
	Rainfall and Snowmelt (m^3)	Upstream Catchment Runoff (m^3)	AET (m^3)	Seepage (m^3)	Spillway Discharge (m^3)	
January	600	0	300	400	0	-100
February	600	0	500	600	0	-500
March	11,300	800	3,800	1,400	2,300	4,600
April	28,200	5,400	12,100	4,300	16,000	1,300
May	9,100	400	18,600	1,600	1,000	-11,800
June	10,000	0	13,100	0	0	-3,000
July	11,200	0	10,500	100	0	600
August	9,000	0	9,100	0	0	-100
September	8,700	0	8,000	0	0	700
October	10,000	0	4,400	200	0	5,400
November	4,500	0	900	600	0	3,000
December	700	0	100	500	0	0
Average Annual Totals	**103,900 (3.3 L/s)**	**6,500 (0.2 L/s)**	**81,400 (2.6 L/s)**	**9,700 (0.3 L/s)**	**19,300 (0.6 L/s)**	**0**

Note:
1. Reflects water stored as pore water in the closure cover over the tailings or in depressions on the surface.

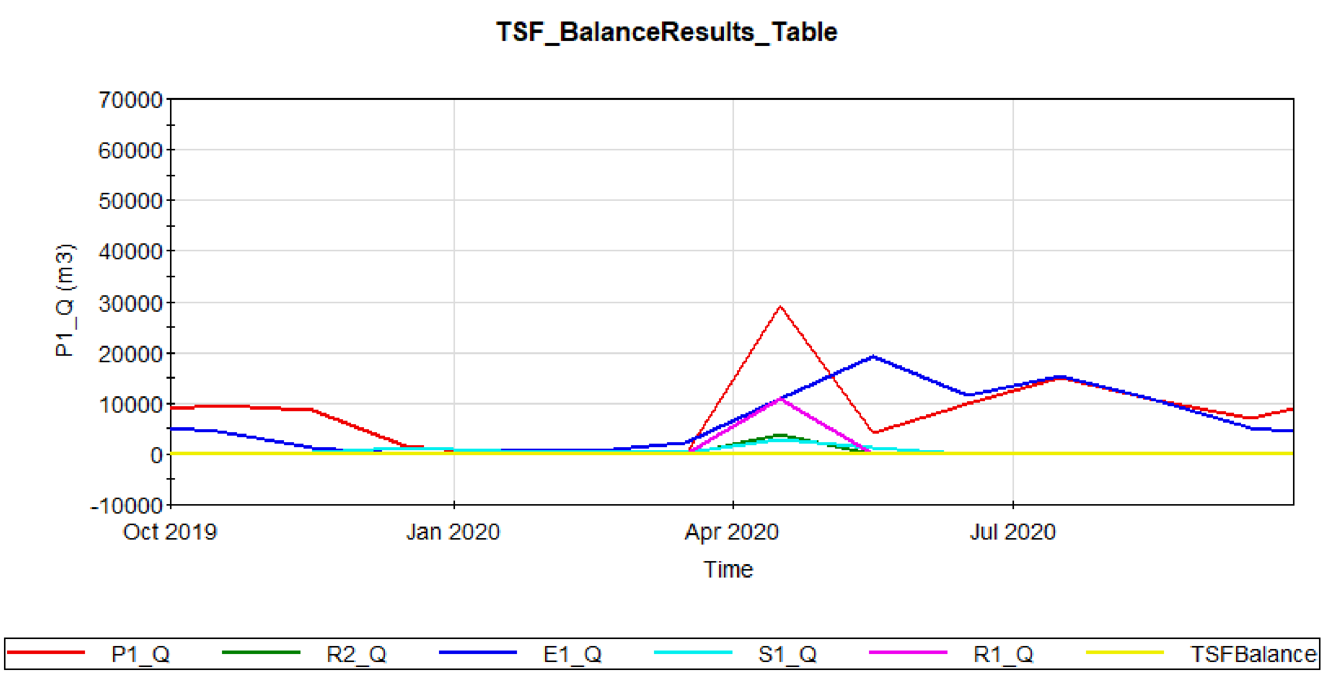
[5] The post-closure water balance used climate data from 1998 to 2020.

Table 3.2 2020 Water Year (October 1, 2019 to September 30, 2020) TSF Water Balance Results

Period	TSF Inflows		TSF Outflows and Storage			
	P1	R2	E1	S1	R1	Change in Storage[1] (m^3)
	Rainfall and Snowmelt (m^3)	Upstream Catchment Runoff (m^3)	AET (m^3)	Seepage (m^3)	Spillway Discharge (m^3)	
October 2019	9,500	0	4,600	0	0	4,900
November 2019	8,700	0	1,300	200	0	7,100
December 2019	1,600	0	100	1,300	0	200
January 2020	0	0	600	600	0	-1,300
February 2020	0	0	600	400	0	-1,000
March 2020	0	0	2,200	300	0	-2,500
April 2020	29,100	3,700	11,000	2,800	11,000	8,000
May 2020	4,100	0	19,100	1,100	0	-16,100
June 2020	10,000	0	11,400	0	0	-1,400
July 2020	15,000	0	15,200	0	0	-200
August 2020	10,600	0	10,700	0	0	-100
September, 2020	6,900	0	5,000	0	0	2,000
Average Annual Totals	**95,600 (3.0 L/s)**	**3,700 (0.1 L/s)**	**81,900 (2.6 L/s)**	**6,900 (0.2 L/s)**	**11,000 (0.3 L/s)**	**-400**

Note:
1. Reflects water stored as pore water in the closure cover over the tailings or in depressions on the surface.

Figure 3.1 2020 Water Year TSF Balance Summary



4 CLOSING

We would like to thank you for the opportunity to work on this assignment. Should you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

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PROFESSIONAL PROVINCE OF S. J. W. CLARK # 42954 BRITISH COLUMBIA ENGINEER 26/08/2022

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REFERENCES

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APPENDIX I

KCB GoldSim Watershed Model Technical Reference

Appendix I
KCB GoldSim Watershed Model
Technical Reference

I-1 INTRODUCTION

The KCB GoldSim Watershed Model (the Model) is a continuous simulation hydrology model that was developed in GoldSim® to estimate snow accumulation, snowmelt, evaporation, and streamflow discharge based primarily on inputs of daily precipitation, daily temperature, and hydrologic model parameters. It can be used as a hydrology module within a larger water balance model, or by itself for estimating climate or hydrological parameters that require a continuous simulation (e.g., run over multiple years). Continuous simulation models lend themselves to calibration to measured snowpack and/or streamflow data; calibration and/or benchmarking are highly recommended when using this model.

The Model maintains a mass balance of water in the watershed and includes mechanisms for both surface runoff and groundwater discharge. It is effective for modelling watersheds where much, or all, of the daily discharge is from either interflow or groundwater, not surface runoff (i.e., most natural catchments). The Model is not suited to estimating peak flows for durations less than one day and is best suited to estimating flows over durations ranging from one week to multiple years.

The Model is analogous to the following industry standard models:

- Soil Moisture Accounting (SMA) model in HEC-HMS (Bennett 1998);
- a continuous simulation model in EPA SWMM using the evaporation, soil infiltration, and aquifer elements with simple groundwater discharge equations; and
- Hydrologic Evaluation of Landfill Performance (HELP) (Schroeder et al. 1994).

