June 29, 2015 Reference No. 1528359-2015-072-L-Rev0-1000

Mr. Mark Slater
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Greenhills Operations
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Sparwood, BC
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RESPONSE TO MINISTRY OF ENERGY AND MINES MEMORANDUM DATED FEBRUARY 3, 2015, REGARDING THE GREENHILLS OPERATIONS TAILINGS STORAGE FACILITY

Dear Mr. Slater,

1.0 INTRODUCTION

The findings of expert review panel (IEEIRP 2015) of the August 4, 2014, Mount Polley tailings dam failure has prompted the BC 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 Greenhills Operations (GHO), 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 addresses the three identified risks and their associated list of specific items for the tailings storage facility at Teck Coal Limited's (Teck Coal) GHO. As requested by BC MEM, the numbering system for each item 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 GHO tailings facility is retained to the southeast by the Main Tailings Dam and to the west by the West Tailings Dam. The facility impounds approximately 13.1 million m^3 of tailings and approximately 2.4 million m^3 of free and entrained water. The original design of the Main Tailings Dam was carried out by Hardy Associates Ltd. for the former owner Westar Mining Ltd. The design for the West Tailings Dam was completed by Golder Associates Ltd. (Golder) in 1993 (Golder 1993). To increase the storage capacity of the tailings pond, designs for several phases of raises of the Main and West dams have been prepared by Golder (Golder 1994, 2005, 2013). The dams are both downstream constructed, zoned earthfill dams with ultimate design crest elevations of 1,735 m (maximum dam height of about 58 m).

The Main Dam currently has a crest length of approximately 750 m, varies from 10 m to 50 m in height, and has a minimum crest elevation of 1,727.5 m as of October 2014. Coarse refuse spoils have been constructed on the downstream side of the Main Dam. The presence of these spoils acts to buttress the dam and increase its factor of safety against instability.

The West Dam currently has a crest length of approximately 390 m, a maximum height of 16 m and a minimum crest elevation of 1,726.6 m as of October 2014.

3.0 RESPONSE TO MEM ORDER

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

As described below, sufficient site investigation information is available to be confident that glacio-lacustrine silt and clay is not present beneath Main Dam or West Dam of the GHO tailings facility. The possible presence of a thin layer of clay colluvium in part of the Main Dam foundation has been known for some time, and stability analyses considering this unit have been included in the design.

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.

George et al. (1986) report that glacio-lacustrine sediments can be found throughout the Elk Valley, usually below elevation 1,384 m. They are, however, found locally at higher elevations—up to 1,676 m in the northernmost reaches of the Elk Valley.

Hardy (1980) reports that the GHO Main Dam base is at elevation 1,677 m and Golder (1993) reports the West Dam base is at elevation 1,705 m.

It is therefore considered unlikely that glacio-lacustrine sediments would be present in the area.

<u>Main Dam Foundation:</u>

Based on geological mapping and the subsurface investigation data described in part b), the foundation conditions beneath the Main Dam are summarized as follows:

- Muskeg up to 3 m in thickness was found overlying the colluvium on the west end of the proposed dam site for the Main Dam.

- Colluvium, generally 1.5 to 2.0 m thick, but up to 8 m thick: Where the colluvium was predominantly clay, it was generally soft to stiff, whereas colluvium that was predominantly gravel or sand was generally dense to very dense (Hardy 1980).
- Very stiff/dense to hard/very dense glacial till greater than 28 m thick (borehole ended in till): Shale bedrock was encountered in boreholes 80-RA1 and 80-RA2 at depths of 12.5 and 12.2 m, respectively.

Glacio-lacustrine silts and clays have not been encountered in site investigations to date, and are not expected to be present based on geological mapping.

The design report indicated that unsuitable or soft materials with undrained strengths (Cu) less than 35 kPa were to be removed during foundation preparation (Hardy 1980). Documentation of the quality and quantity of the clay colluvium that was removed is unavailable.

It was identified that the quality and distribution of the colluvial clay that was potentially left in the foundation of the Main Dam was unknown. The potential for some such soils to have been left in place has been incorporated into the design, as described in Section 1c.

