30 June 2015

TE153004

Teck Coal Ltd. Elkview Operations
R.R. #1, Highway 3
Sparwood, BC V0B 2G0

VIA EMAIL & COURIER

Attention: Don Sander, General Manager

Re: Teck Coal Elkview Operations Mine Tailings Lagoons
Response to February 3, 2015 Memorandum from MEM

1.0 INTRODUCTION

On February 3, 2015, the Chief Inspector's office of the BC Ministry of Energy and Mines (MEM) issued a memorandum to all mines in British Columbia related to the recent findings of the Expert Panel that was convened to examine the Mount Polley tailings dam breach which occurred on August 4, 2014. The memorandum required that a letter be provided from each mine site to determine if the tailings facilities at each site may be at risk due to:

1. Undrained shear failure of silt and clay foundations;
2. Water balance adequacy; or
3. Filter adequacy.

For Teck Coal Ltd. Elkview Operations (Elkview), the request applies to the Lagoon area tailings facilities, namely Lagoons C and D. The West Fork Tailings Facility (WFTF) is not included in this response to the MEM memorandum as it is not operating as a dam embankment until the tailings reach an elevation of 1660 m (AMEC 2014). Lagoons A and B are not discussed in detail herein as they are closed low consequence facilities essentially coincident with original ground and lay between Lagoons C and D. As such, the discussions surrounding Lagoons C and D on the above topics are inherently applicable to that of Lagoons A and B. Therefore, Elkview requested that Amec Foster Wheeler Environmental & Infrastructure (Amec Foster Wheeler), prepare a letter on the above topics in response to the MEM memorandum. This letter is intended to satisfy that request.

The most recent Dam Safety Review (DSR) and Dam Safety Inspection (DSI) of the lagoons were conducted in May 2013 and September 2014, respectively. The results of the DSR and DSI are described in the reports issued on October 7, 2013 and November 7, 2014, respectively. In

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addition, numerous studies have been conducted on the lagoons by Golder in the 1980's and 1990's. Detailed discussions pertinent to several aspects of this letter are documented in those reports and will not be repeated herein. Rather, summary comments are provided in this letter to address the MEM memorandum with references made to the DSR's, DSI's and previous studies where applicable. The commentary presented in this letter is based upon the current existing configurations of Lagoons C and D. For convenience, selected figures and drawings of the Lagoons from previous studies are appended to this letter and referenced throughout the text.

The scope of this letter includes a brief review of the project history and background as it relates to the Lagoon tailings facilities, as well as discussions on the following requirements specified in the memorandum:

- the presence of silt and clay in the foundation of the dams;
- water balance adequacy; and
- filter adequacy.

For clarity, within Section 3.0, the individual assessment requirements specified in the MEM memorandum are listed as Issue #1, Issue #2 and Issue #3, for the foundations, water balance, and filter, respectively.

To summarize this letter, the following statements are made regarding the Elkview Coal Mine TSF in the context of the MEM memorandum of February 3, 2015:

1. Silt and clay soils have been reported as mainly low to non-plastic stiff to very stiff clayey silts to sandy silt beneath Lagoons C and D with highly variable thickness. The soils were slightly over-consolidated prior to the lagoons' construction in the 1970's, however the additional loading of the embankments on the foundations may potentially result in the soils behaving more like a normally consolidated soil. Under Lagoon D, the foundation soils have been reported as 3 to 5 m of sand and gravel underlain by 30 to 80 m of clayey silt. Stability analyses were conducted assuming that the clayey silt unit behaved in an undrained manner. Those analyses indicate that the factor of safety for the dam is greater than 1.5. Under Lagoon C, the foundation soils have been reported as 3 to 6 m of sand and gravel, although it may be thinner in some areas after using the material for construction, underlain by 15 to 20 m of clayey silt. As the design and foundation materials are similar to that of Lagoon D, the factor of safety for Lagoon C is expected to be greater than 1.5.

2. Lagoons C and D are essentially 'ring dykes' and only have a catchment equal to their upstream impoundment area. Lagoon C hasn't received tailings or water for many years and is currently dry. Lagoon D only receives tailings and water during maintenance periods and for dust suppression.

3. The design of the lagoons represents a permeable barrier and consists of a well-drained near homogeneous embankment which is directly filter compatible with the total tailings that it retains. The dam does not contain any internal structural elements that would be prone to internal erosion such as a low permeability core.