I-1.1 Model Files

The Model consists of two files:

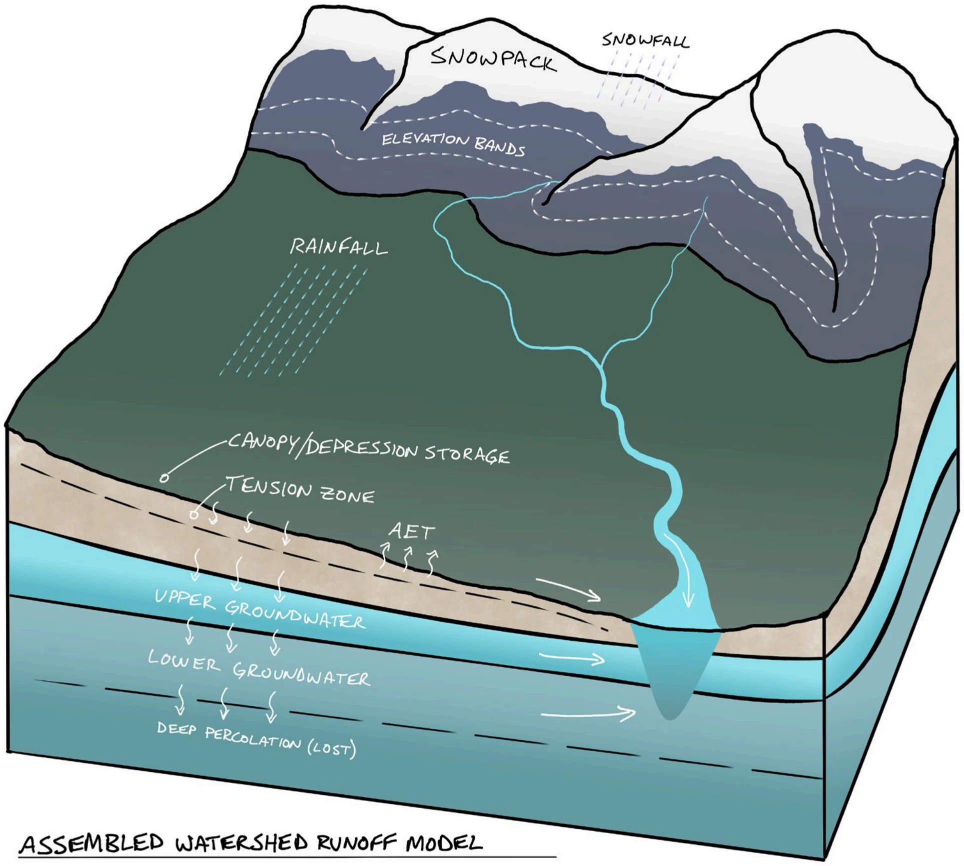
- a GoldSim file titled “Watershed Model_v0.4.3.gsm”; and
- an Excel file titled “GoldSim Inputs - Reference File.xlsx”.

Time series data (climate inputs and streamflow or snowpack data for validation) is entered into the Excel file. Other model parameters are entered into the Dashboards in the GoldSim file.

I-2 HYDROLOGY MODEL

A conceptual schematic of the KCB GoldSim Watershed Model is in Figure I-1.

Figure I-1 Conceptual Schematic of Watershed Runoff Model



I-2.1 Precipitation and Temperature

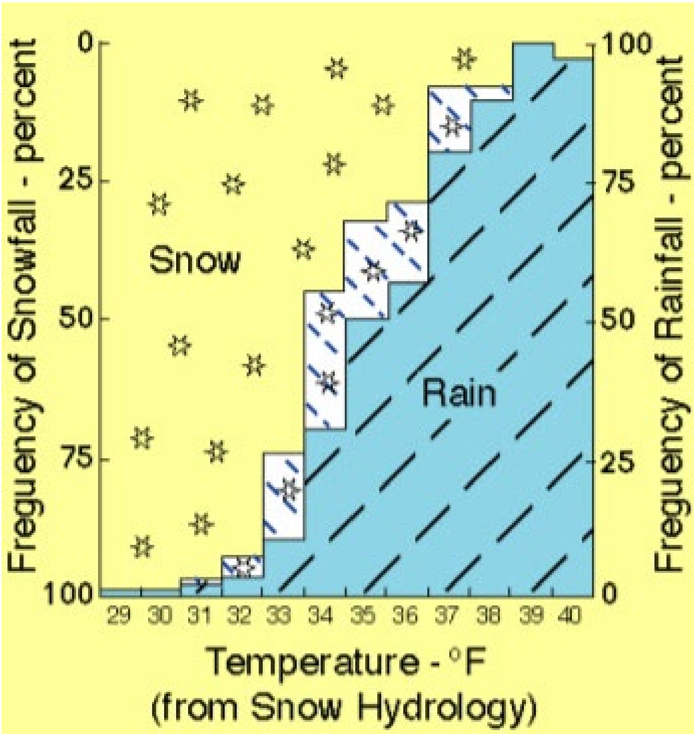
I-2.1.1 Timeseries

The Model requires a complete timeseries of daily precipitation and minimum, maximum, and average daily temperature as an input.

I-2.1.2 Precipitation as Snow Temperature Threshold

Precipitation over the watershed is delineated into rainfall or snowfall with a user input temperature threshold. Precipitation onto reservoirs is always treated as rainfall. Anderson (2006) presents the following graph showing the general range of temperatures that rain transitions to snow.

Figure I-2 Precipitation as Rain or Snow vs. Temperature Graph (Anderson, 2006)



I-2.1.3 Orographic Corrections

The Model will make orographic corrections to the precipitation and temperature timeseries data based on the inputs and equations in Table I-1:

Table I-1 Orographic Correction Parameters

Parameter	Name
Elevation associated w/ climate inputs (m)	*Ref_El*
Precipitation change per 100 m elevation increase (%)	*Precip_El*
Temperature change per 100 m elevation increase (°C)	*Temp_El*
Subcatchment Characteristics – Average Elevation (m)	*SC_El*

$$Precipitation\ Correction\ (\%) = (1 + Precip_{El})^{\frac{SC_{El} - Ref_{El}}{100m}} - 1$$

$$Temperature\ Correction = Temp\_El * \frac{SC\_El - Ref\_El}{100m}$$

I-2.2 Snow Accumulation and Melt

I-2.2.1 Snowmelt Hydrology

Snow accumulates throughout the winter (precipitation as snowfall) and melts in the spring when temperatures rise above zero degrees Celsius. As thermal energy is absorbed into the snowpack, melting occurs in the following three phases:

- warming phase is characterised by snow temperatures rising, but no snowmelt occurring;
- ripening phase is characterised by snow melting, percolating down through the snowpack and either filling the pore space or re-freezing; and
- discharge phase is when the snow is saturated and any further meltwater is discharged, either into the soil or as runoff.

These phases commonly overlap, with the top layer ripening while the middle of the snowpack is still warming for example.

