October 24, 2019 Reference No. 18113464-005-L-Rev0

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2019 ANNUAL PERFORMANCE REPORT FOR TAILINGS MAIN DAM, RED DOG MINE, ALASKA

Tailings and Water Team:

Golder Associates Inc. (Golder) is pleased to submit to Teck Alaska Incorporated (Teck) the 2019 Annual Performance Report (APR) for the Tailings Main Dam (TMD) at Red Dog Mine in northwest Alaska. The TMD has been assigned National Inventory of Dams (NID) identification number AK00201. The Annual Performance Report was supported by a site visit to inspect the dam on June 21, 2019, and a review of monitoring data provided by Teck. This work was performed in general accordance with our proposal dated February 6, 2019.

Based on the field inspection and review of available monitoring data the TMD and its appurtenant components appear to be in satisfactory condition. Other than the historic lateral cracking observed in the Wing Wall crest that appear to have decreased in size since they were initially observed over the last two years, no other signs of instability were observed. Some liner damage was observed that required repair. Teck should continue monitoring dam performance data in accordance with the O&M Manual.

1.0 INTRODUCTION AND BACKGROUND

The Red Dog Mine, a lead-zinc production mine, and Tailings Storage Facility (TSF) are located approximately 90 miles north of Kotzebue, Alaska in the Northwest Arctic Borough, nestled in the De Long Mountains of the Brooks Range. The TMD is composed of the Main Embankment and Wing Wall, designed and operated as a zero-discharge facility. The TMD Main Embankment forms the northern barrier of the Tailings Impoundment (tailings pond) across the South Fork of the Red Dog Creek, while the Wing Wall makes up the northeastern barrier, as depicted in Figures 1 through 3. A Seepage Collection Pond (SCP) and associated rock drain and pumping chambers located along the downstream toe of the TMD Main Embankment works in conjunction with a tailings beach to minimize potential seepage out of the tailings pond. The beach is maintained from a pipe bench built atop tailings adjacent to the TMD upstream slope through discharge operations each year. The SCP is located on the upstream side of the Seepage Collection Dam and at the outlet of an underdrain constructed along the historic

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creek alignment within the TMD Main Embankment (see Figure 2). Sections through the TMD Main Embankment and Wing Wall are shown in Figures 4 and 5.

The dam raise history including year(s) of construction, crest elevation, crest width, crest length, and type of liner-bedrock tie-in is summarized in Table 1. The TMD is a zoned gravel and rockfill embankment with an upstream 100-mil high-density polyethylene (HDPE) geomembrane liner that lies over or is tied into bedrock. The dam embankment generally has 2.5 horizontal to 1 vertical (2.5H:1V) upstream and downstream slopes. Most fill materials (Types 1 through 7) are composed of processed better-quality shales borrowed from the DD2 Quarry except for poorer quality Kivalina Waste Fill (Type 8), Select Shale materials, and Type 9 fill that was sourced from mine waste. A summary of these construction materials and the construction stages where they were used is presented in Table 2. Soil Type 9, which was used as a protective buttress upstream of the geomembrane liner, was discontinued after Stage VIII because it is understood to act as a conduit that allows direct access for impounded water into and under the Stage I cutoff trench, which was the only stage not keyed into bedrock.

Table 1: Dam Raise History

Dam Stage	Year(s) Constructed	Crest El. (feet)	Crest Width (feet)	Crest Length (feet)	HDPE Liner-Bedrock Tie-in
Stage I	1988	865	42	1,088	Cutoff trench
Stage II	1989	890		1,352	Cutoff wall
Stage III	1990	910		1,776	Cutoff wall
Stage IV	1991	925		1,917	Cutoff wall
Stage V	1993	940		2,175	Cutoff wall
Stage VI	1993	950	52	2,427	Cutoff wall
Stage VII-A	2003 to 2005	955		2,550	Cutoff wall
Stage VII-B	2005 to 2007	960		3,457	Cutoff wall and Curtain Wall (Membrane)
Stage VIII	2008 to 2011	970		4,076	Cutoff wall and Curtain Wall (Slurry)
Stage IX	2012 to 2013	976	52 / 32[1]	4,983	Cutoff wall and Curtain Wall (Slurry)
Stage X	2015 to 2016	986	34 / 20[1]	5,594	Cutoff wall and Curtain Wall (Slurry)
Stage XI[2]	2018 to Present	996	-	-	Cutoff wall and Curtain Wall (Slurry)

Notes: 1) These values represent the Main Embankment / Wing Wall crest widths respectively.
2) Stage XI is currently under construction with completion projected in 2021.