2.0 PROJECT DESCRIPTION AND CURRENT STATUS

The Elkview site is located in southeast British Columbia, approximately 3.5 km from the Town of Sparwood. The mine has been in operation since 1969 and has a remaining reserve life of approximately 34 years at a planned annual production rate of 6.8 million tonnes of clean coal (AMEC 2014).

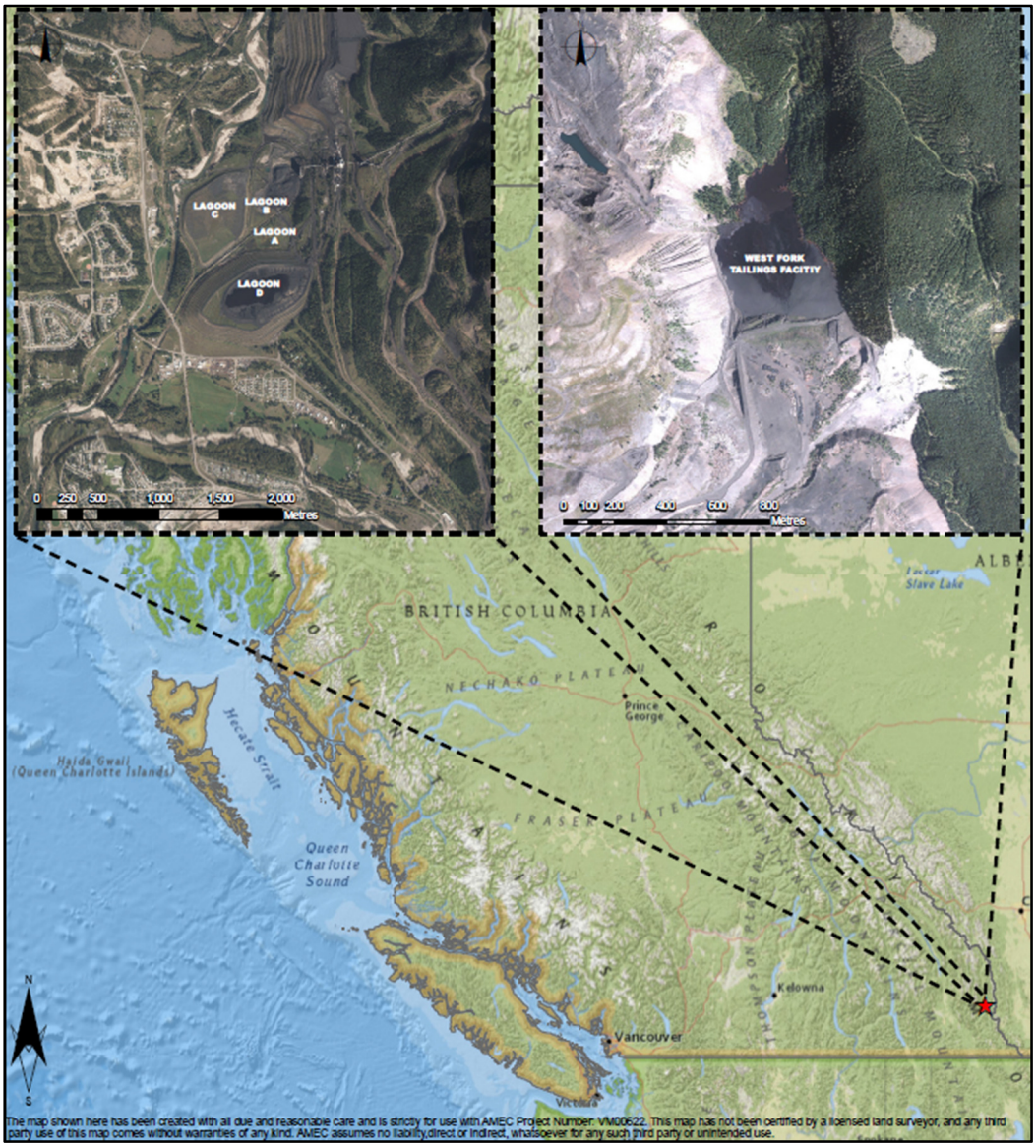

Figure 1 Site Location Plan (AMEC 2014)

The clean coal is obtained by washing the mined material to isolate the saleable coal from other materials. Up until 2006, the majority of the fine refuse was placed into tailings storage areas designated as Lagoons A, B, C and D within the Lagoon Tailings area. These lagoons are immediately down slope of the process plant, on a plain adjacent to the Elk River, as on Figure 2. Table 1 below contains a summary of the existing lagoon configurations.

