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

Golder Associates Inc. (Golder) is pleased to present to Teck Alaska Incorporated (TAK) this addendum to the 2018 Annual Performance Report[1] for the Tailings Main Dam (TMD) 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). 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 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
- 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 Tailings Main Dam Annual Performance Report for additional details of information and/or data referenced in this document.

[1] Golder. 2018a. 2018 Annual Performance Report for Tailings Main Dam, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated November 5. (Project Number 1895982). Anchorage, AK: Golder.

1.0 REVIEW OF O&M MANUAL AND EAP

The O&M Manual, which includes an EAP, was revised in 2016 (Revision 12)[2] to generally meet the TWRS Guidelines. There have been no significant changes to the operation of the facility since Revision 12 was issued; therefore, the O&M Manual and EAP is considered up-to-date and adequate in its purpose. Golder performed a geotechnical investigation at the TMD during the summer of 2018[3] that included installation of temporary temperature acquisition casings (TACs) and vibrating wire piezometers (VWPs) in and about the TMD and Wing Wall. These instruments facilitated characterization of the local phreatic surface and subsurface thermal regime along the downstream side of the structures. Some of these newly installed VWPs and TACs may be incorporated into a revised O&M Manual. A thirteenth revision of the O&M Manual is planned for 2020, after the TMD Stage XI raise is completed.

2.0 HAZARD POTENTIAL CLASSIFICATION REVIEW

The TMD is classified as a significant (Class II) hazard potential by ADNR Dam Safety based on anadromous fish habitats located downstream of the TMD in the Red Dog and Ikalukrok Creeks. Seasonally occupied cabins exist 40 miles and further downstream of the TMD, affected in both sunny day and flood stage dam breach analyses[4]. The EAP enumerates mine staff to contact these locations should a breach occur. Based on a review, the current significant (Class II) hazard potential classification is still appropriate for the TMD at its current configuration.

3.0 VISUAL INSPECTION AND CLOSE OUT MEETING

The visual inspection performed on June 22, 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 TMD and preliminary recommendations. A copy of the presentation was provided to TAK following the close-out meeting and an e-mail summarizing the recommended immediate maintenance or corrective actions was sent to TAK on July 5, 2018[5].

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 TMD, an action is recommended, and the timing of the recommended action is given. Each item is designated by unique numbers including the year they were made and given a priority based on the descriptions provided in the TWRS Guidelines.

[2] AECOM. 2016b. Operation and Maintenance Manual, Revision 12, Tailings Main Dam, Red Dog Mine, Alaska, submitted to Teck Alaska Incorporated, dated November 21. (Job 60494023). Seattle, WA: AECOM.

[3] Golder. 2018b. Results of the 2018 Geotechnical Investigation at the Tailings Main Dam and Wing Wall, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated December 21. (Project Number 1896929) Anchorage, AK: Golder.

[4] AECOM. 2016a. Dam Breach and Inundation Assessment Report, Tailings Main Dam, Red Dog Mine, Alaska, submitted to Teck Alaska Incorporated, dated November 14. (Job 60494627). Seattle, WA: AECOM.

[5] 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

Steven L. Anderson, PE
Associate and Senior Engineering Consultant

SPS/SLA/bah

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

https://golderassociates.sharepoint.com/sites/18959822/6_deliverables/008 tmd twrs addendum/rev 0/1895982-008-l-rev0-red dog 2018 tmd apr twrs addendum-20190103.docx