For Stages I through VII-A, the TMD was constructed across the South Fork of Red Dog Creek with an approximate west-east linear alignment. Beginning with Stage VII-B, a bend was incorporated around the right abutment of the TMD Main Embankment, and the TMD was continued from the west-east alignment along an approximately north-south direction through incorporation and development of the Wing Wall.

The TMD Main Embankment Stage I Starter Dam is generally founded on slightly to moderately weathered shale bedrock. However, most of the future stages (Stages II to VIII) are founded on native alluvial and colluvial soils after most of the organic materials were stripped. Some organic soils remain under the Kivalina Waste Fill downstream of the Stage I Starter Dam, which was not removed during the later stages. Subgrade preparation for the Stage IX and X raises included removal of native materials below the expanded fill footprint (URS 2013, AECOM 2016b). The Stage X raise construction also included a shear key and a buttress with a 2H:1V downstream slope to improve stability.

Permafrost below the TMD Main Embankment is typically below the native soils and within the bedrock near the embankment abutments, but permafrost has thawed completely below the underdrain and the historic creek channel. Golder's recent geotechnical investigation (2019a) has shown that permafrost may still be present within the native soils below the TMD Main Embankment, particularly at the East Abutment. WHPacific (2017), in their review of data from 2012 to 2016, asserted that ground temperatures in the vicinity of the TMD have continued to increase in response to proximity of the tailings pond and surface mine operations.

The Wing Wall embankment is founded on mine development fill materials as well as the native soils (including the organic layer) that overly bedrock. These native soils were partially excavated for the Stage IX widening (URS 2013) and fully excavated for the Stage X extension (AECOM 2016b). Permafrost is understood to be typically thawed below the native soils on the upstream side of the embankment but still lies within the native soils on the downstream side, as noted in both AECOM's (2017b) and Golder's (2019a) recent geotechnical investigations.

Stage XI construction activities began in 2018 and generally consisted of excavation removing unsuitable materials (native soils, residual soils, completely weathered rock, ice, and ice-rich materials) and backfill operations downstream of the West Abutment, Stability Buttress, and East Abutment to prepare the TMD Main Embankment foundation for raising the dam crest up to 996 feet elevation and preparation of the Stage XII footprint (Golder 2019c). Construction for the 2019 season will be completed in a manner designed not to interfere with the operation of the TMD. A summary of scheduled/ongoing construction activities for 2019 includes the following:

- Excavation, preparation, raise, and regrading of the existing Seepage Collection Dam and geomembrane liner to 803 feet elevation including relocation of the spillway at the west abutment.
- Construction of a new platform for the SCP Pumphouse and associated pump chambers, including the abandonment of the existing pumphouse and pump chambers.
- Continued subgrade and foundation preparation along the East Abutment
- Extension of instrumentation cables
- Embankment widening in preparation of the 996 feet elevation crest raise

The current Certificate of Approval to Operate a Dam (Certificate No. FY2018-12-AK00201) issued by the Alaska Department of Natural Resources Dam Safety and Construction Unit (ADNR Dam Safety) on February 12, 2018

stipulates that the holder of the certificate shall submit an APR by an engineer qualified in accordance with 11 AAC 93.193(b) by October 31 of each year during active mine operations. This submittal meets the above requirement.