There are two "ring dyke" tailings dams of significance: Lagoons C and Lagoon D. Lagoon C has been inactive since 1987 and has been used as an emergency water decant facility for Lagoon D as well as periodic pond sediment storage. Lagoon D has been used since the early 1970's, however with the commissioning of the WFTF for storage of fine refuse materials in 2006, Lagoon D has now become an operating backup storage option for when tailings cannot be sent to the WFTF. There is roughly 500,000 tonnes of tailings storage remaining in Lagoon D under current operating conditions (AMEC, 2014). The largest of the lagoons, Lagoon D, is approximately 57 m in height (crest elevation of 1166 m) while Lagoon C is approximately 21 m in height (crest elevation of 1128 m).

Figure 2 Site plan of Lagoons A, B, C and D

Table 1 Summary of Lagoon Configurations (AMEC 2014)

Tailings Facility	Year Started	Year Ended	Crest Length (m)	Crest Elevation (m)	Maximum Height (m)	Typical Overall Downstream Slope[1] (H:V)
Lagoon A	-	-	1,100	1,119	4	-
Lagoon B	-	-	-	1,119	4	-
Lagoon C	1970	1987[2]	1,970	1,129	21	2:1
Lagoon D	1972	2011[3]	2,230	1,166	57	3:1

Notes:
1 – The lower levels of the embankments were constructed with a slope of 1.75:1, and 3:1 or 3.4:1 in upper sections.
2 – Tailings deposition ended in 1987. Only minor amounts of water was pumped to Lagoon C from1992 to 2012.
3 – Ongoing use as an upset storage option.

Lagoons C and D are defined as major dams and impoundments under the Health Safety and Reclamation Code (HSRC). Under the CDA Guidelines, Lagoon C has been designated with a "High" consequence classification for both sunny day conditions and flooding events as outlined in the 2013 DSR. Lagoon D has been designated with a "High" consequence classification under sunny day conditions and a "Very High" consequence classification under flooding events; the "Very High" classification governs (AMEC, 2014).

Lagoons A and B were only used during mine start-up and are essentially coincidental with the natural ground. Water from the mining operations is sometimes discharged to Lagoon B during emergency situations and plant maintenance activities. Thus, Lagoons A and B are not defined as major dams or impoundments under the HSRC for Mines in British Columbia. Under the CDA Guidelines the consequence classification for Lagoons A and B are considered as "Low" (AMEC, 2014).

3.0 INDIVIDUAL ASSESSMENT REQUIREMENTS – ISSUES 1, 2, 3

3.1 Issue #1 - Undrained Shear Failure of Silt and Clay Foundations

The MEM memorandum requested an assessment with respect to the potential for undrained shear failure of silt and clay foundations. It is our understanding that the objective of this request is to ascertain if rapid contractant behaviour during shear (i.e. constant volume during shear leading to excess pore pressures and rapid reduction in effective stress or strength conditions) has been adequately considered in the design.

a) Determination with respect to whether or not foundation conditions similar to the Mount Polley dam exist below the dams at Elkview.

The Elkview Lagoons tailings storage area is located near the confluence of the Elk River and Michel Creek on a terrace at the base of the Harmer Ridge (Figure 2). Before the lagoons were built, the elevation of the original ground in the area varied from 1109 to 1113 m at Lagoon C (Golder, 1996a) and 1111 m to 1128 m at Lagoon D (Golder 1996b), which was partially constructed on a higher alluvial terrace. The Elk River near the lagoons is at approximately elevation 1110 m.

Publically available surficial geology information indicates that the area of the lagoons was within floodplain deposits, however, glaciolacustrine soils are mapped just north along the Elk River (GSC Open File Map 1084). Glaciolacustrine soils are found throughout the Elk Valley, typically below elevation 1384 m (although on occasion it can be found higher) (George et al, 1986).

