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Project No. 1895461

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ADDENDUM TO 2018 ANNUAL PERFORMANCE REPORT FOR TAILINGS BACK DAM, RED DOG MINE, ALASKA

Mr. Sangha:

Golder Associates Inc. (Golder) is pleased to present to Teck Alaska Incorporated (TAK) this addendum to the 2018 Annual Performance Report¹ for the Tailings Back Dam (TBD) at the Red Dog Mine in northwest Alaska. This addendum includes the inspection and reporting requirements per the *Guideline for Tailings and Water Retaining Structures* (TWRS Guidelines) dated November 2014 by Teck Resources, Inc. (Teck), which is beyond what is required by the Alaska Department of Natural Resources Dam Safety and Construction Unit (ADNR Dam Safety). This work was done in accordance with our proposal dated February 8, 2018.

The tasks associated with this addendum included:

- A review and evaluation of the Operations and Maintenance (O&M) Manual and the Emergency Action Plan (EAP)
- Review and confirmation of consequence classification (hazard potential classification) and recommended schedule for the next dam safety review
- Performing a Task 1 visual inspection under the consideration of "Technical Bulletin: Surveillance of Dam Facilities," by the Canadian Dam Association (CDA) dated 2007
- Performing a close-out meeting on site with tailings management personnel that summarizes site observations and dam performance, including identification of immediate maintenance or corrective actions that will be documented in writing within one week of the site inspection

¹ Golder Associates Inc. (Golder). 2018a. 2018 Annual Performance Report for Tailings Back Dam, Red Dog Mine, Alaska, report prepared for Teck Alaska Incorporated, dated October 01. (Project Number 1895461). Anchorage, AK: Golder.

- Summary and priority ranking of outstanding key issues and recommended actions, including recommendations from previous dam safety inspections.

These tasks are described in the following sections. The reader should refer to the 2018 Back Dam Annual Inspection Report for additional details of information and/or data referenced in this document.

1.0 REVIEW OF O&M MANUAL AND EAP

The O&M Manual, which includes an EAP, was revised in 2016 (Revision 3)² to generally meet the TWRS Guidelines. There have been no significant changes to the operation of the facility since Revision 3 was issued; therefore, the O&M manual is considered up-to-date and adequate in its purpose. A fourth revision is planned for 2019, after the TBD Stage IV construction is completed. The revised O&M manual will incorporate changes to the monitoring plan and instrumentation array.

2.0 HAZARD POTENTIAL CLASSIFICATION REVIEW

The TBD has been given a Class II significant hazard potential classification based on anadromous fish habitat located in Bons Creek downstream of the TBD. Occupied development downstream of the TBD includes the Emulsion Plant and Blasters Garage, which are located at an approximate elevation of 974 feet and not at risk to inundation by the reservoir at its current level (recently variable between elevation ~970 to 975 feet). There is also a construction camp about 1.6 miles downstream of the dam that is generally in operation during the warmer part of the year (June to October). This construction camp is located at an elevation of about 955 feet but is not at risk to inundation based on its location relative to the Bons Creek stream channel. Based on a qualitative review, the current Class II significant hazard potential classification is still appropriate for the Back Dam at its current configuration.

3.0 VISUAL INSPECTION AND CLOSE OUT MEETING

The visual inspection performed on June 25-26, 2018 was completed in general compliance with the Technical Bulletin: Surveillance of Dam Facilities (CDA 2007) and included a close-out meeting and presentation to TAK immediately following the inspection. The presentation summarized the results of the visual investigation, the instrumentation data review, conclusions on the performance of the TBD and preliminary recommendations. A copy of the presentation was provided to TAK following the close-out meeting and an email summarizing the recommended immediate maintenance or corrective actions was sent to TAK on July 5, 2018³.

4.0 KEY ISSUES AND RECOMMENDED ACTIONS

Key issues and recommended actions are summarized in Table 1, attached. Each deficiency or non-conformance is discussed in the context of risk to the TBD, an action is recommended, and the timing of the recommended action is given. Each item designated by unique numbers including the year they were made and given a priority based on the descriptions provided in the TWRS Guidelines.