West Dam Foundation:

The foundation conditions are summarized as follows:

- variable fill (reworked colluvial clay, granular fill, or reworked glacial till with some organics) up to 8.8 m thick in borehole 92-13.
- colluvial clay up to 2.5 m thick, generally soft to firm.
- very stiff/dense to hard/very dense glacial till with thickness ranging from 0.8 m to greater than 7.6 m (borehole ended in till).
- siltstone bedrock.

Removal of superficial loose, soft, organic or other deleterious materials from the West Dam foundation footprint was carried out for foundation preparation in the dam footprint area on the west side of the mine road, and replaced with select free-draining material as reported in the 1998 Annual Tailings Dams Report (Golder 1999).

No foundation preparation beneath the mine road foundation was reported, but pockets of clay fill or colluvial clay would have been restricted to the upstream portion of the dam, and therefore not affect downstream stability.

Fill and colluvial clay were removed from the downstream toe of the existing West Dam during 2014 as part of ongoing dam raise construction. The resulting in situ foundation conditions beneath the new construction footprint (for elevation 1,735 m dam) are glacial till or bedrock.

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

<u>Main Dam Investigations:</u>

- Twenty boreholes at an approximate spacing of 150 m along the Main Dam crest were completed by Hardy (1980).
- An additional four boreholes were drilled into the underlying till during upgrades to the monitoring program by Golder (2005).

<u>West Dam Investigations:</u>

- Nine boreholes at an approximate spacing of 50 m along the West Dam crest were completed by Golder (1993).
- Eight boreholes and six test pits at an approximate spacing of 100 m along the West Dam crest were completed by Golder (2014).

The existing records of drill holes were examined for evidence of a glacio-lacustrine unit within the glacial till, with no evidence of a glacio-lacustrine unit nor layers of clay or silt being noted within the glacial till.

Sufficient site investigation has been completed to have confidence in the determination of the foundation conditions as discussed in Section 1a.

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

<u>Main Dam:</u>

Hardy (1980) completed both effective (drained analysis) and total stress (undrained analysis) stability analyses for Starter Dam and Main Dam to elevation 1,705 m.

Key assumptions used in the analyses were as follows:

- The muskeg and organics would be stripped prior to dam construction.
- The dam would be constructed on top of a "thin" layer of colluvium.
- For total stress analysis, the undrained shear strength (Cu) of the colluvial clay was assumed to be 45 kPa.

Golder completed effective (drained analysis) stability analyses for the Main Dam to elevations 1,725 m and 1,735 m (Golder 1994, 2005). The stability of the Main Dam met the minimum required factor of safety for the long-term (drained) case without considering the buttressing effect of the downstream coarse refuse spoil. In the short-term (undrained loading) case, analyses indicated that the factor of safety <u>without</u> considering the effect of the downstream coarse refuse spoils (Site C) is less than the 1.3 required by Canadian Dam Association (CDA) *Dam Safety Guidelines* (CDA 2013). However, the buttressing effect of the existing Site C spoils against the downstream face of the dam would result in a factor of safety than exceeds the minimum requirements for the short-term case.

West Dam:

The stability of the West Dam was assessed in the initial and subsequent design reports by Golder (1993, 1994, 2014), and recommendations on foundation preparation were provided. Construction field reports by Golder and Teck Coal GHO personnel indicate that all soft fills and colluvial clay have been removed from the 1,735 m elevation construction footprint of the West Dam, exceeding the design requirements, and the resulting in situ foundation conditions beneath the downstream footprint of the West Dam are glacial till or bedrock.

No foundation preparation beneath the original mine road foundation was reported, but pockets of clay fill or colluvial clay are restricted to the upstream portion of the dam, and therefore do not affect downstream stability.

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

Confirmation of the extent of buttressing effect required to exceed the minimum required factor of safety for short-term conditions will be performed as part of the 2015 dam safety inspection. No additional subsurface investigation is recommended.

2. Risk Due to Water Balance Adequacy

The water balance of the GHO tailings facility is included in the site-wide water balance (SWWB) model for GHO that was developed by Golder (2013). The water balance is calibrated against measured pond elevations, current and historical climate data, and available site and plant flow data. GHO uses the SWWB to support decisions on the optimization of water management practices at the mine site.

