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ADDENDUM TO 2019 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 2019 Annual Performance Report (Golder 2019c) 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). We understand that Teck recently updated the TWRS Guidelines in January 2019, however, TAK directed Golder to utilize the 2014 document for the 2019 Annual Performance Review. The January 2019 TWRS Guidelines will be applied and referenced in future reporting efforts. The tasks associated with this addendum included:

- Performing a Task 1 visual inspection under the consideration of “Technical Bulletin: Surveillance of Dam Facilities,” by the Canadian Dam Association (CDA) dated 2007.
- Completing a close-out meeting onsite with tailings management personnel that summarized: site observations, dam performance, and identified immediate maintenance or corrective actions. These immediate concerns were documented in writing within one week of the site inspection.
- Review and confirmation of consequence classification (hazard potential classification) and recommended schedule for the next dam safety review.
- A review and evaluation of the Operations and Maintenance (O&M) Manual and the Emergency Action Plan (EAP).
- 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 and associated attachment. The reader is directed towards the 2019 Tailings Main Dam Annual Performance Report (2019 TMD APR, Golder 2019c) for additional details on information and/or data referenced in this document, unless another source is specified.

1.0 VISUAL INSPECTION AND CLOSE OUT MEETING

The visual inspection performed on June 21, 2019 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 on June 24, 2019 following completion of all scheduled structure performance inspections onsite. 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 7, 2019 (Anderson 2019). The 2019 TMD APR (Golder 2019c) concluded that the dam is being maintained in a satisfactory condition and performing as designed as well as providing recommendations for consideration in an upcoming revision to the O&M Manual.

2.0 HAZARD POTENTIAL CLASSIFICATION REVIEW

The TMD is classified as a Class II significant hazard potential by ADNOR Dam Safety based on anadromous fish habitats located downstream of the TMD in the Red Dog and Ikalukrok Creeks, the seasonal occupancy of downstream cabins, and the downstream Kivalina townsite including their drinking water intake located at the mouth of the Wulik River (AECOM 2016a, KCB 2017). The TMD is currently permitted to a dam crest elevation of 986 feet, congruent with its Stage X configuration. The completion of the Stage XI construction will raise the structure to a dam crest elevation 996 feet, with the planned ultimate Stage XII configuration to achieve a dam crest elevation of 1,006 feet.

AECOM completed a dam breach and inundation study assessing failure of the TMD at its currently permitted dam crest elevation of 986 feet in both “sunny day” and “flood stage” scenarios (AECOM 2016a). Seasonally occupied cabins, greater than 30 miles downstream of the TMD, were affected by both scenarios, resulting in a total flow depth of 5.2 feet at the nearest downstream cabin in “flood stage” conditions. The AECOM dam breach assessment results do not affect the main camp site or ancillary mine structures beyond disturbance of: a mine road leading to the fish weir, a triple-culvert under the mine road at the confluence of Red Dog Creek, the fish weir across Red Dog Creek which is approximately 1.2 miles downstream of the TMD, and temporary exploration roads (AECOM 2016a). The locations are situationally occupied by mine staff on an as-needed basis. Affects on the Kivalina townsite, greater than 60 miles downstream, include a total flow depth of 8.4 feet during “flood stage” conditions modeled at the mouth of the Wulik River, about 1-foot greater than the flow modeled for the natural 100-year flood event at the same location. However, due to the nature of attenuated flow via the presence of Kivalina Lagoon, a “flood stage” scenario breach would likely result in less than a 1-foot increased flow depth at the Kivalina townsite proper as compared to the natural 100-year flood event (AECOM 2016a).

A recently completed dam breach and inundation study modeling failure of the TMD (GAL 2019) in both a “sunny day” and “flood stage” dam breach scenarios assessed the TMD at its ultimate configuration geometry of dam crest elevation 1,006 feet. This 2019 dam breach analysis considered two breach locations: one along the Main Embankment and the other along the Wing Wall. The 2019 assessment found that the seasonally occupied cabins are affected in both “sunny day” and “flood stage” scenarios, resulting in a peak depth of 10.2 feet at the nearest downstream cabin in “flood stage” conditions. Results found that the Wing Wall breach in either scenario type inundated mine structures of the main camp site, which are continually inhabited by mine staff. Both the Main Embankment and Wing Wall breaches included inundation of the Main Pit water reservoir, while the Wing Wall

scenarios additionally inundated the active Aqqaluk Pit as well (GAL 2019). Affects on the Kivalina townsite are tempered by existing environmental conditions at that area when a dam breach is occurring. Qualitatively, based on the limitations inherent to the recent dam beach and inundation study, a 100% release of the complete volume of the tailings storage facility would not be large enough to overtop and flood the Kivalina townsite during fair weather conditions (GAL 2019). Further information would be required to provide a more accurate assessment of the potential, incremental impacts to the Kivalina townsite during a dam breach.

The current EAP enumerates mine staff to contact the downstream cabins and Kivalina townsite should a breach occur, described below. Based on a qualitative review, the current Class II significant hazard potential classification is still appropriate for the TMD at its current permitted Stage X configuration at dam crest elevation 986 feet.

3.0 REVIEW OF O&M MANUAL AND EAP

The O&M Manual, which includes an EAP, was revised in 2016 (Revision 12, AECOM 2016b) to generally meet the TWRS Guidelines. There have been no significant changes to the operation of the facility since Revision 12 (AECOM 2016b) was issued; therefore, the O&M Manual and EAP is considered up-to-date and adequate in its purpose. The TMD currently operates as a Class II significant hazard potential structure at its permitted Stage X dam crest elevation of 986 feet.