² Golder. 2016. Operation and Maintenance Manual Revision 3, Tailings Back Dam, Red Dog Mine, AK, submitted to Teck Alaska Incorporated, dated October 21. (Project 1545935). Anchorage, AK: Golder.

³ Anderson, S. L. 2018. Personal communication (email) between Steven L. Anderson, PE (Senior Engineering Consultant and Associate, Golder Associates Inc.) and Nancy Tracy (Senior Mine Engineer-Projects, Teck Alaska Incorporated) regarding: Immediate Maintenance or Corrective Actions resulting from Annual Dam Safety Inspections, GAI 1895461 and 1895982, July 5.

5.0 CLOSING

The work program followed the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty expressed or implied is made.

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

Golder Associates Inc.



Samuel P. Saunders, PE
Senior Project Engineer

SPS/SLA/sps



Steven L. Anderson, PE
Associate and Senior Engineering Consultant

Attachments: Table 1 – Key Issues and Recommended Actions for the Tailings Back Dam

[https://golderassociates.sharepoint.com/sites/23601g/deliverables/002 2018 back dam twrs addendum/rev0/1895461-002-l-rev0-2018 tbd apr twrs addendum-20181120.docx](https://golderassociates.sharepoint.com/sites/23601g/deliverables/002%2018%20back%20dam%20twrs%20addendum/rev0/1895461-002-l-rev0-2018%20td%20apr%20twrs%20addendum-20181120.docx)

Table 1: Key Issues and Recommended Actions for the Tailings Back Dam

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

ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2016-01	O&M Manual Section 6.0	Unprotected Instrument Cables	SAA and piezometers may become damaged	4	Install cables within protective conduit	Q2 2019
2016-02	O&M Manual Section 6.0	Uninsulated SAA Protective Casing	Frost could penetrate into cut-off wall and increase permeability leading to higher seepage	3	Inspect penetration through board insulation and make repairs to improve seal if necessary. Add insulation on outside of protective casing.	Q2 2019
2016-04	O&M Manual Section 6.0	Pipe penetrations through insulation layer	May lead to increased frost penetration into the cut-off wall and increase permeability leading to higher seepage	3	Reroute pipelines over insulation layer	Q2 2019
2017-01	O&M Manual Section 8.0	Hazard potential classification needs to be reviewed	Downstream facilities could be at risk to dam failure	Completed	A qualitative assessment of the effects of a breach in the TBD was completed for current conditions and it was concluded that there is no risk of inundation to downstream developments for the existing TBD configuration. As the TBD is raised, the Emulsion Plant facilities become at risk to inundation and the hazard potential classification should be raised to Class I.	n/a
2017-02	n/a	None - the Observational Method has already been adopted	Mitigation options to prevent dam failure may not be available	Completed	Review whether the Observational Method (Peck, 1969) should be adopted for the existing TBD and future raises to be consistent with the approach adopted for the Tailings Main Dam.	n/a
2017-03	n/a	Design and site characterization information is not summarized	None	Completed	Standalone reports are recommended that summarize key project information applicable to the TBD, specifically for: - Design Basis I Criteria; and - Dam Site Characterization. These documents should be reviewed annually (minimum), then, if appropriate, updated and reissued (with revision control) by the EoR, similar to O&M and emergency planning documents.	n/a
2017-04	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	3	Teck and the EoR are recommended to review and implement, as appropriate, a combination of the following to monitor the permeability performance of the COW: - new surveillance activities or instrumentation; and - additional thresholds and criteria for existing activities. One criteria that should be developed is the allowable horizontal strain (to maintain permeability criteria) which is necessary to relate inclinometer movements to COW performance.	End of 2019
2017-05	n/a	None - this has already been completed	An understanding of the response of the COW to thaw deformations and the design earthquake has not been developed	Completed	Teck and the EoR should complete the planned deformation model (static and dynamic loading) to confirm design assumptions regarding COW strain (Teck report this is in progress). The model should be calibrated to the observed conditions in the field (i.e. crack) under the existing loads. As part of the deformation analysis, the EoR should characterize the undrained shear strength and pore pressure response to select appropriate design parameters for any soils that could potentially thaw, including the fine-grained ice-rich deposits.	n/a