Quick and Pipes (1976) describes the three major sources of thermal energy input to a snowpack as:

1. convective heat transfer from warm air;
2. net shortwave (i.e., solar) and longwave (i.e., atmospheric) radiation; and
3. latent heat exchanges associated with evaporation and condensation.

Rainfall is usually a secondary source of thermal energy input (USACE 1956) and was found to increase water available for runoff by 25% to 30% during intense (>40 mm/day) rain-on-snow events at high elevation sites on the south coast of BC (Trubilowicz and Moore 2017).

I-2.2.2 Snowmelt Equations

Snowmelt is modelled using the method proposed by Quick and Pipes (1976) and applied in the UBC Watershed Model (UBCWM) on sunny days, and using the method proposed by USACE (1956) on days with rain.

Sunny Day Snowmelt

This method, commonly known as the UBC Watershed Model, was developed by M. Quick and A. Pipes (1976) and estimates snowmelt from:

- convective heat transfer, using daily average temperature;
- solar radiation from the daily temperature range; and
- latent heat exchanges from the daily minimum temperature.

This method does not account for thermal energy from rainfall.

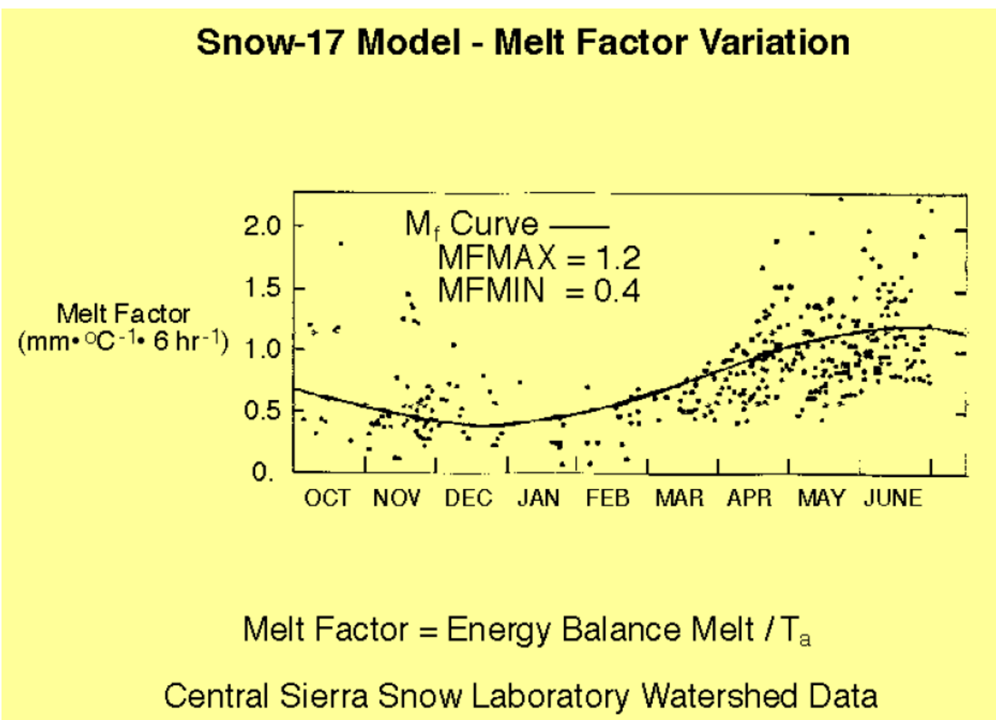
The UBC Watershed Model snowmelt equation is:

$$SM = m\left(T_a + \beta\left(\left(\frac{T_x - T_n}{\alpha}\right) + T_n\right)\right)$$

where:
SM is snowmelt in mm/day
m is the point melt factor, 3 mm/day/°C
T_a is daily average temperature in °C
T_x is daily maximum temperature in °C
T_n is daily minimum temperature in °C
α is the radiant energy factor, assumed to be 8
$\beta = T_n/\gamma$, where γ is the reference dewpoint, assumed to be 10, and $0 < \beta < 1.5$

The melt factor, m, should be selected based on a site latitude of 39.33 degrees north[1] and date of April 30. The melt factor is adjusted based on calculated extraterrestrial solar radiation, which varies based on time of year and latitude. Anderson (2006) presents the following graph showing the seasonal variation in melt factor.

Figure I-3 Seasonal Variation in Melt Factor (Anderson, 2006)



[1] 39.33 degrees north is the latitude of Donner Pass, where the Central Sierra Snow Laboratory is located. The seasonal variation in observed melt factors is reported by Anderson (2006) and used in the SNOW-17 model based on data from this station.

Rainy Day Snowmelt

This method was developed by the US Army Corps of Engineers (USACE 1956) for the Pacific Northwest region and estimates snowmelt from convective heat transfer, using daily average temperature, and rainfall. The method does not directly account for solar radiation or latent heat exchanges.

USACE snowmelt equation:

$$SM = T_a\left(3.39\frac{mm}{day - °C} + 0.0126°\text{C}^{-1}R\right) + 1.26\frac{mm}{day}$$

where: SM is snowmelt in mm/day
T_a is daily average temperature in °C
R is rainfall in mm/day

A similar version of this method is presented in the Manual of Operation Hydrology in British Columbia (Coulson 1991) for forested areas.

I-2.2.3 Antecedent Temperature Index (Heat Deficit)

Antecedent temperature index (ATI) is a method proposed by Anderson (2006) to model the "warming" phase of the snowpack. ATI represents the temperature of the snowpack at some distance from the surface. Heat transfer into the snowpack is then based on the temperature gradient between the surface of the snowpack, T_{sur}, and the temperature within the snowpack, ATI.

The following equation represents the change in ATI with air temperature:

$$ATI_2 = ATI_1 + TIPM_{\Delta t} * (T_a - ATI_1)$$

where:

ATI_1 is the antecedent temperature index in °C at timestep 1.
If ATI>0°C, then ATI = 0°C
T_a is the air temperature in °C
$TIPM_{\Delta t}$ is a model parameter that reflects the rate of transfer of heat from the air to the surface of the snowpack.

$TIPM_{\Delta t}$ is a calibrated parameter, but a common value is 0.5 day^{-1}.

Following a large snowfall (e.g., more than 1.5 mm/hr, or 36 mm/day), ATI will be updated to reflect the temperature of the falling snow (i.e., the air temperature).