Geotechnical reports pertaining to the foundation soils of Lagoon C and D include:

- Golder, 1996 – Review of the Geotechnical Design Criteria for the Proposed Lagoon D Ultimate Configuration.
- Golder, 1996 – Stability Review of Lagoon C Ultimate Configuration.
- Golder, 1987 – Long Term Raising of Lagoons C and D above Elevation 3705.
- Golder, 1986 – Interim Report on Long Term Raising of Lagoons C and D above Elevation 3705.
- Golder, 1981 – Lagoon C Extension, Elkview Plant.

More recent geotechnical reports of Lagoons C and D have been produced since the 1990's including an additional site investigation in 2001, however, the reports and investigation were mainly focussed on the tailings. Site investigations of the foundations used conventional drilling and sampling techniques, including relatively undisturbed samples, as well as cone penetration tests. Stability analyses in the reports indicate acceptable factors of safety assuming conservative parameters for shear strength.

Figure 3 shows the location of boreholes and test pits that have been advanced into the foundations of the Lagoons.

Based on the boreholes and test pits, the lagoons are underlain by approximately 3 to 6 m of sand and gravel, followed by a highly variable thickness (15 m to 80 m) of clayey silt to sandy silt, interpreted to be floodplain deposits. Below the silts is another layer of sand and gravel underlain by bedrock (Golder 1996a). The clayey to sandy silt (floodplain deposits) did not exhibit the laminated texture typically found in the glaciolacustrine deposits located on the north side of the Elk River.

An indication of typical plasticity limits from the site investigations is also lacking (two tests are available with plastic limit of 18 to 19% and liquid limit of 22 to 25%). The lack of limits testing may be due to the fact that the soils have mainly been reported as low or non-plastic. Reported grain size plots indicate a range of 48% to 100% fines content with 7% to 48% clay.

The clayey silt was consistently reported as stiff to very stiff and test results confirm that the foundation soils were slightly over-consolidated prior to the construction of the lagoons. The over-consolidation of the soils has reduced to some degree with the added overburden of the lagoons and it is possible the soils may behave with some contractancy during shear, but the additional loading since the site investigations completed in the 1980's is expected to result in greater undrained shear strength than the values used in stability analyses to-date.

Figure 3: Elkview Lagoon Foundation Investigation Sites

N

0 0.05 0.1 0.2 0.3 0.4 Kilometers

1:5,000

This map shows the approximate locations of past foundation investigations (boreholes, test pits and insitu testing) around Teck Coal's Elkview Operations Lagoons Tailings Facilities. Site labels refer back to the table found in EVOFoundationData.xlsx.

Data is not to be used or copied without the express permission of Elkview Geotechnical Staff.

Date: June 15, 2015

Investigation Sites

Location Source Document

- 5: Golder 1981
- 12: Golder 1986
- 15: Golder 1987
- Elkview June 2015

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

Figure 3 showed the location of the investigations that provided information on the foundation conditions. A site investigation in 1981 was carried out by Golder, including 11 boreholes and 45 test pits. A total of 16 CPT's and 5 boreholes were completed in 1984, with locations of the boreholes shown in Figure 3. These investigations formed the basis of the dam geotechnical design. Since those reports, there has not been a significant investigation done that penetrates below the sand and gravel. It was considered at the time that the investigation was sufficient for the geotechnical design, provided the construction continued to proceed slowly (which it has throughout the history of the operation of Lagoons C and D).

Subsurface investigations included collection of undisturbed samples of clayey silt at depth below Lagoons C and D for detailed laboratory strength testing. A total of four triaxial compression tests were completed in 1981 and another four were completed in addition to nine one-dimensional consolidation tests in 1984.

The 1984 investigation sought out whether the foundation clayey silts beneath Lagoons C and D had undergone strength gains since 1981 under the weight of the constructed dykes and tailings. The 1986 report indicates that the 'stressed' silts undrained strength had increased significantly, from approximately 60 kPa to 125 kPa (Golder 1996a). The significant strength gain was interpreted from testing of undisturbed samples as well as with correlation to piezocone penetration resistance. The results of the investigations into the clayey silt have shown the properties are consistent beneath both Lagoon C and D. A lower bound drained shear strength of 34° was reported for both original and 'stressed' conditions.

