June 30, 2015 Reference No. 1214280022-018-L-Rev0-11000

Dave Ryder
Senior Environmental Coordinator, Legacy Properties
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Kimberley, BC
V1A 1C7

**RESPONSE TO MINISTRY OF ENERGY AND MINES MEMORANDUM DATED FEBRUARY 3, 2015 REGARDING THE BEAVERDELL TAILINGS FACILITIES**

Dear Mr. Ryder,

## 1.0 INTRODUCTION

The findings of expert review panel (IEEIRP 2015) of the August 4, 2014, Mount Polley tailings dam failure has prompted the British Columbia Ministry of Energy and Mines (BC MEM) to request review of the design and operations of all tailings dams in BC. In a memorandum dated February 3, 2015, the BC MEM directed all mines in BC, including Beaverdell, to undertake an assessment to determine if the dams associated with the tailings facilities on site may be at risk due to:

1) undrained shear failure of silt and clay foundations;

2) water balance adequacy; and

3) filter adequacy.

Each identified risk included a list of specific items to be addressed (BC MEM 2015).

This letter response addresses the three identified risks and their associated list of specific items outlined in the BC MEM February 3, 2015, memorandum for the tailings storage facilities at Teck Resources Limited's (Teck) closed Beaverdell site. As requested by the BC MEM, the numbering system in this response is consistent with that presented in the BC MEM memorandum. Background information about the tailings facility is also included for reference.

This letter should be read in conjunction with the attached ***Study Limitations***.

## 2.0 BACKGROUND INFORMATION

The Beaverdell Mine is a permanently closed facility under active care and maintenance, with no current or planned mining activities. The primary remaining facilities from the mining development include the tailings management facilities (TMFs) which consist of a series of tailings deposition ponds located to the west of the community of Beaverdell, across the West Kettle River. The TMFs are divided into two major components, the South TMF and the North TMF.

The South TMF consists of an earthfill dam with a maximum height of about 9 m. It is understood to have been developed using a downstream construction technique. The South TMF consists of five tailings cells (Ponds 1 to 5) contained by the South TMF Dam, which is located mainly to the south and east sides of the facility.

The North TMF consists of an earthfill dam with a maximum height of about 12 m. It is understood to have been developed using a downstream construction technique. The North TMF consists of two cells (Ponds 6 and 7) contained by the North TMF Dam, which is located mainly to the south, east, and north sides of that facility.

Initial construction of the South TMF was presumably concurrent with the opening of the Beaverdell mill in the 1950s. At the time, the site was owned by Highland Bell Limited and Leith Gold Mines Limited. There is no historical information available that describes the design, construction details, or operation of Ponds 1, 2, or 3.

Beaverdell Mine was acquired by Teck Corporation Limited in 1969. A stability report by Robert F. Binnie Ltd. (Binnie 1971) includes observations on the operations of Pond 4 and assumed design details based on discussions with mine personnel at the time.

Pond 5 of the South TMF and the North TMF (Pond 6 and 7) were constructed after Teck Corporation Limited obtained the property. Ponds 5, 6, and 7 were designed by Robert F. Binnie Ltd. (Binnie 1973, 1980a,b, 1988a). Pond 7 of the North TMF is only partially filled with tailings.

Beaverdell Mine was permanently closed in 1991.

The embankment dams were classified as low consequence structures by the BC MEM in 2003 (BC MEM 2003) and updated to significant structures as reported in Golder (2013). Golder Associates Ltd. (Golder) has recently become the Engineer of Record for the Beaverdell TMFs. Golder's first involvement with the TMFs was the dam safety review inspection, completed in 2012 (Golder 2013). A full listing of recently available background information is provided on the references page.

## 3.0 RESPONSE TO MEM ORDER

### 1. Risk Due to Undrained Shear Failure of Silt and Clay Foundations

The available site investigation information for the Beaverdell TMFs is limited. Glacio-lacustrine silt and clay deposits may be present beneath TMFs based on a desktop geomorphological assessment using LiDAR survey and orthophotos of the site. The risk of a static undrained shear failure of the foundation is considered to be low as no additional static loading is planned.

**a) Including a determination with respect to whether or not similar foundation conditions [to those found at the Mount Polley site] exist below the dams on your site.**

Based on the limited subsurface site investigation records, the site is understood to be underlain by a variable thickness of alluvial sand and gravel. Soil units under the sand and gravel are unknown. Bedrock outcrops are present west of Pond 7.