The heat deficit, or cold content, of the snowpack (i.e., the heat required to bring the entire snow column up to 0°C) is modelled using the temperature gradient between the air (T_a) and the snowpack (ATI). Heat deficit is modelled as a reservoir element with the following inflows and outflows:

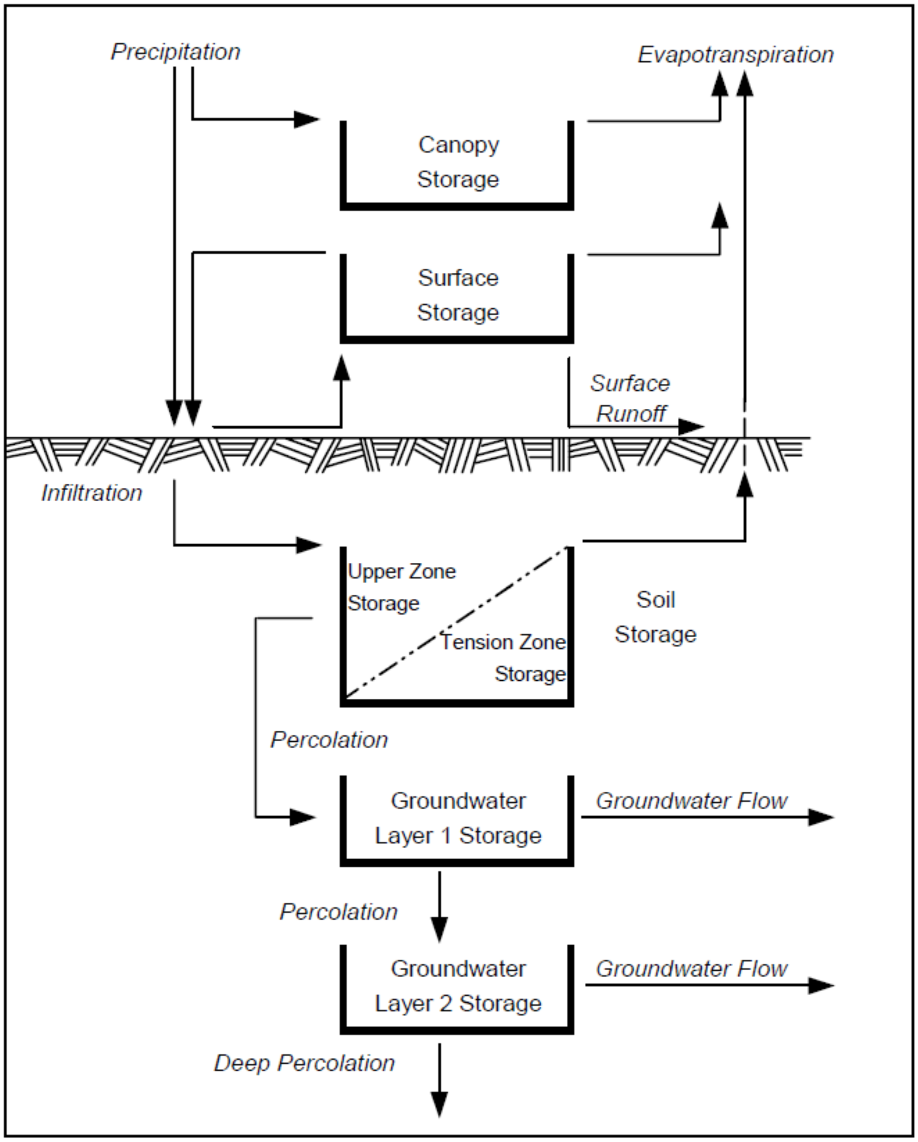
Table I-2: Heat Deficit Model Elements

Warming/Cooling	Description	Model Element Name	Equation
Warming and Cooling	Heat Transfer from Snowpack Surface	dD_AirWarming dD_AirCooling	$\Delta D = NMF * (ATI - T_{sur})$, where ΔD is the change in heat deficit, in mm of snowmelt NMF is a user-defined Negative Melt Factor; and T_{sur} is the surface temperature of the snow, which is the lesser of the air temperature or 0°C
Warming	Heat Transfer from Rain	Daily_Rain	$\Delta D = -R$ where R is rainfall in mm
Cooling	Heat Transfer from New Snow	dD_NewSnow	$\Delta D = -(T_a - 0°C) * PAS/(L_f/c_i)$, where T_a is the air temperature; PAS is precipitation as snow in mm; L_f is the latent heat of fusion (80 cal/g); and c_i is the specific heat capacity of ice (cal/g-C)
Warming	Snowmelt	SnowmeltSelector	SM in mm, as calculated using the equations presented in Section I-2.2.2.

I-2.3 Soil Storage Zone

The overall concept for modelling runoff, evaporation, infiltration, and groundwater discharge follows the HEC-HMS Soil Moisture Accounting Model (Bennett 1998), as shown in Figure I-4. In this concept, the Soil Storage zone represents the surface layer of soil (~1 ft to 2 ft) that is involved in infiltration and evaporation processes. The Model balances water inflows and outflows. Inflows are rainfall and snowmelt, while outflows are evapotranspiration and “deep percolation” from Groundwater Layer 2. Aside from this, there are a series of storage elements (Canopy Storage, Surface Storage, Soil Storage, and Groundwater Storage) that serve to temporarily store and attenuate flows in the watershed.

Figure I-4 Flowchart of Runoff, Evapotranspiration, Infiltration and Groundwater Discharge (Bennett 1998)



I-2.3.1 Moisture Retention and Hydraulic Conductivity Properties

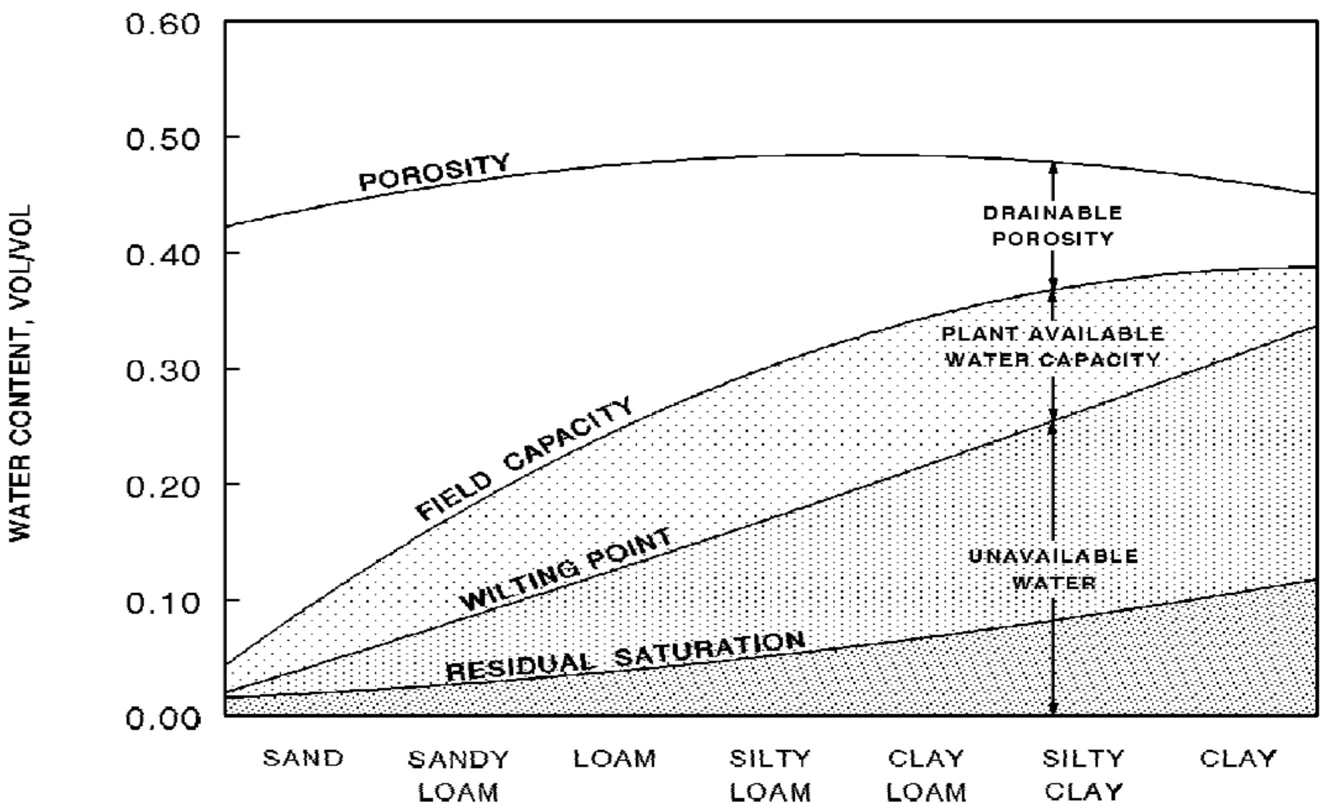
The Model requires the following inputs to characterize the storage, infiltration, and percolation characteristics of the Soil Storage zone:

- depth of surficial soil, which is involved in both the infiltration and evaporation processes;
- saturated hydraulic conductivity, K_s;
- Green-Ampt suction head, which is involved in infiltration processes and can be estimated as a function of pore size distribution (USACE 2000);

- porosity, φ, which represents the total amount of water that can be stored within the soil;
- field capacity volumetric water content, FC, below which downward infiltration of water through the soil ceases (defined at capillary pressure of 0.33 bars); and
- wilting point, WP, the volumetric water content below which evapotranspiration of water from the soil ceases (defined at a capillary pressure of 15 bars).

Typical soil moisture retention properties for different soil texture classes are shown on Figure I-5. Numerous hydrology reference manuals contain the above information.

Figure I-5 Soil Moisture Retention Properties by Soil Texture Class (Schroeder et al. 1994)



I-2.3.2 Infiltration

The Green and Ampt (1911) method for infiltration is employed with the initial soil moisture deficit calculated in GoldSim based on the current water content in the soil layer. The concept of the Green and Ampt method is that infiltration is limited by the rate of downward travel of a saturated “wetting front” through an unsaturated soil layer. The method is described in detail in a number of hydrology reference books and is not restated here. This method lends itself well to a soil moisture accounting model.

I-2.3.3 Percolation

Percolation from the Soil Storage zone into the Groundwater Layer 1 Storage is based on unsaturated flow theory, as described in the Hydrologic Evaluation of Landfill Performance (HELP) technical reference manual (Schroeder et al. 1994). The equation for unsaturated flow was developed by Campbell (1974) as follows:

$$K_u = K_s * \left(\frac{\theta - \theta_r}{\varphi - \theta_r}\right)^{3+\frac{2}{\lambda}}$$

where:

K_u is the unsaturated hydraulic conductivity in mm/hr
K_s is the saturated hydraulic conductivity in mm/hr
θ is the actual water content of the soil
φ is the porosity of the soil
θ_r is the residual saturation water content of the soil
λ is the pore-size distribution index

K_s and φ are model inputs, while the Model uses the input WP and FC to calculate θ_r and λ. θ tracks the soil moisture, which varies throughout the simulation.

θ_r of the soil is first calculated based on WP using the following equation:

$$\theta_r = \begin{cases} 0.014 + 0.25\,WP & for\ WP \geq 0.04 \\ 0.6\,WP & for\ WP < 0.04 \end{cases}$$

The pore-size distribution index, which is essentially the log-slope of the soil water retention curve, can be calculated from WP and FC using their respective capillary pressures (0.33 bars and 15 bars), as discussed by Schroeder et al. (1994). The equation presented by Schroeder et al. is rearranged below and used to directly calculate λ in the GoldSim model:

$$\lambda = \ln\left(\frac{FC - \theta_r}{WP - \theta_r}\right) / \ln\left(\frac{15}{0.33}\right)$$

I-2.4 Evapotranspiration

Reference potential evapotranspiration (ET_0) is calculated using a modified version of the Hargreaves equation (Hargreaves and Samani 1985).

$$ET_0 = 0.0023\,(\theta_x - \theta_n)^{0.5}(\theta_a + 17.8°C)R_a/\lambda$$

where:

ET_0: Reference potential evapotranspiration, mm/day
$\theta_x, \theta_n, and\ \theta_a$: maximum, minimum and average daily air temperature, respectively, °C
R_a: Extraterrestrial solar radiation, MJ/m^2/day
λ: Latent heat of vaporization, MJ/kg

R_a is calculated based on site latitude and time of year.

Potential evapotranspiration (PET) is calculated as ET_0 multiplied by a "crop" coefficient to represent the enhancement of evaporation by vegetation.

Actual evapotranspiration (AET) is the amount of evaporation that leaves the soil and is limited by the amount of water available in the soil for evaporation. AET from the soil is zero when the moisture content in the soil is below the wilting point, equal to PET when the moisture content is at or above field capacity, and linearly interpolated when between wilting point and field capacity. AET from canopy storage and from surface storage is always equal to PET while there is water available to evaporate.

I-2.5 Groundwater

Water that infiltrates through the soil layer enters the "Groundwater Layer 1 Storage" and is released to surface water, usually over a period of days to weeks, or percolates into the "Groundwater Layer 2 Storage" and is released over a period of weeks to months. Baseflow recession constants are used to calculate the rate of release from groundwater to surface water. A recession constant of 0.7 day^{-1}, for example, means that 30% of the stored volume is released each day, and 70% is retained. An illustration of the baseflow recession curves for typical recession constants is in Figure I-6, typical values are presented in Table I-3.

Figure I-6 Illustration of Groundwater Recession Equations

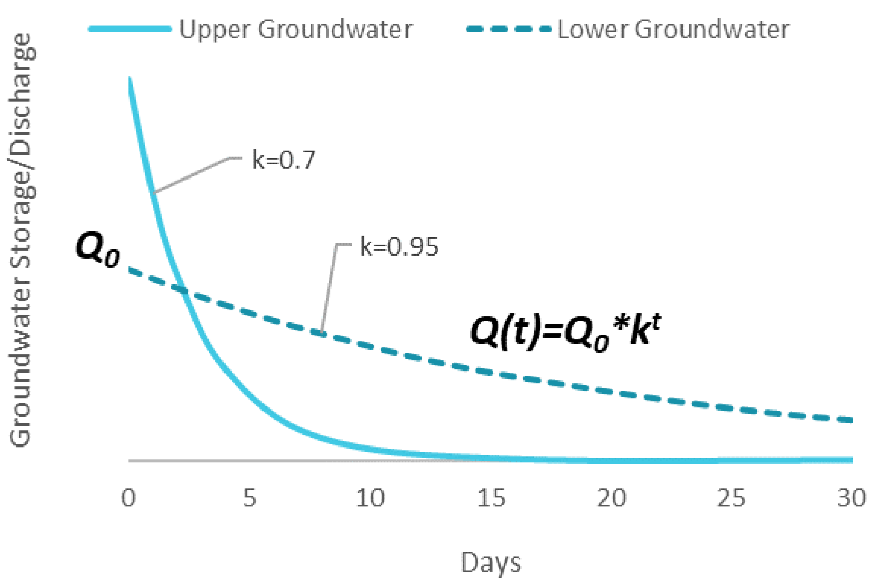


Table I-3 Typical Groundwater Recession Constants

Flow Component	Recession Constant, Daily
Groundwater	0.95
Interflow	0.8 to 0.9
Surface runoff	0.3 to 0.8

Source: USACE (2000); Pilgrim and Cordery (1992).