In 2015, five test pits were excavated on the south side of Lagoon D beyond the toe of the containment dam. The findings from these test pits were consistent with the other investigations and confirmed the presence of the clayey silt layer on the south side of the Lagoon D, from which we have interpreted that the clayey silt layer extends beneath the entire Lagoon D facility.

The level of investigation performed to-date is considered to be commensurate with the understanding of the geologic variability of the site and scale of the facility and the margin of stability of the dam, as indicated by the stability analyses below. The similar foundation conditions across the two lagoon sites and sufficient reported evidence of strength gains in the soils and rapid dissipation of pore pressures relative to the construction schedule suggest the clayey silt foundation soils are not a significant stability issue.

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

Stability analyses conducted in the late 1990's for both Lagoons C and D focused on the properties of the foundation materials to support ultimate height predictions for the two facilities (Golder 1997a and 1997b). More recent stability analyses have focussed on the internal structure of the lagoons and lower reaches of the dam shell (AMEC 2004). This was due to the relatively high strengths interpreted for the sand and gravel unit as well as the deeper clayey silts (a drained

friction angle of 34° was reported for the silt which was reported to be a lower bound based on the investigations).

The clayey silt layer was incorporated into two-dimensional limit equilibrium stability analysis methods for Lagoons C and D for the currently planned ultimate elevations of 1154 m and 1177 m, respectively in the 1996 Golder reports. The parameters used for the material properties were based on the 1980's site investigations as no new investigations were conducted for the 1996 report. The typical value for the coefficient of consolidation, CV, was reported as $1.5x10^{-3}$ cm^2/s in the 1987 Golder report, indicating fairly quick dissipation of pore-water pressures[1]. Drained conditions were modelled in the 1980's and 1990's reports due to the relatively slow increase in embankment height and tailings deposition versus the evident pore water pressure dissipation. The resulting factor of safety was greater than 1.5 (Golder 1996a). An updated analysis was done in 2015 that indicated a factor of safety of 2.0, which is a result of a reduction of pore pressures.

It is important to note that there are two key factors benefiting the stability of the dams:

1. The bulk unit weight of the coal tailings has been reported to be on average 13.2 kN/m^3 (AMEC, 2002b), which is less than the unit weight of other mine tailings deposits.
2. The sand and gravel layer below the coal tailings at Lagoons C and D acts as an underdrain and the pore pressures in tailings at Lagoons C and D are very low.

As noted above, the MEM memorandum focuses on the concept of undrained shear failure which is considered appropriate for normally consolidated clays or clays that behave in a contractant manner. The undrained/contractant condition was not considered to be a valid failure mechanism by the original designers of Lagoons C and D. As noted, drained analyses were conducted because of the low likelihood of triggering an undrained failure event in the foundation. This is still considered valid.

The Mount Polley Mine tailings facility failure has been attributed to sliding through glaciolacustrine silt and clay present in the foundation (Morgenstern et al, 2015). Back calculations performed by the independent review panel yielded a S_u/σ_v' ratio of 0.23-0.27 in these sediments. The results of past Elkview site investigations have indicated that the S_u/σ_v' ratio is much greater in the Lagoons area than the values determined for the Mount Polley failure. Nonetheless, as a check, a stability analysis was run assuming an S_u/σ_v' of 0.25 in the Lagoon D foundation and the resulting factor of safety was determined to be 1.3. The actual factor of safety for an undrained failure mode in the clayey silt foundation is likely in excess of 1.5 due to facility drain down and consolidation induced strength gains. Based on this, there is not a concern with the potential for an undrained failure in the foundation clayey silt.

[1] Based on a preliminary analysis, Amec Foster Wheeler has determined that pore-water pressures can dissipate in approximately three years.

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

No additional investigation is recommended at this time because of the following:

1. The available information is sufficient to characterize the foundation clayey silt.
2. The lagoons are not planned to be raised any higher, and Lagoon D is only being filled in as an upset storage option.
3. There is no triggering mechanism for an undrained event. The potential for the earthquake design ground motions to trigger liquefaction is considered very low (AMEC 2013).
4. Assuming a conservative condition where an undrained event is triggered, then the analysis indicates an acceptable factor of safety.