Based on the geomorphological assessment using LiDAR survey and orthophotos of the site, possible glacio-lacustrine deposits could exist in the area; however, deposits have not been confirmed in the area of the TMFs. It is possible that glacio-lacustrine units could be present beneath the alluvial sand and gravel that the TMFs are founded on. The available construction and design records do not include any mention of silt or clay layers found during investigations or construction of Ponds 5, 6, or 7.

**b) Whether or not sufficient site investigation (drill holes, etc.) has been completed to have confidence in this determination.**

Known site investigations for each pond include the following:

- Pond 1: no known site investigations, conditions inferred;
- Pond 2: no known site investigations, conditions inferred;
- Pond 3: no known site investigations, conditions inferred;
- Pond 4: samples taken from existing dam, conditions as described by site personnel (Binnie 1971);
- Pond 5: surface and subsurface soil samples for gradation testing (Binnie 1973);
- Pond 6: surface soil samples for gradation testing (Binnie 1980a); and
- Pond 7: three test pits, samples taken for gradation testing (Binnie 1988a).

Construction of Ponds 5, 6, and 7 consisted of excavation of the centre of the pond area to source material for construction of the dams.

There appears to be insufficient subsurface investigation at depth to confirm whether or not glacio-lacustrine or other silt or clay units are present beneath the fluvial sand and gravel deposit.

**c) If present, whether or not the dam design properly accounts for these materials.**

The dam design accounts for the fluvial sand and gravel deposits, but does not appear to account for any potential silt and/or clay units that may be present beneath the dams of the TMFs.

### d) If any gaps have been identified, a plan and schedule for additional subsurface investigation.

Site subsurface conditions beneath the surficial alluvial sand and gravel unit are unknown.

A number of historical reports were made available by the BC MEM in June 2015. The reports identified engineers from R.F. Binnie & Associates Ltd. who were involved with the design and annual inspections of the TMFs. R.F. Binnie & Associates Ltd. may have additional reports that could provide subsurface information. Teck should contact R.F. Binnie & Associates Ltd. and request they review their historical files and provide any available data regarding the Beaverdell Mine Site TMFs.

The Beaverdell TMFs are in the Closure - Active Care Phase, as per the Canadian Dam Association (CDA) definition (CDA 2014) and there are no plans to re-start tailings operations or raise the tailings dams. A risk informed approach to the analysis and assessment of dam safety is considered an appropriate approach and consistent with CDA Dam Safety Guidelines (CDA 2013). Teck should undertake a design review based on this approach within the next year.

## 2. Risk Due to Water Balance Adequacy

The Beaverdell TMFs are in the Closure - Active Care Phase, per the Canadian Dam Association (CDA) definition (CDA 2014).

The water balance for the tailings facility is relatively simple as most of the flow into the tailings facility is from direct precipitation and runoff from a very small adjacent watershed. Accumulated surface water may be conveyed to the receiving environment through percolation (seepage) or is lost to the atmosphere through evaporation. Pond 1 potentially allows some surface water to flow downstream of the South TMF, however there is no evidence this has occurred since the mine closed. Plans are in place to redirect this surface water to Pond 5 in accordance with recommendations in the dam safety review (Golder 2013) and the dam safety inspections (Golder 2014a,b).

### a) Including the total volume of surplus mine site water (if any) stored in the tailings storage facility.

No surplus mine water is stored in the TMFs. The Beaverdell Mine is closed.

### b) The volume of surplus mine water that has been added to the facility over each of the past five years.

No surplus mine water has been added to the TMFs in the last five years. The Beaverdell Mine was closed in 1991.

### c) Any plans that are in place or that are under development to release surplus mine water to the environment.

Teck personnel report that there are no plans in place or under development to discharge surplus mine water from the tailings facility to the environment.

### d) Recommended beach width(s), and the ability of the mine to maintain these widths.

As the TMFs are in Closure - Active Care Phase with no plans to add tailings, beach widths recommendations do not apply.

### e) The ability of the TSF embankments to undergo deformation without the release of water (i.e., the adequacy of the recommended beach width).

There is low volume of stored free water contained within the TMFs at Beaverdell. A small volume of water contained in a shallow pond is seasonally present in Pond 4 and Pond 6. Deformation of the TMF dams would not be expected to result in a release of a significant volume of water.

### f) Provisions and contingencies that are in place to account for wet years.

There are no structures for the release of flow to the environment from the South TMF, and outflows to the receiving environment from the North TMF may take place through the spillway at Pond 7 as described in the Operation, Maintenance and Surveillance (OMS) plan and Emergency Preparedness Plan (EPP) for the closed Beaverdell Mine site (Golder 2014c). The inflow design flood is expected to be retained within the South TMF, however survey of Pond 3 should be completed to confirm the available storage volume.