I-2.6 Subcatchment Areas

Hydrologic modelling parameters, catchment areas, and catchment elevations can be entered for up to four different subcatchments within the watershed. This can be used to model a number of elevation bands within a single catchment area, or various land use types.

I-3 RESULTS

Key results, where to find them, and notes on how they are calculated, are as follows:

Table I-4 Key Results

Result	Location on Dashboards	Calculation Notes
All daily/monthly climate and watershed results	Watershed Types\ 1991 to 2020 Monthly SMA All Flows	Provides detailed results for selected watershed, set “Period” to Minor for daily results, or to Major for monthly results.
Select daily/monthly climate and watershed results	Watershed Types\1991 to 2020 Monthly SMA Graph	Provides detailed results for selected watershed, set “Period” to Minor for daily results, or to Major for monthly results.
Modelled versus measured snowpack	Climate Inputs\Graph: Snowpack Validation	Only in Watershed Type 1.
Modelled versus measured discharge	Reservoir Inputs\Graph: Reservoir Validation	Outflow from reservoir (i.e., sum of Watershed Types 1 to 4). If no reservoir, set stage-storage values to be very low.
Monthly climate averages	Climate Inputs\1991-2020 Monthly Climate Averages	Calculates averages for the years specified in Array Label “Years”.
Annual climate totals	Climate Inputs\ 1991-2020 Annual Climate Totals	Calculates totals for the years specified in Array Label “Years”.
Annual maximums	Climate Inputs\Annual Maximums\...	1-day and 7-day maximums for precipitation, rain, rain-on-snow, and snow accumulation for the years specified in Array Label “Years”.

I-4 CASE STUDIES

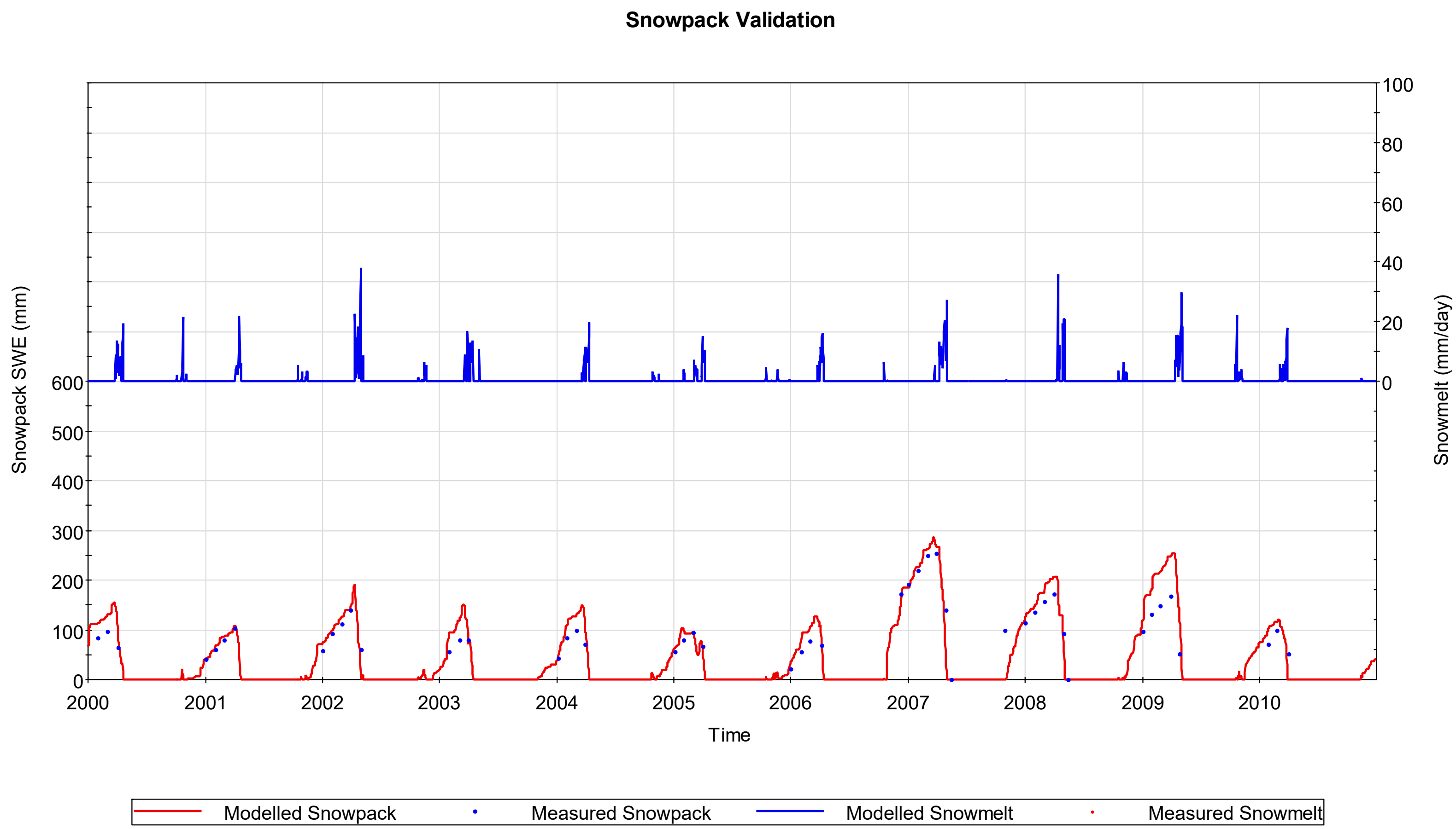
The Model was applied to two case studies: the Tsilcoh River and Buck Creek, both in central BC. For each case study, several hydrologic parameters were calibrated until a good fit with measured data (snow course and streamflow) was achieved.

Table I-5 summarizes the final hydrologic model input parameters that were used for each of the two case studies. Comparisons of measured versus modelled snowpack and streamflow for the two case studies are shown in Figure I-7 to Figure I-10.