Table 2: Construction Materials Used

Material ID	Description	Stages
Type 1	Random Rockfill: 24-inch minus	Stages II to XI
Type 2	Rockfill: 24-inch minus	Stage I (Starter Dam)
Type 3	Processed Select: 3-inch minus	Stages I to VII and XI
	Processed Select: 1.5-inch minus	Stages VIII to X
Type 4	Processed Select: 1-inch minus	Stages I to VII
	Processed Select: 3/8-inch minus	Stages VIII to XI
Type 5	Rock Drain and Riprap	Stage II and XI
Type 6	Random Rockfill: 12-inch minus	Stage II
Type 7	Transition Rockfill: 12-inch minus	Stages I to X
Type 8	Kivalina Waste Fill	Stages I to IV
Type 9	Random Mine Waste Fill: 24-inch minus	Stages I to VIII
Select Shale	Type 1 Rockfill composed of Okpikruak Shale and Kivalina Shale	Stages VI and VII
Geomembrane	100-mil HDPE Liner	Stages I to X
Geotextile	16 oz/yd^2 Non-Woven, placed between Soil Types 3 and 4	Stages I to VII and X
	10 oz/yd^2 Non-Woven, placed between Soil Types 3 and 7	Stages I to VII
Cutoff Trench	About 15 feet deep and backfilled with Type 9	Stage I (Starter Dam)
Cutoff Wall	At least 4 feet deep and backfilled with Concrete or Plastic Concrete	Stage II to XI
Curtain Wall	Vertical HDPE Geomembrane (GSE Panels) backfilled with Controlled Density Fill	Stage VIIB
	Slurry Wall composed of Soil-Clay Slurry with Soil-Slag-Cement-Clay Cap	Stages VIII to X

The performance of the TMD is monitored through a system of instruments, surveys, and visual inspections. The instruments used at the TMD are:

- ShapeAccelArray inclinometers (SAAs) on the downstream embankment that measure and record displacements – 3 SAAs
- Vibrating wire piezometers (VWPs) that measure and record the total pressure head and provide water elevations – 38 monitored as required by the O&M Manual and 28 other VWPs
- Flowmeter that records the volume of water pumped into the TSF from the Seepage Collection System.
- Thermistor string arrays (thermistors) that measure subsurface ground temperatures and provide information on changes to the permafrost regime – 5 thermistor strings
- Accelerographs that record seismic data – 2 accelerographs
- Turbidity sensors that estimate the Total Suspended Solids (TSS) contained within the seepage water – 2 turbidity sensors

The locations of the SAA's, VWPs, turbidity sensors, and thermistors are shown in Figures 2 and 3. The location of some of these instruments are also projected onto the Main Embankment sections in Figure 4 along with their offset distance from the section alignment. The monitoring systems are discussed further in Section 3.0.

2.0 FIELD INSPECTION

The field inspection was conducted on June 21, 2019, by Golder employees Steven L. Anderson, PE, the designated Engineer of Record (EoR) for the TMD, and Matthew Gillaspy. Golder was accompanied by Teck Dam Safety Geotechnical Engineer Aaron Sangha. During the field inspection, the weather was partly cloudy with no precipitation. Selected photographs taken during the site visit are included in Appendix A and Figure 6. During the inspection, the Alaska Department of Natural Resources (ADNR) Visual Inspection Checklist was filled out and is included in Appendix B. Highlights from the field inspection are summarized below, along with callouts to photos in Appendix A.

- The tailings pond elevation during the site visit was approximately 976 feet, and the tailings beach was visually estimated to be approximately 700 feet wide from the upstream face of the TMD.
- The upstream and downstream slopes of the TMD Main Embankment and Wing Wall appeared to be stable with no signs of slumping, seeps, or lateral movements. Transverse cracking that was observed along the Wing Wall crest in previous inspections was unchanged during this inspection, as shown in Photos 11 and 14. These historical lateral cracks were typically very small and seemed to have healed since initially observed based on discussion with Teck. No signs of distress or instability were noted in the upstream liner or on the downstream slope near the crack. This lateral cracking is thought to be related to thaw consolidation of ice-rich native soils. The lateral nature of the cracks may be related to the orientation and variable ice content of ice-rich zones that are not uniform within the foundation and induce differential settlements when thawed.
- The exposed upstream liner generally appeared to be in good condition, except for some liner damage observed near Stations 3+00, 19+00, and 51+ 00 (Photos 5 and 6). Teck was aware of this damage and

Golder produced a technical memorandum (Golder 2019d) that summarized the defects and recommended repair methods. The defects were repaired according to the recommendations in the Golder technical memorandum (Golder 2019e).