Table 1: Key Issues and Recommended Actions for the Tailings Main 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
2014-01	*O&M Manual Section 6.0*	*None -this has already been completed*	*Noncompliance of the active care/zero discharge scenario of the water management plan*	*Completed*	*Complete and maintain the gently sloping 600-foot tailings beach to accommodate wave run-up and thus reduce the estimated freeboard*	*n/a*
2014-02	*n/a*	*None -this has already been completed*	*Inaccurate water balance*	*Completed*	*Installed a french drain on the west abutment slope below the mill site to intercept groundwater that might flow from the mill site to the SCP*	*n/a*
2014-03	*n/a*	*Curtain wall leak*	*Increased seepage through the curtain wall*	*Completed*	*Mitigation measures should be implemented if the leak is confirmed after evaluation*	*Potential leak being mitigated through tailings beach*
2014-04	*O&M Manual Section 5.0*	*None -this has already been completed*	*Unknown magnitude of movements at the base of the dam*	*Completed*	*Install an accelerograph at the base of the TMD instead of assuming instruments elsewhere are the same as the dam base motions*	*n/a*
2014-05	*O&M Manual Section 5.0*	*Monitoring programs needs to be updated*	*Current program may not adequately address all dam failure modes*	*Completed*	*Revise the O&M Manual to reflect responses to earthquakes based on criteria on site rather than magnitude of movement measurements at origin locations*	*n/a*
2014-06	*n/a*	*None -this has already been completed*	*Old data may not accurately reflect current conditions*	*Completed*	*Update the filter, seepage, and stability criteria analyses for the TMD with new performance parameter data from 2013 and 2014 geotechnical investigations, recent tailings gradations, and new guidelines from FEMA*	*n/a*
2015-01	*n/a*	*None -this has already been completed*	*Increased seepage at the left abutment*	*Completed*	*Fill the excavation hole in the tailings beach near the left abutment with tailings to create a uniformly sloping beach and keep water away from the left abutment*	*n/a*
2015-02	*O&M Manual Section 5.0*	*Monitoring programs needs to be updated*	*Current program may not adequately address all dam failure modes*	*Completed*	*Monitor the tailings beach for holes or cracks. Survey and mark new holes that develop*	*n/a*
2015-03	*O&M Manual Section 5.0*	*Monitoring programs needs to be updated*	*Current program may not adequately address all dam failure modes*	*Completed*	*Monitor water flows for changes in turbidity and flow rates at the downstream toe, right abutment, and left abutment of the TMD*	*n/a*
2015-04	*n/a*	*None -this has already been completed*	*Continued cracking could indicate embankment deformation*	*Completed*	*Fill in and monitor the transverse crack on the wing wall around STA 32+25 and record any further changes in size during future inspections*	*n/a*
2015-05	*n/a*	*None -this has already been completed*	*Potentially high phreatic surface*	*Completed*	*Evaluate and understand P-06-74's variable readings and place mitigation measures as necessary*	*n/a*
2015-06	*n/a*	*None -this has already been completed*		*Completed*	*Integrate pH test results measured during the inspection into the water quality sampling database*	*n/a*
2015-07	*n/a*	*None -this has already been completed*	*Seepage through the embankment has a major impact on stability*	*Completed*	*Conduct a geochemical study of the pooled and flowing water quality data down gradient of the TMD to better understand the source of water*	*n/a*
2016-01	*n/a*	*None -this has already been completed*	*Continued cracking could indicate embankment deformation*	*Completed*	*Monitor the wing wall crest near the diagonal crack in the gravel surface that was identified during the inspection*	*n/a*
2017-01	n/a	Hazard potential classification needs to be reviewed	Downstream facilities could be at risk to dam failure	3	An inundation analysis is currently being completed to understand how the downstream facilities will be impacted from a breach in the TMD. It is already concluded that the TMD should be classified as a Class I structure.	Q1 2019
2017-02	n/a	Design and site characterization information is not summarized	None	4	Standalone reports are recommended that summarize key project information applicable to the TMD, specifically for: Design Basis/ 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.	Q2 2019
2017-03	n/a	Observation Method needs to be reviewed and updated	Mitigation options to prevent dam failure may not be available	4	Review and action, as appropriate, recommendations and opportunities to improve implementation of the Observational Method at the TMD.	End of 2020

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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
2017-04	*n/a*	*None -this has already been completed*	*An inaccurate design shear strength can lead to dam failure*	*Completed*	*The basis for an undrained shear strength of 0.26 and minimum undrained shear strength for the colluvium/alluvium (static and seismic loading) is not well supported in the Stage X design documents and should be clarified. It was concluded that an undrained shear strength of 0.22 is appropriate for NC materials.*	*n/a*
2017-05	n/a	Potentially inaccurate strain weakening behavior used in deformation model	The deformation model may not represent existing conditions	3	The strain weakening behavior observed in the laboratory tests of the colluvium/alluvium should be compared to predicted strain levels within the unit by the deformation models for all loading conditions (Method 1, 2, and 3). Where appropriate, run additional sensitivity analyses to assess the potential impact of strain weakening on design.	Q2 2019
2017-06	n/a	Factor of safety is less than design criteria	Potential dam failure at the highest section	3	The reported factor of safety (FOS) for the Stage X raise along the highest section of the dam, 1.42, is less than the minimum design criteria (1.5). AECOM should complete the three-dimensional (3D) stability analysis they state as the basis for design compliance. Akhtar (2011) is a useful reference when reviewing analyses methods and applicability of 3D stability analyses.	Q2 2019
2017-07	*n/a*	*Lack of assumption justification in Stage X Buttress deformation model*	*Potential to impact condition statement of the TMD*	*n/a*	*The EoR is recommended to document all model and material property assumptions relevant to the Stage X Shear Key Buttress deformation model, with appropriate technical justification and complete a review of the model as described in Section 3.2.2. Golder will run a deformation analysis instead as part of the Stage XI design.*	*n/a - an independent deformation analysis as part of the Stage XI design*
2017-08	*n/a*	*None -this has already been completed*	*Documentation of design compliance actions are not recorded*	*Completed*	*Record document should be prepared or approved by the EoR that summarizes actions taken to address recommendations from Stage IX review (TMD37) to bring the Stage IX Raise into design compliance.*	*n/a*
2017-09	n/a	Monitoring programs needs to be updated	Mitigation options to prevent dam failure may not be available	3	The risk reduction measures identified by AECOM during the filter workshop (TMD11), or similar, should be incorporated into the TMD monitoring program and documented in the O&M Manual in manner consistent with the Observational Method framework.	Q4 2020
2017-10	n/a	A seepage model is needed as tailings level rise	Seepage through the tailings beach is critical for embankment stability	3	Teck and AECOM are recommended to develop a 3D seepage model for the TMD. The effort associated with this activity is believed justified because of increasing importance of understanding of seepage and prediction capability as the tailings level rises and the project approaches closure.	TBD
2017-11	O&M Manual Section 3.0	Teck has not designated the Responsible Party	In an emergency situation, there could be initial confusion related to the chain of command	3	Recommended inclusions that should be incorporated into the next revision of the O&M Manual to improve the document further include: • Update the discussion of the Observational Method based on the discussion herein and recommended activities, specifically the threshold values, refer to Section 6.2.2. • Identify the Responsible Position for the TMD, who currently holds that position and their designated alternates. • Clearing of vegetation growth from the Seepage Collection Dam spillway should be defined as part of routine maintenance.	Q4 2020
2017-12	n/a	Key information on the tailings storage facility are not summarized	None	4	To limit risks associated with omission of key information and staff turnover, Teck is recommended to prepare a document that summarizes design basis information for the TSF and key components as an integrated system, such as: TMD; Tailings Back Dam; water balance; deposition planning and beach management; seepage management; regulatory; closure and other relevant information. This document would consolidate information similar to that recommended in PSI-R-02 for all components of the TSF.	Q4 2020