### g) If any gaps have been identified, a plan and schedule for addressing these issues.

Survey of Pond 3 should be completed to confirm the available storage volume.

## 3. Risk Due to Filter Adequacy

Based on review of the available reports, it is understood that the dams were constructed of locally borrowed free-draining sand and gravel materials. The design reports considered a coarse tailings beach adjacent to the sand and gravel dams which were required to act as a filter for the slimes (fine fraction of tailings). Filter compatibility between the coarse tailings and the sand and gravel dam section was defined graphically by multiplying the gradation of the coarse tailings by a factor of five (Binnie 1973).

The CDA (2007) recommends alternative filter specifications based on Sherard et al. (1984) and Sherard and Dunningan (1989), which recommend the following filter $D_{15}$ for sandy silts, such as the slimes:

$$D_{15(filter)} = 0.7 \text{ mm}$$

Therefore, the coarse tailings (beach) should have a $D_{15}$ no greater than 0.7 mm to act as a filter for slimes.

The sand and gravel dam section must also be filter compatible with the coarse tailings (beach). Sherard et al. (1984) and Sherard and Dunningan (1989) recommend the Terzaghi (1922) method shown below for sand and gravel base soils, such as the coarse tailings beach.

$$D_{15(filter)} / d_{85(base)} \leq 4$$

The CDA (2007) further recommends that suffusion be considered based on an assessment of internal stability of the filter.

The available gradations of sand and gravel understood to be used for the dam are generally not considered to be susceptible to internal erosion, however some gradations were found to not meet the criteria. Due to the current low hydraulic gradients, internal erosion is considered a low risk.

### a) Including the beach width and filter specifications necessary to prevent potential piping.

A wedge of coarse tailings (beach) was identified as necessary to act as a filter for the slimes for Pond 5 (Binnie 1973), Pond 6 (Binnie 1980a), and Pond 7 (Binnie 1988a), but the minimum dimension of the beach was not identified.

The $D_{15}$ size of sand and gravel samples used for construction of the dam section were as follows:

- Pond 5: 0.25 to 0.5 mm;
- Pond 6: 0.4 to 0.8 mm; and
- Pond 7: less than 0.1 to 1.3 mm.

The coarse tailings wedge (beach) therefore had to develop a $d_{85}$ of at least the following to be filter compatible with the coarsest sand and gravel material:

- Pond 5: 0.13 mm;
- Pond 6: 0.20 mm; and
- Pond 7: 0.32 mm.

To provide adequate filter compatibility with the slimes the coarse tailings wedge (beach) also had to develop a $D_{15}$ no greater than 0.7 mm.

The internal stability of the filter was assessed based on the Li-Fannin criteria, an update to the original Kenney-Lau criteria (Kenney and Lau 1985; Li et al. 2009). The available gradations of sand and gravel understood to be used for the dams of Ponds 4, 5 and 6 generally met the updated Li-Fannin criteria although 2 samples from Pond 6 were assessed as being marginal. Three of four samples from Pond 7 did not meet the criteria. Therefore portions of the constructed dam may be susceptible to internal erosion if there is sufficient hydraulic gradient.

Ponds 1, 2, 3, and most of Pond 4 are believed to have been operated such that no wedge of coarse tailings was developed. Tailings may have migrated into the dams of these ponds; the dams are assumed to have been constructed with the alluvial sand and gravel found on site.

The TMFs are no longer active and there is very little free water contained within the Beaverdell TMFs. A small, shallow pond is occasionally present in Pond 4 and a damp area was noted in the centre of Pond 6 during the 2015 site inspection. Due to the expected drained, non-saturated condition of the tailings within the TMFs and the sand and gravel dams, it is believed there is limited hydraulic gradient that would drive a potential piping failure.

## b) Whether or not the filter has been constructed in accordance with the design.

There are no known design or construction records for Ponds 1, 2, or 3. Binnie (1971) indicates that Pond 4 experienced tailings migration through the dam section during the winter of 1970/1971. In response to this event, coarse rock was placed on the downstream slope of a section of the Pond 4 dam and operations were change to spigotted deposition to deposit coarse tailings against the upstream slope and push the slimes toward the centre of the facility (Binnie 1971). Samples of the gravels used for construction of Pond 4 were taken (Binnie 1971). Binnie (1973) followed up on the tailings deposition recommendations from 1971 and tailings samples were taken from Pond 4 to compare the gradation of tailings deposited near the dam faces against the unsegregated tailings. The tailings against the upstream face were found to contain less fines than the unsegregated tailings, which confirmed a wedge of coarse tailings was being successfully developed to act as a filter. The remedial measures directed in Binnie (1971) were determined to have been successful (Binnie 1973).