- Longitudinal cracking (Photos 15 and 16) was observed at the Wing Wall near Station 55+50 along the geomembrane anchor trench and attributed to the settlement of the anchor trench fill; therefore, it was not believed to be related to instability or movements of the embankment fill.
- The tailings beach appeared to be flatter and smoother as compared to observations during previous inspections (Photos 2, 5, and 7 to 9). An area where the tailings pipe bench had been washed out was observed near Piezometer P-11 (Photo 8).
- The downstream abutments of the TMD Main Embankment were observed (Photos 18 to 20) with no signs of instability or seepage. We also did not observe any signs of instability for the TMD Main Embankment buttress, such as cracking, slumps, or indications of lateral movement.
- Near the center of the downstream embankment buttress slope, an irregularity in the fill on the slope was noted (Photo 24). This was identified as a remnant from the 2018 construction and should be repaired as part of the 2019 construction.
- The SCP was at an elevation of about 789 feet and the seepage collection pump station was being switched over to the newly constructed system (see Photo 25). Some iron staining was observed near the toe of the buttress and around the SCP (see Photo 26). A seep entering the SCP that appeared to be near where the underdrain connects into it, which was noted in previous inspections, was not visible during this inspection due to the dam embankment construction.
- The Seepage Collection Dam appeared to be in satisfactory condition with no indications of instability (Photos 25 and 26). The Seepage Seepage Pumpback located downstream of the Seepage Collection Dam was also observed (Photo 27) and did not appear to be actively pumping at that time.

3.0 REVIEW OF MONITORING DATA AND INSPECTIONS

The monitoring data that was reviewed as part of this APR included weekly and quarterly inspection reports, horizontal displacements from SAA inclinometers, air temperature, precipitation data, seepage pump back flowmeter data, groundwater monitoring data from VWPs, and ground temperature from thermistors. Turbidity monitoring is under development and no accelerograph data was provided for this APR. Instrumentation data reviewed for this APR generally included data collected between July 2017 and May 2019, including the data in the 2018 Annual Instrumentation Report (Teck 2019). However, comments are mainly regarding the monitoring data between July 2018 and May 2019. An extended-time period was reviewed for the ground temperature readings. This monitoring data was collected as described in the latest Operations and Maintenance (O&M) Manual for the TMD (AECOM 2016c).

3.1 Inspections and Periodic Performance Assessments

As required in the O&M Manual, Teck completes daily, weekly, and quarterly inspections of the TMD. Golder generally reviewed only the weekly and quarterly inspections performed by Teck between the dates of January 2018 and May 2019. Daily reports were reviewed occasionally to get more detailed information on notable observations in the weekly and quarterly inspection reports.

3.1.1 Weekly and Quarterly Inspection Reports

The visual inspection reports provide a means to monitor and record the air temperature, weather conditions, snow cover, wave action, ponded water condition, and stability condition of the TMD, including signs of cracks, slumps, and seepage. The inspection reports provided for review included 65 Visual Tailings (Main) Dam and Seepage Dam Inspection reports from January 4, 2018, to May 26, 2019. Quarterly reports for 2018 were also reviewed. Weekly inspection reports were missing for 3 occasions.

Based on our review, the weekly and quarterly visual inspections have been performed as described in the O&M Manual. The dam slopes, crest, and buttresses could not be observed over the winter when they were obscured by snow. Highlights identified over the review period include:

- The quarterly inspection dated September 26, 2018, identified a new longitudinal crack along the anchor trench upstream of the Wing Wall approximately 2 feet long, likely attributed to the movement of the liner where it is not in direct contact with the bedding soil.
- The weekly inspections dated May 5 and May 12, 2019, denoted water ponding on the crest of the structure due to snowmelt. The ponding had evaporated and/or infiltrated by the May 19, 2019 inspection as no comment is made. No ponding was seen during the June 21, 2019 inspection.
- The weekly inspection dated May 19, 2019, denoted cracks resurfacing near the powerhouse in the same location as last year. These cracks were noted during the June 21, 2019 inspection (see Section 2.0).

3.1.2 Periodic Instrumentation Assessments

Beginning in July 2018, Teck started implementing Periodic Instrumentation Assessments to have Golder monitor, review, and discuss instrumentation data of the TMD according to the procedures prescribed in the O&M Manual. These assessments occur monthly, with data reports from Teck typically given within a week after the month's end. Data is reviewed according to the monitoring frequencies described in the O&M Manual and includes both weekly and quarterly inspection sheets. The assessments have helped facilitate timely conversation between Teck and Golder regarding unusual events and monitoring data that exceed trigger levels. The following presents the dates of each Periodic Instrumentation Assessment:

- July 2018 Periodic Instrumentation Assessment – Dated August 5, 2018
- August 2018 Periodic Instrumentation Assessment – Dated September 13, 2018
- September 2018 Periodic Instrumentation Assessment – Dated October 8, 2018