The water balance for the tailings facility is relatively simple as most of the flow into the tailings facility is from the coal processing plant. Flows of surface water into the tailings facility are limited to those from Upper Cousins Creek and the immediate catchment of the tailings facility. Surplus flows from other facilities are not redirected to the tailings facility.

The quantity of tailings solids are determined by periodic bathymetry readings provided by Teck Coal and the volume change is used to estimate the amount of water retained within the pore space of the deposited tailings.

Pond level and available freeboard in the tailings facility is monitored continuously, and an emergency plan is in place in the event of a high water level. As such, the tailings facility is not considered to be at risk due to the adequacy of the water balance.

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

For the purpose of this assessment, surplus mine water is defined as mine water redirected to a tailings facility for storage.

No surplus mine water is stored in the GHO tailings facility. The free water in the GHO tailings facility is required for the plant processes and is therefore not considered surplus. The total volume of free water in the tailings facility has been relatively consistent over recent years at about 1 million m^3.

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 GHO tailings facility in the last five years.

The estimated total free water in the pond in the last five years (excluding water entrained the pore spaces of the tailings) is shown in Chart 1.

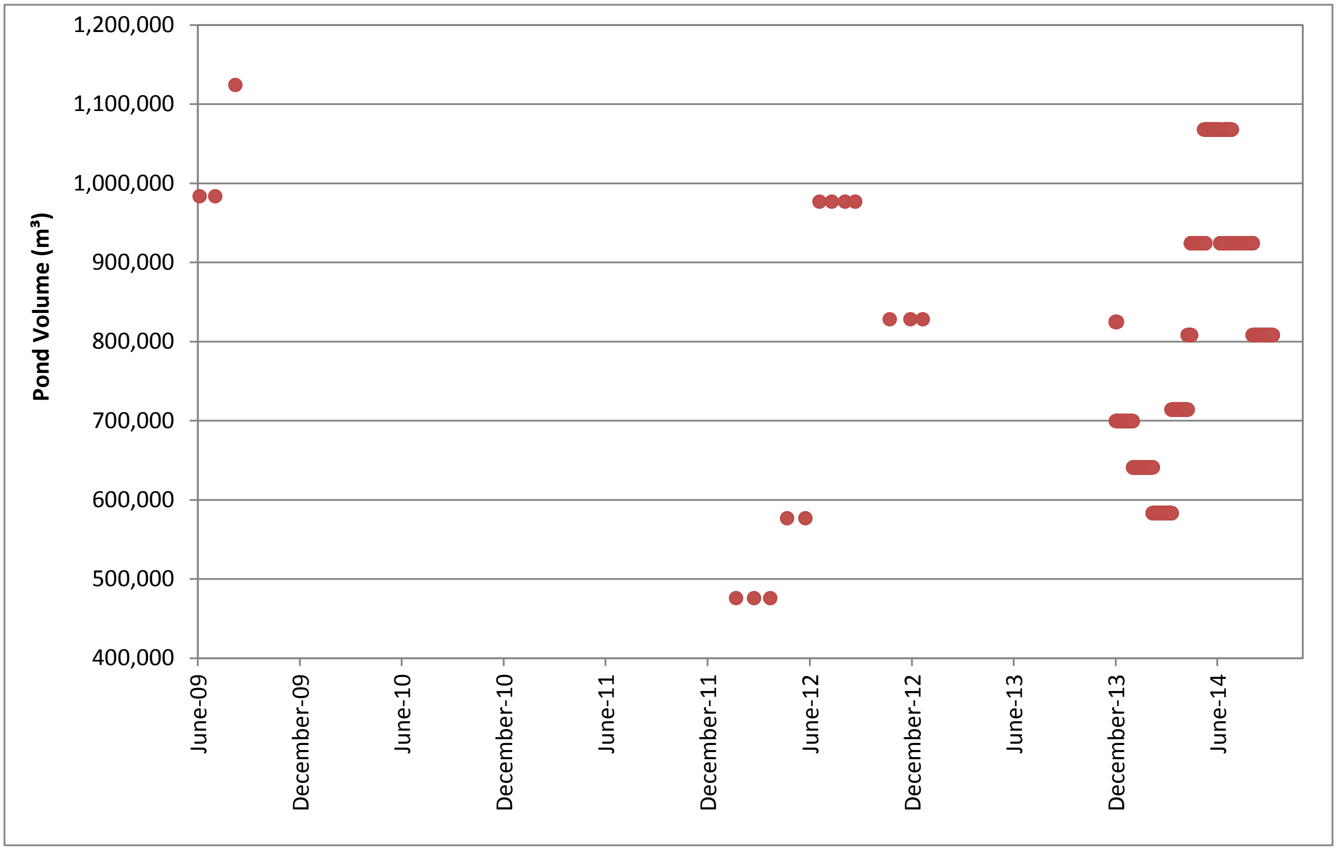

Chart 1: Observed Tailings Pond Free Water Volume Over Five Years

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

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

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

There is no minimum or recommended beach width. The dams are designed to accommodate the conditions of having water against the dams or having a tailings beach against the dams.

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

As noted above, this tailings facility does not have a minimum or recommended beach width. The dams are designed as water retaining structures, where containment of water is a provided by the freeboard and the integrity of the upstream clay blanket.

The standard pond operating level allows for 2.0 m of freeboard (measured vertically from lowest point of the dam crest to the pond elevation). Deformations in an earth dam can result from a new or increased load to the facility such as a raise or an externally imposed load by an earthquake. As the GHO tailings dams are being progressively raised, deformations associated with the construction are incorporated into the following raise, such that the minimum freeboard is not impacted. In the event of the design seismic event, settlement is predicted to be less than 0.05 m (Swaisgood 2003). Therefore, the freeboard is sufficient to accommodate potential deformations.