Available records indicate that design reports for Ponds 5, 6, and 7 required that operations create a wedge of coarse tailings against the upstream slope of the TMF dams to act as a filter for the slimes. Samples of the tailings were taken once deposited to confirm the coarse tailings wedge (beach) was being created and spigotting methods were observed (Binnie 1980a, 1983, 1988a).

Charts 1, 2, 3, and 4 show the gradations of the sand and gravel material that were used to construct the dam section, the coarse tailings wedge (beach) developed to filter slimes, and the unsegregated tailings or slimes for each of Ponds 4, 5, 6, and 7, based on gradations of samples taken (Binnie 1971, 1980a, 1983, 1988a).

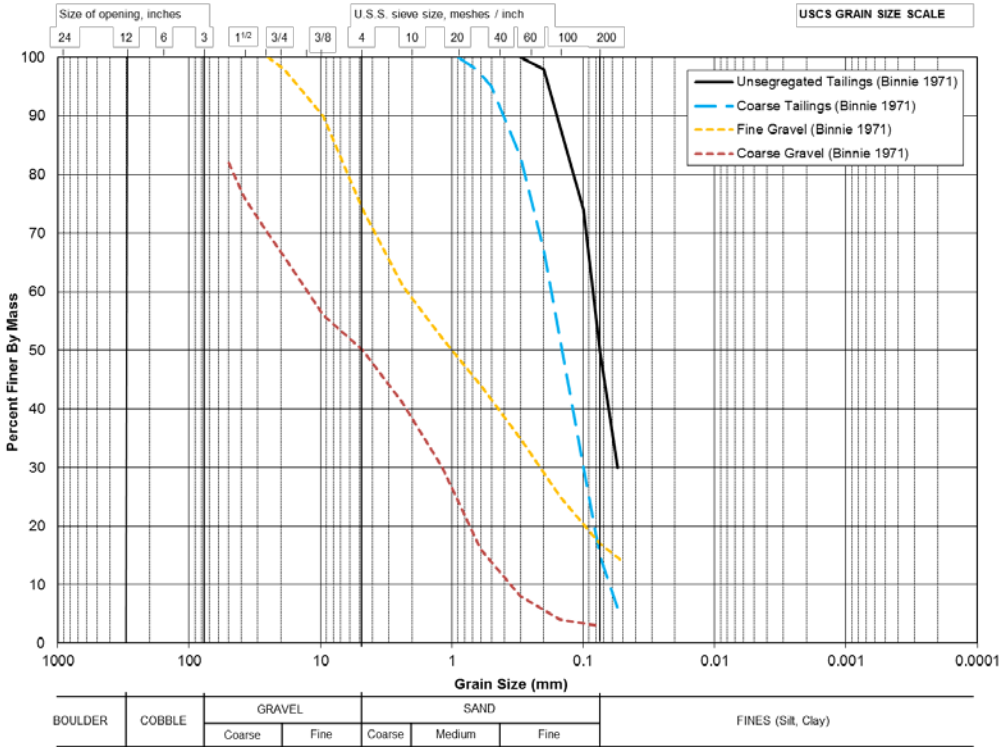



*Chart 1: Pond 4 Gradations for Filter Compatibility Comparison*

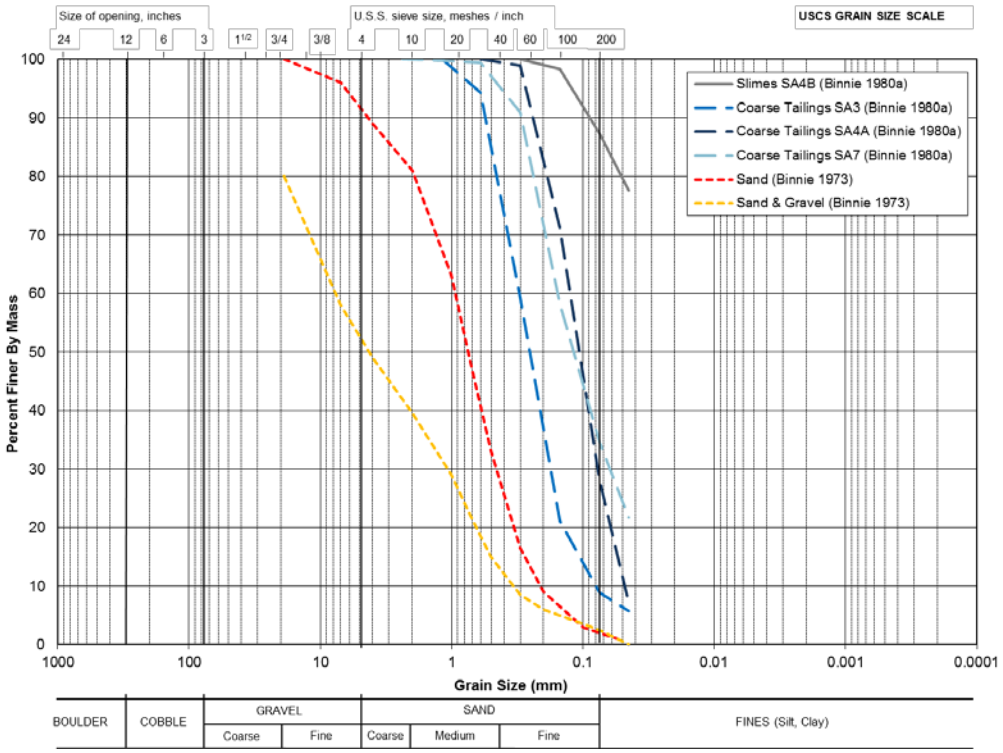



*Chart 2: Pond 5 Gradations for Filter Compatibility Comparison*

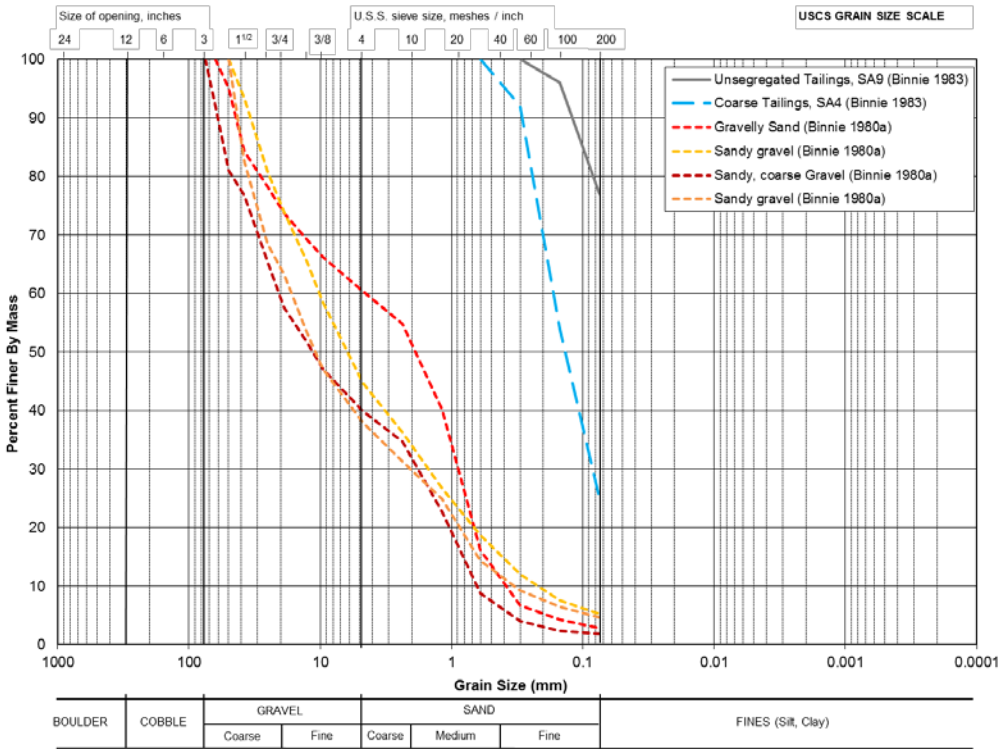



*Chart 3: Pond 6 Gradations for Filter Compatibility Comparison*

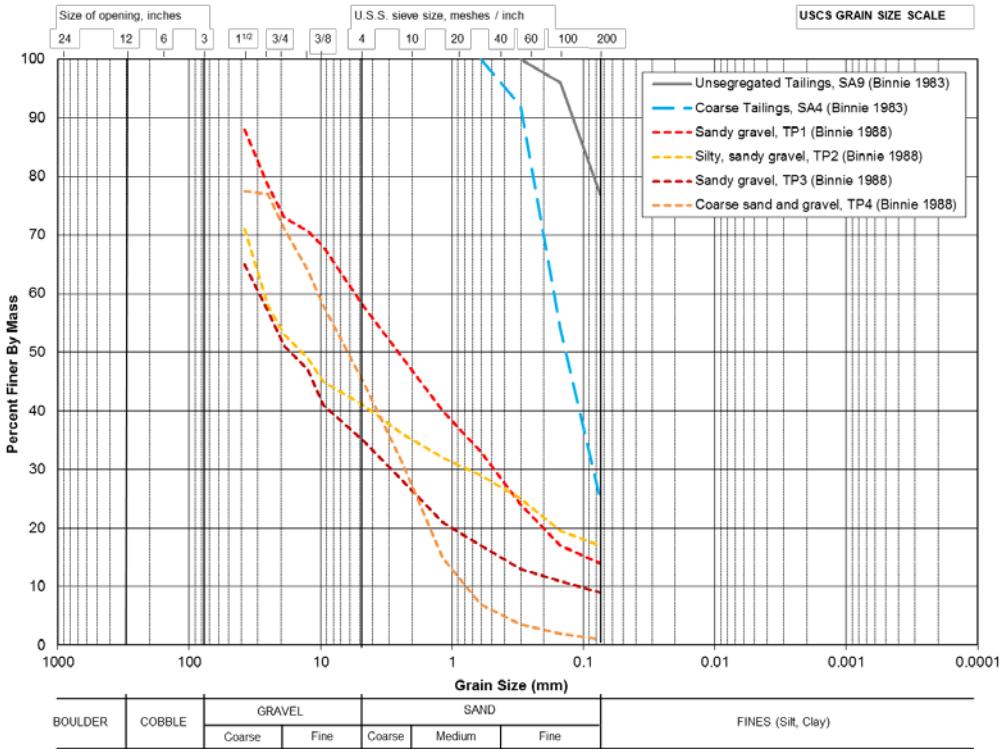