Table I-5 Key Hydrologic Model Input Parameters

Parameter	Calibrated Value for Tsilcoh River, BC	Calibrated Value for Buck Creek, BC
Precipitation and Temperature		
Precipitation-Elevation Relationship	+6.7%/100m	+6.7%/100m
Temperature-Elevation Relationship	-0.65°C/100m	-0.65°C/100m
PAS Threshold	1.0°C	1.0°C
Snow Accumulation and Melt		
UBCWM Melt factor	3 mm/day/°C	3 mm/day/°C
SNOW-17 TIPM	0.5 day^{-1}	0.5 day^{-1}
SNOW-17 Negative Melt Factor	1.0 mm/day/°C	1.5 mm/day/°C
Canopy and Depression Storage		
Canopy Storage	10 mm	10 mm
Depression Storage	5 mm	5 mm
Soil Storage Zone		
Soil Depth	500 mm	500 mm
Saturated hydraulic conductivity	2.5 mm/hr	2.5 mm/hr
Porosity	0.43	0.43
Field Capacity	0.321	0.321
Wilting Point	0.221	0.221
Green-Ampt Suction Head	-200 mm	-200 mm
Green-Ampt Soil Moisture Deficit	Calculated from soil moisture accounting	Calculated from soil moisture accounting
Evapotranspiration		
Site Latitude	54.63°N	54.2°N
PET "Crop" Coefficient	0.8	1.0
Groundwater Layers 1 and 2 Storage		
Groundwater Layer 1 Percolation Rate	0.5 mm/day	1.5 mm/day
Groundwater Layer 1 Recession Constant	0.92 day^{-1}	0.85 day^{-1}
Groundwater Layer 2 Percolation Rate	0 mm/day	0 mm/day
Groundwater Layer 2 Recession Constant	0.99 day^{-1}	0.97 day^{-1}

Figure I-7 Snow Accumulation and Melt Benchmarking – Tsilcoh River



Note: Snowmelt measurements do not exist for the Burns Lake Snow Course Station 1A16 which is the reference station for the Tsilcoh River catchment.