Following completion of the Stage XI raise to dam crest elevation 996 feet, and any future raises of the structure, the TMD will then operate as a Class I high hazard potential dam where design, seismic, and hydrologic analyses completed are commensurate with Class I high hazard potential requirements (Golder 2019b). Golder has designed the Stage XI configuration and its appurtenant structures with respect to a Class I high hazard potential rating (Golder 2019b) and is in the process of completing similar assessments for the ultimate Stage XII configuration to dam crest elevation 1,006 feet. Golder recommends separating the EAP and presenting it as a standalone document, prepared and referenced concurrently with the O&M Manual, to be implemented in future revisions of both works once the structure is elevated to operation as a Class I high hazard potential dam.

A thirteenth revision of the O&M Manual is planned for the first quarter of 2020, after completion of the 2019 summer TMD Stage XI construction efforts but may be postponed to late 2020 per priority recommendations provided by TAK. The revised O&M Manual will incorporate changes to the monitoring plan and instrumentation array related to the recommendations described in the 2019 TMD APR, completion of Golder's recent 2018 geotechnical investigation (Golder 2019a) and ongoing 2019 geotechnical investigation at the TMD Main Embankment and Wing Wall, and the completion of the summer 2019 Stage XI construction efforts.

4.0 KEY ISSUES AND RECOMMENDED ACTIONS

Key issues and recommended actions are summarized in Table 1, which is 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.

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.



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Steven L. Anderson, PE
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BAH/SLA/bah

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

[https://golderassociates.sharepoint.com/sites/101201/deliverables/3.0 issued/18113464-008-l-tmd twrs addendum/rev0/18113464-008-l-rev0-red dog 2019 tmd apr twrs addendum-20191031.docx](https://golderassociates.sharepoint.com/sites/101201/deliverables/3.0%20issued/18113464-008-l-tmd%20twrs%20addendum/rev0/18113464-008-l-rev0-red%20dog%202019%20tmd%20apr%20twrs%20addendum-20191031.docx)

6.0 REFERENCES

- 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.
- 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.
- Anderson, S. L. 2019. Personal communication (e-mail) between Steven L. Anderson, PE (Golder Associates Inc.) and Tyler Oester and Tanna DeRuyter (Teck Alaska Incorporated) regarding: Draft Geomembrane Defect Repair Technical Memorandum and Immediate Maintenance or Corrective Actions, Reference Document 18113464-001-RevA, July 7.
- CDA (Canadian Dam Association). 2007. Technical Bulletin: Surveillance of Dam Facilities.
- Golder (Golder Associates Inc.). 2019a. Results of the 2018 Geotechnical Investigation at the Tailings Main Dam and Wing Wall, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated January 8. (Project Number 1896929) Anchorage, AK: Golder.
- Golder. 2019b. Tailings Main Dam Stage XI Widening Detailed Design Report, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated June 20. (Project Number 18103660) Anchorage, AK: Golder.
- Golder. 2019c. 2019 Annual Performance Report for Tailings Main Dam, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated October 9. (Project Number 18113464). Anchorage, AK: Golder.
- GAL (Golder Associates Limited). 2019. Red Dog Tailings Main Dam, 2019 Dam Breach and Inundation Study, prepared for Golder Associates Inc., dated October 4. (Project 1895976) Vancouver, BC, CA: Golder.
- KCB (Klohn Crippen Berger Ltd.). 2017. Red Dog 2017 Inspections, Tailings Main Dam Facility Periodic Safety Inspection Report, prepared for Teck Alaska Incorporated, dated December 1. (Project Number M09811A05.730) Vancouver, BC, CA: Klohn Crippen Berger.
- Teck (Teck Resources Ltd.). 2014. Guidelines for Tailings and Water Retaining Structures, dated November.

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	None -this has already been completed	Downstream facilities could be at risk to dam failure	Completed	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.	n/a
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.	Q4 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.	Q4 2021

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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	n/a	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.	n/a - the material properties of the native coarse and fine materials have been reassessed by Golder
2017-06	n/a	None -this has already been completed	Potential dam failure at the highest section	Completed	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.	n/a
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 2021
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: <ul style="list-style-type: none">• 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

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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
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: <ul style="list-style-type: none"> • 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	Completed	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.	n/a
2018-01	n/a	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

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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	None -this has already been completed	Additional fill material may settle into the slurry wall and/or reduce the geomembrane liner tie-in depth	Completed	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.	n/a
2019-01	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	3	Continue working with Measurand, NavStar, and Golder to determine best practices for SAA inclinometer data reduction and replicability procedures	Ongoing
2019-02	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	3	Install another shallow piezometer downstream of the SCP and piezometer SPP-97-002 to verify and assure a gradient toward the SCP and that the seepage seepage pumpback is capturing seepage through the Seepage Collection Dam	Q4 2020
2019-03	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	3	Review the readings collected from piezometers CPT-12-13B and CPT-13-13C to verify they have not been switched. Consider an audit of all the piezometers to verify they are being read at their assumed location	Q4 2020
2019-04	O&M Manual Section 5.0	Monitoring programs needs to be updated	Current program may not adequately address all dam failure modes	2	Repair or install piezometers on the upstream side of the liner along the northern leg of the Wing Wall to monitor changes in the measured phreatic surface. Coverage during the spring freshet, tailings beach production efforts, and precipitation events will help identify potential seeps or leaks through the liner system	Q3 2020

Note: Recommendations that reiterated incomplete recommendations made in previous reports were not repeated in this list.