- October 2018 Periodic Instrumentation Assessment – Dated October 31, 2018
- November 2018 Periodic Instrumentation Assessment – Dated December 5, 2018
- December 2018 Periodic Instrumentation Assessment – Dated January 1, 2019
- January 2019 Periodic Instrumentation Assessment – Dated February 1, 2019
- February 2019 Periodic Instrumentation Assessment – Dated March 1, 2019
- March 2019 Periodic Instrumentation Assessment – Dated April 1, 2019
- April 2019 Periodic Instrumentation Assessment – Dated May 2, 2019
- May 2019 Periodic Assessment – Dated June 5, 2019

3.2 Horizontal Movement Monitoring –SAA Inclinometers

The 3 SAA inclinometers installed on the downstream slope of TMD Main Embankment record horizontal displacements that are measured with respect to baseline readings taken in September 2014 for INC-01-13 and INC-02-13 and in August 2014 for INC-03-14. The SAA inclinometer readings are taken manually at least once per month, but typically once per week during weekly inspections. The SAA inclinometer data is periodically uploaded to the Red Dog intranet and is accessible from the computers in the mine offices. The raw SAA inclinometer readings data are processed and presented according to the procedure described in the O&M Manual. Due to issues with data reduction during the Winter of 2018, Teck has been in contact with Measurand, NavStar, and Golder to determine best practices to address inconsistencies and replicability of data reduction for their instruments. Following the consensus of this effort, the determined best practice will be applied moving forward for reduction and presentation of SAA inclinometer data.

SAA inclinometer data is presented in Figures C-1 through C-3 (Appendix C) for INC-01-13, INC-02-13, and INC-03-14, respectively. These figures present the cumulative magnitude of displacement with depth, the cumulative magnitude of displacement over time presented at the elevation in which the greatest displacement has occurred, and direction of movement with respect to grid north. A summary of the SAA inclinometer data reviewed is as follows:

- **INC-01-13:** As shown in Figure C-1, INC-01-13 has recorded a cumulative maximum horizontal displacement of approximately 0.93 inches at an elevation of about 809 feet (since the September 2014 baseline). The majority of this movement (about 0.8 inches) coincides with the Stage X Raise and shear key/buttress construction, and displacements have stabilized after that construction. Due to the movement point occurring at the top sensor located within the rockfill and the relative lack of displacement since the Stage X Raise construction was completed, this movement is understood to be related directly to construction activity as deflections of the casing due to placement and compaction of fill materials. The cumulative displacement is in the downstream direction (approximately north-northeast), and the average annual rate of cumulative displacement is about 0.23 inches per year. During the Fall of 2018, the instrument displayed and has maintained a reversal in movement from the historical trend of the north towards the south. Given that the instrument tolerance is about 0.06 inches and the potential disturbance related to construction, this unusual movement direction is not a concern. The SAA inclinometer monitoring data

indicates the cumulative displacements and movement rates are within the acceptable limits prescribed in the O&M Manual.

- **INC-02-13**: As shown in Figure C-2, INC-02-13 has recorded a cumulative maximum horizontal displacement of approximately 0.29 inches at an elevation of about 822 feet (since the September 2014 baseline). The cumulative displacement direction is primarily to the west, parallel to the dam crest. This displacement direction appears unusual as movement would be expected to be in the downstream direction. This unusual movement may be related to twisting of the instrument during the Stage X Raise construction. During the Fall of 2018, the instrument displayed a reversal in movement from its historical trend of the west towards the east. This trend falls within the instrument tolerance and is likely related to construction activities, hence the unusual movement direction is not a concern. The average annual rate of cumulative displacement is about 0.07 inches per year. The SAA inclinometer monitoring data indicates the cumulative displacements and movement rates and are within the acceptable limits prescribed in the O&M Manual.
- **INC-03-14:** As shown in Figure C-3, INC-03-14 has recorded a cumulative maximum horizontal displacement of approximately 0.12 inches at an elevation of about 750 feet (since the August 2014 baseline). The cumulative direction of movement is approximate to the northeast, in the downstream direction. This displacement direction appears opposite to what was observed during the last APR (Golder 2019c) and is possibly related to the 2018 construction activities. Movements in the east-west direction appear to have occurred during the 2016 buttress construction and again during the 2018 construction season. Since the size of the movement is similar to the accuracy of the instrument, this unusual movement direction is not a concern. The average annual rate of cumulative displacement is about 0.03 inches per year. The SAA inclinometer monitoring data indicates the cumulative displacements and movement rates and are within the acceptable limits prescribed in the O&M Manual.