Figure I-8 Snow Accumulation and Melt Benchmarking – Buck Creek

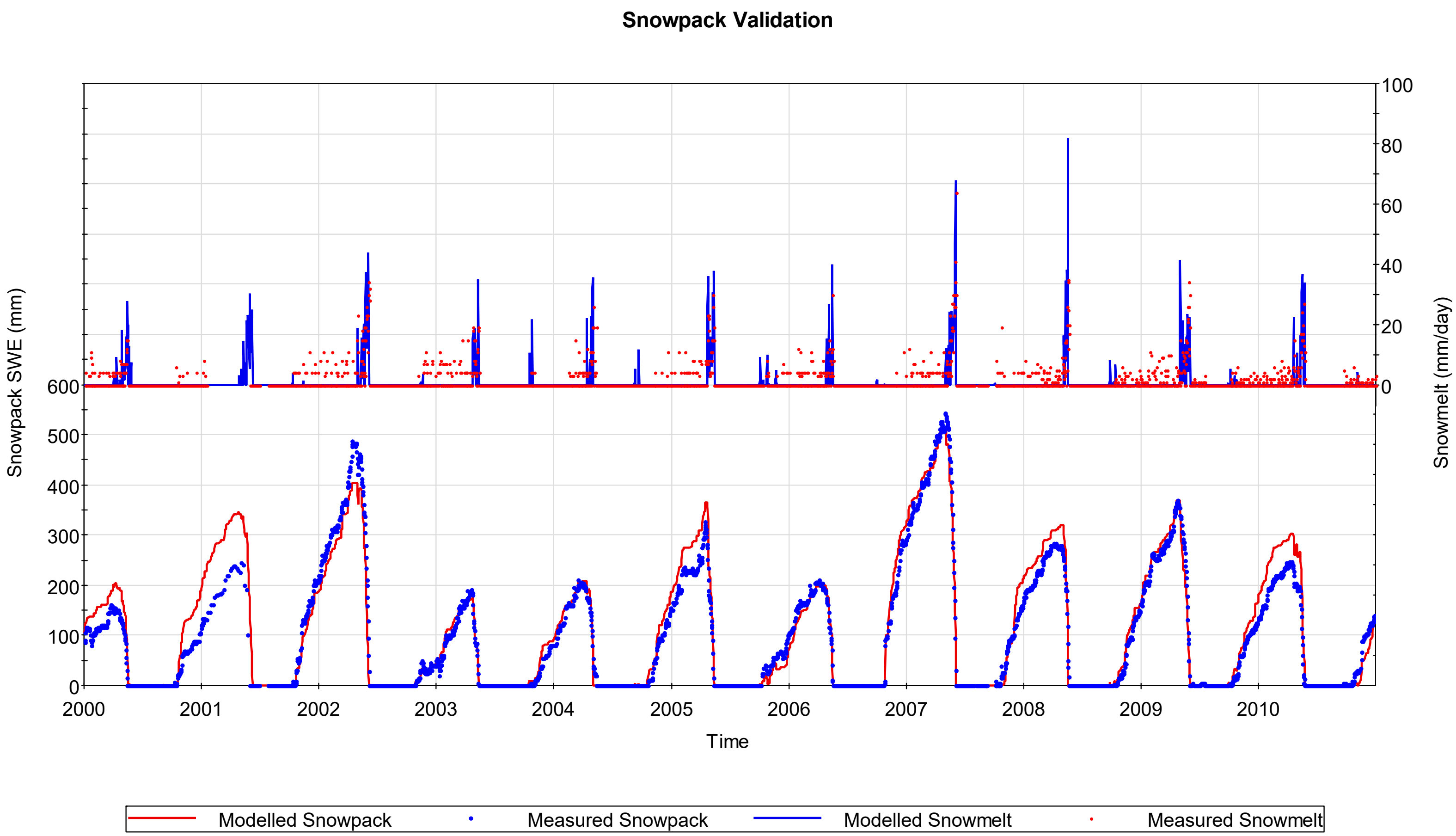


Figure I-9 Flow and Water Level Benchmarking – Tsilcoh River

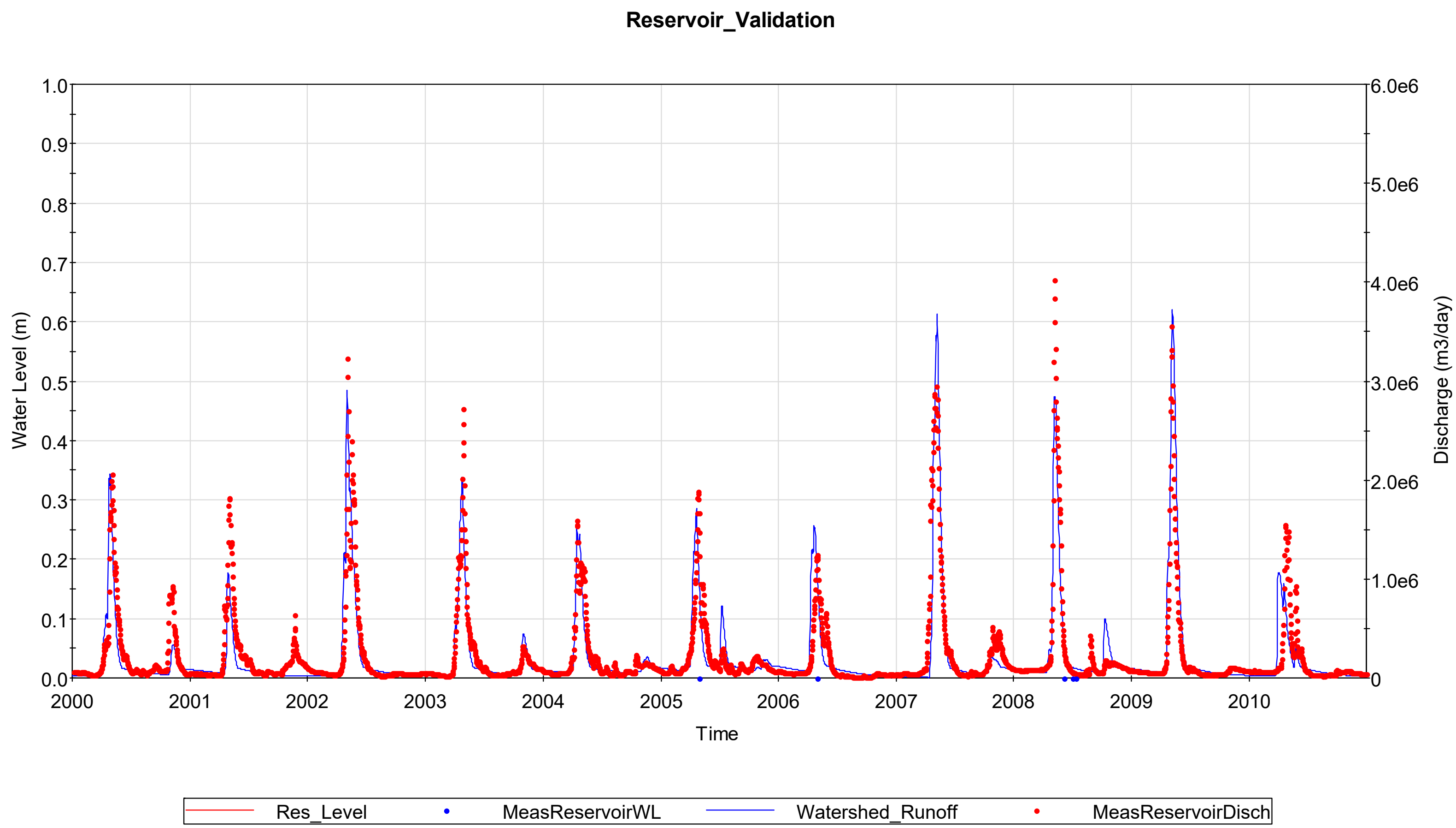
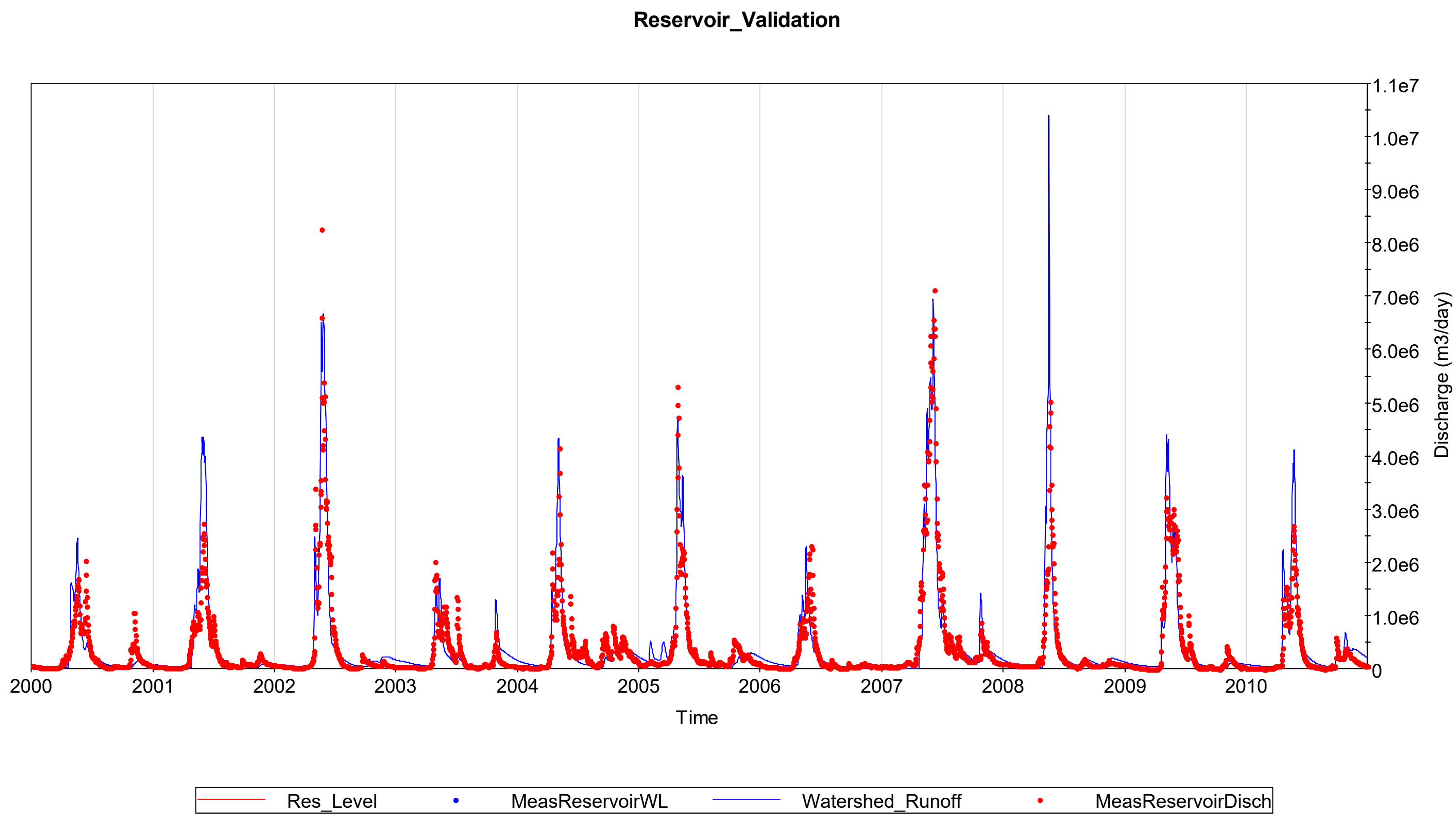


Figure I-10 Flow and Water Level Benchmarking – Buck Creek



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APPENDIX VI

Quantifiable Performance Objectives

Appendix VI
Quantifiable Performance Objectives

Quantifiable Performance Objectives for the Pinchi Lake Mine Tailings Storage Facility are as follows.

VI-1 PIEZOMETERS

The threshold levels established for piezometers are based on stability analysis and are summarized in Table VI-1. Threshold level exceedances will be reviewed by the Engineer of Record, and further action will be advised based on subsequent engineering analysis.

Table VI-1 Threshold Levels for Piezometers

Piezometer ID	Serial	Threshold Value (Piezometric Elevation in metres)
DH16-01-VWP1	VW38610	736.1
DH16-01-VWP2	VW38611	736.1
DH16-02-VWP1	VW38608	738.5
DH16-02-VWP2	VW38609	738.5
DH16-03-VWP1	VW38606	737.0
DH16-03-VWP2	VW38607	737.0

VI-2 SURVEY MONUMENTS

Alert criteria for displacement of survey monuments on the embankment are as follows (read on a 10-year frequency basis):

- Vertical displacements over ten years greater than 70 mm.
- Horizontal displacements over ten years, perpendicular to the embankment alignment, greater than 70 mm.
- A continuing trend of movement with cumulative displacements of the embankment in a credible (i.e., plausible) direction greater than 100 mm, relative to the baseline readings.