3.2 Issue #2 - Water Balance Adequacy

As indicated in the most recent DSR and DSI reports, Elkview does not have an explicit water balance for the Lagoon Tailings Facility; however, it was previously judged that this was acceptable for both Lagoons C and D as neither facility has contributing catchment area reporting to the tailings area other than its own impoundment surface area. To-date, the available freeboard at any time in both Lagoons C and D has been far in excess of the annual precipitation, Probable Maximum Precipitation (PMP), and/or maximum snowpack melt. Pumping systems are able to adequately remove surplus water from the Lagoons if/as required.

a) Total volume of surplus mine site water stored in the tailings storage facility.

As stated earlier, water and tailings are no longer directed to Lagoon C, while Lagoon D is only used during maintenance and to offset seepage and evaporation losses. A pond is maintained in Lagoon D to mitigate dust concerns. Table 2 below summarizes the impounded tailings and water volumes for the lagoons.

Table 2 Tailings Facility Configuration Information (AMEC, 2014)

Tailings Facility	Max Embankment Height (m)	Approx. Footprint Area (ha)	Impounded Tailings Volume (m^3)	Impounded Water Volume (m^3)
Lagoon A	4	5.8	185,000	550
Lagoon B	4	4.5	287,700	0
Lagoon C	19.5	32.6	4,658,600	0
Lagoon D	57	58.8	22,004,700	202,000

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

As Lagoon C is no longer utilized and Lagoon D is used sparingly and for dust suppression, there is very little water reported to the facilities.

c) Plans to release surplus mine water to the environment.

As noted above, a small supernatant pond is maintained at Lagoon D to meet dusting requirements with no requirement to release ponded water to the environment due to an overall water balance deficit. Thus, no plans for release are required or being developed at this time.

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

Maintenance of recommended beach width is not an issue at Lagoon D, as they are only infilling. The beach length guidance is indicated in the OMS Manual and has been recommended to vary from 60 m to 250 m by Design Section (AMEC, 2002).

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

The design of the lagoons essentially consists of a well-drained near homogeneous embankment with no internal thin structural elements such as a low permeability core or chimney filter/drainage system. This design section provides ample flexibility for the system to accommodate deformations without the risk of release of the relatively small operating water pond.

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

The inflow design flood requirements per the CDA Guidelines for a “Very High” consequence structure are 2/3 between the 1/1000 and Probable Maximum Flood (PMF). The contributing catchment area reporting to Lagoon D was assumed to be its own impoundment surface area (AMEC 2002); all efforts are being made and must continue to prevent upslope water from draining into the Lagoon D system.

In the event of an emergency, Elkview would stop the plant and pump water to the WFTF. Since Otto Creek and potentially Lagoon C could be used as an emergency decant pond for Lagoon D, the development of an integrated water balance for flood routing and water management between Otto Creek, Lagoons C, and D would be prudent. A site-wide water management model using *GoldSim* is currently being updated and may be able to address this issue (AMEC 2014).

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

No gaps have been identified with respect to water balance adequacy.

3.3 Issue #3 - Filter Adequacy

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

The design of the lagoons represents a permeable mass barrier and essentially consists of a well-drained near homogeneous embankment which is directly filter compatible with the total tailings that it retains. The dam does not contain any internal structural elements that would be prone to internal erosion such as a low permeability core.

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

The embankments do not contain a filter; this issue is not applicable.

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

No gaps have been identified with respect to filter compatibility.

4.0 CLOSING REMARKS AND LIMITATIONS

This letter was prepared by Victor Marques, P.Eng., Andrew Witte, P.Eng., Andy Small, P.Eng. and reviewed by Steve Rice, P.Eng. We trust that this meets your current needs regarding the February 3, 2015 MEM memorandum.

The conclusions presented herein are based on a technical evaluation of the findings of the work noted. If conditions other than those reported are noted, Amec Foster Wheeler should be notified and be given the opportunity to review and revise the current conclusions, if necessary.

This letter has been prepared for the exclusive use of Teck Coal Ltd. Elkview Operations for specific application to the area within this letter. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. Amec Foster Wheeler accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this letter. It has been prepared in accordance with generally accepted soil and tailings dam engineering practices. No other warranty, expressed or implied, is made.

Please contact the undersigned at 506-458-1000 should you have any questions or wish to discuss any aspects of this letter.
Respectfully submitted,

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5.0 REFERENCES

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