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

The SWWB model includes a deterministic mode which allows predictions for wet years (Golder 2013).

The Operation, Maintenance and Surveillance Manual for the tailings facility includes the levels of response that are triggered by rising water during an extreme precipitation and flood event. The responses to rising pond levels are summarized in Table 1.

Table 1: Summary of Pond Level Emergency Response

Freeboard (m)	Response	Notes
>2.0	■ Surveyed at least monthly	Typical operations, meets minimum freeboard as per CDA
1.2 to 2.0	■ Checked weekly ■ Direct surface water and site drainage away from tailings pond	Meets minimum freeboard as per CDA
0.6 to 1.2	■ Checked daily ■ Notify Senior Geotechnical Engineer ■ Direct recovered process water away from pond. ■ Notify Ministry of (Environment in Cranbrook for invoking emergency discharge clause in GHO effluent permit PE-6248 ■ Discharge tailings pond water by pump and/or siphon to the GHO Settling Pond	Minimum freeboard as per CDA = 1.1 m
<0.6	■ Emergency overflow spillway will be constructed on the West Dam	

CDA = Canadian Dam Association *Dam Safety Guidelines* (2013)

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

No gaps in relation to the water balance have been identified.

3. Risk Due to Filter Adequacy

The Main and West dams were constructed with an upstream clay till blanket and a coarse refuse shell which also acts as the filter. The materials used for construction were generally found to be filter compatible, except where noted in Section 3c.

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

The West Dam and Main Dam do not have a minimum or recommended beach width.

Although the dam designs predate current filter criteria, they have been assessed relative to current filter criteria. The Canadian Dam Association (CDA 2007) recommends filter specifications based on Sherard et al. (1984) and Sherard and Dunningan (1989), which recommend the following filter D_{15} for typical glacial tills grading from coarse gravel to fines:

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

The CDA (2007) further recommends that suffusion be considered based on an assessment of internal stability of the filter, in this case the coarse refuse. This is discussed in Section 3b.

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

The gradations of the clay blanket material and coarse refuse shell material are monitored during dam construction.

Of the 11 clay till blanket samples and 13 coarse refuse samples from available construction reports (Golder 1989, 1990, 1992, 2015), the coarsest and finest gradations of each material are shown in Chart 2.