*Chart 4: Pond 7 Foundation/Dam Section Gradations and Pond 6 Tailings Gradations for Filter Compatibility Comparison*

Gradations of the coarse tailings (beach) are filter compatible with the gradations of the slimes for samples taken in Ponds 4, 5, 6, and 7.

Gradations of the coarse tailings (beach) are filter compatible with the gradations of the sand and gravel dam for all samples taken except for the coarse sand and gravel from test pit (TP) 4 in Pond 7. However, Pond 7 was never filled with tailings, so this gap represents a low risk for piping failure.

### c) If any gaps have been identified, a plan and schedule for addressing these issues.

The filter compatibility of Ponds 1, 2, and 3 is unknown. Pond 1, 2 and 3 dams are lower height than Ponds 4, 5, 6 and 7. If Ponds 1 and 2 were to experience filter compatibility related issues, any failure or piping would flow to Pond 5 and/or to Pond 4.

Some sand and gravel gradations for Ponds 4, 5, 6 and 7 are susceptible to internal stability. Foundations below the dams have not been confirmed.

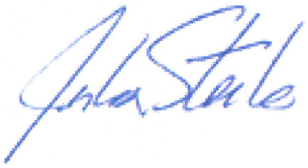
Due to the expected drained, non-saturated condition of the tailings within all ponds and the sand and gravel dams of the TMFs, it is believed that there is typically insufficient hydraulic gradient to drive a potential piping failure. A risk informed approach to the analysis and assessment of dam safety is considered an appropriate approach and consistent with CDA Dam Safety Guidelines (CDA 2013). Teck should undertake a design review based on this approach within the next year.

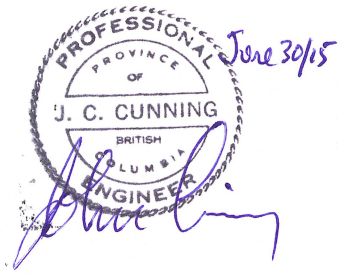
## 4.0 CLOSURE

We trust this letter satisfies your current requirements. The reader is referred to the Study Limitations, which follows the text and forms an integral part of this memorandum. If you have any questions or require further assistance, please do not hesitate to contact the undersigned.

Yours very truly,

**GOLDER ASSOCIATES LTD.**



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JMS/JCC/kp/bb

Attachment: Study Limitations

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## STUDY LIMITATIONS

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