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2017-13	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	3	Installation of inclinometers and additional piezometers to monitor displacement and pore pressure generation within the colluvium / alluvium unit is recommended. Number of instruments, type and locations should be recommended by the EoR.	Q4 2020
2017-14	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	3	Teck's plan to establish additional threshold levels that improve the implementation of the Observational Method is supported and should be completed. Additional recommendations related to thresholds include: • EoR to review whether horizontal gradient thresholds should be defined between piezometers referenced in Section 6.2.2 of main text. • Establish thresholds for seepage pumpback based on pumping rate, in addition to the existing thresholds that are based on Seepage Collection Dam pond level. • Establish thresholds for tailings beach width based on design assumptions and observations of impact of beach width on seepage rates. • Develop incremental and cumulative inclinometer thresholds for each foundation and dam fill unit, as appropriate, based on deformation model predictions of "most probable conditions" and "most unfavorable conditions."	Q4 2020
2017-15	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	4	Given the importance of the tailings beach on seepage management and structural stability in the short and long-term, Teck has refined their tailings planning to maintain a wide beach at the TMD. The same criteria should be defined in TMD design basis and O&M Manual, including an appropriate monitoring program.	Q4 2020
2017-16	O&M Manual Section 5.0	None -this has already been completed	Seepage through the tailings beach is critical for embankment stability	Completed	Teck is recommended to plot tailings beach widths, include historic where available, and pumpback rates to identify whether a correlation can be identified.	n/a
2017-17	n/a	Design analyses needs to be reviewed	Potential to impact condition statement of the TMD	3	Recommendations have been made for the EoR to review specific components of the design analyses. If these reviews indicate that minimum required criteria are not met, the condition assessment should be lowered to FAIR, based on ADNR definitions, until the appropriate remedial activities are completed to bring the TMD back into compliance for all loading conditions.	Q2 2019
2018-01		None	None	4	Continue monitoring the TMD in accordance to the O&M Manual until it is revised.	Ongoing
2018-02	n/a	Cracks on the Wing Wall	May indicate deformation of the embankment	3	Continue monitoring the lateral cracks on the crest of the Wing Wall, looking for changes in length, width, or depth. Survey, photograph, and document in writing any increase observed.	Ongoing
2018-03	*n/a*	*None -this has already been completed*	*Frost could penetrate into the embankment*	*Completed*	*Backfill the void space within the annulus of the 2017 AECOM borehole located on the Wing Wall. Install a cap over the open PVC pipe, and place a safety cone over it as well to highlight it for any traffic along the crest. Golder understands this has already been accomplished by Teck.*	*n/a*
2018-04	n/a	Liner at longitudinal crack needs to be examined	Additional fill material may settle into the slurry wall and/or reduce the geomembrane liner tie-in depth	3	Carefully expose the liner and examine the condition of the SCC cap and geomembrane liner tie-in at the location of the longitudinal cracking observed along the upstream toe of the Stage X Wing Wall extension.	Q3 2019