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ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2017-06	n/a	Groundwater behavior at the TBD is not well understood	Changing conditions could impact the containment abilities of the TBD system	Will not be adopted	<i>Following installation of the additional instrumentation and better definition regarding future tailings beach development, Teck and the EoR should prepare an updated seepage assessment for the TBD which is calibrated to existing conditions to further understand the long-term seepage regime around the TBD and potential impacts of increasing ground temperatures in Overburden Stockpile foundation.</i> Golder and Teck have discussed a calibrated seepage model including the influences of permafrost and downstream catchments. At this time, Golder and Teck are not planning on pursuing this further due to the limited benefits of such a model and the amount of assumptions required.	n/a
2017-07	O&M Manual Section 3.0	Teck has not designated Responsible Party	In an emergency situation, there could be initial confusion related to the chain of command	2	Recommended inclusions that should be incorporated into the next revision of the O&M manual to improve the document further include: - An event-driven inspection criteria should be added to the monitoring program and added to the O&M manual. - Identify the Responsible Position for the TBD, who currently holds that position and their designated alternates.	End of 2019
2017-08	n/a	None - this has already been completed	Key correspondence may not be correctly documented and recorded	Completed	Teck is recommended to record key correspondence between Teck and the EoR related to dam safety (operations and maintenance) with a technical memorandum, or similar, to limit the amount of information documented in emails.	n/a
2017-09	O&M Manual Section 6.0	Potential movement between Stations 22+00 and 23+00 is not adequately captured in instrumentation	Damage to the TBD could occur without warning from the monitoring array	3	Install additional inclinometers upstream and downstream of the COW where the continuous crack is present in the downstream slope and thickness of ice-rich soils (including ice lenses) is thickest (between Sta. 21+00 and Sta. 23+00). - Inclinometers should be installed at same centreline station. - At least one inclinometer should be installed downstream of the COW in the Select Fill zone. Teck and the EoR may wish to install an additional instrument downstream of the crack, through the Rockfill zone.	2020
2017-10	O&M Manual Section 6.0	None - this has already been completed	The extent of permafrost in the Overburden Stockpile may be less than the design requires	Completed	Install thermistor strings in the Overburden Stockpile west of T-96-008 to confirm extent of permafrost downstream of dam between Sta. 10+00 and Sta. 20+00.	n/a
2017-11	O&M Manual Section 6.0	None - this has already been completed	The groundwater elevation around the Overburden Stockpile may be higher than the design considers	Completed	Install piezometers downstream of the TBD beyond the extent of the Overburden Stockpile (i.e. <Sta. 10+00 and >Sta. 32.00) to confirm that seepage flow is all directed towards the sump in areas where seepage is not constrained by permafrost in the Overburden Stockpile.	n/a
2017-12	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	3	The frequency of data reviews for all key instruments should be reviewed and increased where appropriate to reduce the timeframe that an alert value exceedance can go undetected.	End of 2019

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ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2017-13	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	Will not be adopted	Revise the sump pump alert levels as follows: - Non-freshet - as discussed in Section 8.5, based on measured values and define criteria for determining "non-freshet" time periods. - Freshet - add an additional alert to identify pumping rates outside of expected behaviour . Golder does not agree with the benefits or basis for two separate alert levels.	Q4 2018
2017-14	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	3	Displacement thresholds (horizontal and vertical) for inclinometers and survey monuments should be established based on expected movement rates from a calibrated deformation model when complete	End of 2019
2017-15	n/a	No tailings beach is established at the TBD	The TBD is being subjected to higher seepage gradients and more acidic seepage than if a beach was in place	4	Teck commented that establishing a tailings beach at the TBD is part of their long-term deposition goals which is strongly supported and should be implemented	2020
2017-16	n/a	The COW may have been affected by freeze-thaw cycling	The effects of freeze-thaw cycling on the COW performance are unknown	2	As part of design of the next raise, if completed, the EoR should assess whether freeze-thaw cycles from lateral temperature changes around the insulation layer have impacted the COW performance.	Q4 2019
2018-01	n/a	The sump freezes up in cold weather shutting down the pumpback system	The functionality of the TBD pumpback system is required	1	Upgrade the sump pumphouse to prevent freezing of the sump pump / pumpback system.	Q4 2018