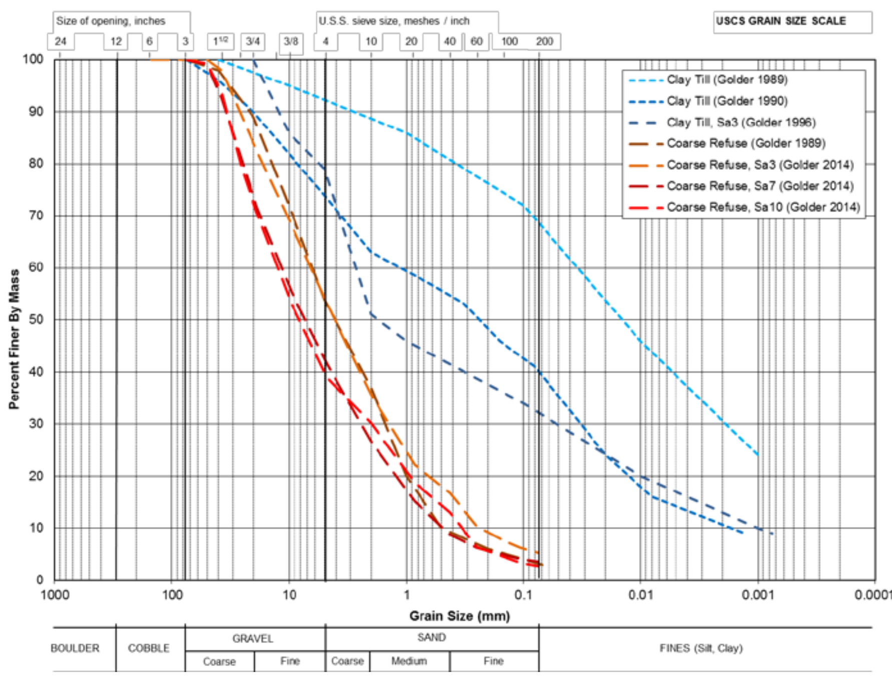

Chart 2: Coarsest and Finest Gradations of Clay Till and Coarse Refuse for Filter Compatibility Comparison

The filter compatibility between the clay blanket material and coarse refuse shell material was reviewed based on grain size distributions of 11 clay blanket samples and 13 coarse refuse samples from available construction reports from 1989, 1990, 1992, and 2014 (Golder 1989, 1990, 1992, 2015).

Ten of the 13 coarse refuse (filter) gradations met the filter criteria, with 3 gradations slightly outside of the Sherard criteria (D_{15} = 0.85 mm compared to the criteria of $D_{15} \leq$ 0.7 mm). All samples met the accepted filter criteria in use at the time of the original design.

The internal stability of the coarse refuse filter was assessed based on an update to the original Kenney-Lau criteria by Li and Fannin (Kenney and Lau 1985; Li et al. 2009). The coarse refuse gradations meet the updated Li-Fannin criteria.

It is noted that there are some gaps in construction quality assurance records for some raises. Where data were available, they indicated that filter compatibility was achieved relative to criteria in place at the time of design and construction, and is generally in conformance with current design criteria. As the 11 clay till and 13 coarse refuse samples reviewed were found to be consistent and generally meet filter criteria, it is expected that the gaps in the construction quality assurance records present a low risk for having materials that are different than those assessed, since neither material is processed prior to placement.

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

The coarse refuse material that makes up the shell of the Main and West dams met the design criteria that were in place at the time of design and construction, generally meets current filter design criteria with some exceptions, and is considered internally stable per the Li-Fannin criteria. Based on the performance of the dam, internal erosion or piping due to filter incompatible materials is expected to be a low risk. However, for future construction, specifications for the coarse refuse placed adjacent to the clay blanket will be formalized, and quality control of the materials placed during construction will be performed to confirm conformance with current design criteria.

4.0 CLOSURE

We trust this letter satisfies your current requirements. 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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Senior Geotechnical Engineer

Andy Haynes, P.Eng.
Principal, Senior Engineer

JMS/AJH/jc/bb/jc/it

Attachment: Study Limitations

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REFERENCES

BC MEM (British Columbia Ministry of Energy and Mines). 2015. *To: Geoff Brick, Mine Manager – Greenhills Operations – Teck Coal*. Memorandum from the Ministry of Energy and Mines, Mines and Mineral Resources Division. Dated February 3, 2015.

CDA (Canadian Dam Association). 2007. *Technical Bulletin: Geotechnical Considerations for Dam Safety.*

CDA. 2013. *Dam Safety Guidelines* 2007 (Revised 2013).

Golder (Golder Associates Ltd.). 1989. *Report on Raising of Upstream Impervious Blanket to El. 1702*. Report prepared for Fording Coal Limited, Greenhills Operations. Project Number 882-1406C. Submitted October 1989.

Golder 1990. *Report on Raising of Upstream Impervious Blanket to El. 1704*. Report prepared for Fording Coal Limited, Greenhills Operations. Project Number 902-1406B. Submitted December 1990.

Golder 1992. *Report on Raising of Upstream Impervious Blanket to El. 1707*. Report prepared for Fording Coal Limited, Greenhills Operations. Project Number 912-1406B. Submitted January 1992.

Golder. 1993. *Fine Tailings Lagoon West Dam Construction to 1711 m Elevation*. Report prepared for Fording Coal Limited, Greenhills Operations. Project Number 932-2403. Submitted August 1993.

Golder. 1994. *Report on Raising Tailings Dams to Elevation 1725 m.* Report prepared for Fording Coal Limited, Greenhills Operations. Project Number 932-2416. Submitted January 1994.

Golder. 1999. *1998 Annual Report on Tailings Dams, Coarse Rejects Stockpiles, Settling Ponds*. Report prepared for Fording Coal Limited, Greenhills Operations. Project Number 982-2420. Submitted February 1999.

Golder. 2005. *Raising Main Tailings Dam to Elevation 1735 m, Greenhills Operations*. Report prepared for Elk Valley Coal Corporation, Greenhills Operations. Document No. 04-1321-021. Submitted July 2005.

Golder. 2013. *Site Water Balance Model.* Draft Report Prepared for Teck Coal Limited, Greenhills Operations. Reference No. 1314280015-2013-455-R-RevB-4000. Submitted November 1, 2013.

Golder. 2014. *Greenhills Operations West Tailings Dam Raise to Elevation 1735 m*. Report prepared for Teck Coal Limited, Greenhills Operations. Report No. 13-1321-0018. Submitted February 11, 2014.

Golder. 2015. *2014 Interim Construction Summary Report. Greenhills Operations Main and West Tailings Dam*. Report prepared for Teck Coal Limited, Greenhills Operations. Report No. 13-1396-0014. Submitted January 30, 2015.

George, H., W.A. Gorman, and D.F. VanDine. 1986. *Late Quaternary Geology and Geomorphology of the Elk Valley, Southeastern British Columbia.* Can. J. Earth Sci. 24, 741-751.

Hardy (Hardy Associates [1978] Ltd.). 1980. *Tailings Dam Greenhills Surface Coal Mining Project.* Report Prepared for Kaiser Resources Ltd. Project No. K5131-013. October 30, 1980. (revised from September 12, 1980).

IEEIRP (Independent Expert Engineering Investigation and Review Panel). 2015. *Report on Mount Polley Tailings Storage Facility Breach*. Report prepared for the Province of British Columbia. Dated January 30, 2015.

Kenney, T.C. and D. Lau. 1985. *Internal stability of granular filters.* Canadian Geotechnical Journal. Volume 22. February 1985.

Li, M., R.J. Fannin, S.J. Garner. 2009. *Application of a New Criterion for Assessing the Susceptibility to Internal Erosion.* Canadian Dam Association 2009 Annual Conference, Whistler, BC, Canada. Dated October 3-8, 2009.

Sherard, J.L., L.P. Dunningan, and J.R. Talbot. 1984. *Basic Properties of Sand and Gravel Filters.* Journal of Geotechnical Engineering. ASCE. June 1984.

Sherard, J.L. and L.P. Dunningan. 1989. *Critical Filters for Impervious Soils.* Journal of Geotechnical Engineering. ASCE. July 1989.

Swaisgood, J.R. 2003. *Embankment dam deformations caused by earthquakes.* 2003 Pacific Conference on Earthquake Engineering. Paper 014.

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