3.3 Vibrating Wire Piezometers

There are 64 VWPs identified in the data files and documents provided to Golder from Teck for this APR. This includes 38 VWPs that are required to be monitored under the O&M Manual and an additional 28 VWPs that provide supplementary data but are not formally monitored. Raw data from the VWPs are collected with dataloggers, most of which are on a wireless data collection system (GeoExplorer by NavStar) that can be monitored in real-time by Teck in the mine offices. Teck is currently in the process of upgrading all piezometers to the GeoExplorer system. VWPs not on the GeoExplorer system will remain on manually read dataloggers until they are upgraded.

The O&M Manual catalogs 38 piezometers that are classified as either “critical” or “non-critical.” Generally, “critical” piezometers have an associated trigger elevation, whereas all others do not. As per the O&M Manual, the 38 piezometers are subdivided into six groups:

1) Critical Underdrain Piezometers (5 VWPs)
2) Critical Near Underdrain Piezometer (10 VWPs)
3) Critical Downstream Shell Piezometers (6 VWPs)
4) Noncritical Piezometers Beneath Tailings Main Dam (5 VWPs)

5) Noncritical piezometers near Wing Wall (10 VWPs)

6) Seepage Collection Dam Piezometers (2 VWPs)

The O&M Manual and the 2018 Annual Instrumentation Report contain further details of each VWP, such as the embedment elevation, target embedment material, trigger elevation (if applicable), historical minimums and maximums, and the name of the borehole drilled for the installation.

The following sections summarize the significant findings of Golder's review of VWP data, generally collected between July 2017 and May 2019. Overall none of the critical piezometers exceeded their trigger elevation. Significant gaps in data were noted but are typically the result of system upgrades or construction activities and are not of concern. Plots of water elevations, precipitation, and seepage pumpback rates are also shown in Figures D-1 through D-9 (Appendix D).

3.3.1 Critical Underdrain Piezometer Analysis

Five VWPs are identified in the O&M Manual as being located in the underdrain. A plot of VWP data is shown in Figure D-1 and a summary of significant findings of the analysis is presented below:

- Generally, the VWPs showed a decreasing piezometric level from upstream to downstream with typically increased levels during the spring freshet, heavy precipitation events, and when the tailings beach width (distance from the lined dam face) was smaller. As anticipated, higher piezometric levels correspond to the higher flow rates. Piezometers P-08A and P-16-151A were near the same elevation during the 2018 freshet and showed a similar response during the 2019 freshet where data trends overlap. It is speculated this is due to the influence of abutment flows from the downstream side of the liner following the Stage X construction, which likely impacted groundwater flows.
- In August 2018, piezometer P-05-62 had its tip elevation adjusted by determining the location of the phreatic surface with a water tape and adjusting the tip elevation accordingly. This was in response to phreatic surface elevation spikes captured in previous years and a concern that the instrument had been improperly replaced after removal for environmental water sampling procedures. No spikes have been recorded since the tip elevation was adjusted.
- P-06-74, P-08A, and P-16-151A have exceeded the rapid rise trigger level (rise of 4 vertical feet per week) for the review period, related to the spring freshet each year. The influence of heavy precipitation events on rapid rise events has been reduced, likely due to improvements in tailings beach production, as compared to previous years. Piezometers P-06-74 and P-16-151A experienced a lower water level elevation and less variability compared to previous years, also likely due to the increased tailings beaching efforts.
- The O&M Manual prescribes monitoring the hydraulic gradients between four of the critical underdrain VWPs to evaluate the likelihood of soil particle migration (erosion). Horizontal distances between instruments are provided in the O&M Manual and the calculated hydraulic gradients are compared to the assigned critical (trigger) hydraulic gradient of 0.17. All of the gradients remained under the trigger level for the review period with a maximum gradient of 0.11 between P-06-74 and P-08A during September 2017.

3.3.2 Critical Near Underdrain Piezometer Analysis

There are 11 VWPs located in the general vicinity of the underdrain. A plot of this VWP data is shown in Figure D-2 and a summary of significant findings from the data review are listed below.

- P-16-145B (identified in the O&M Manual as “P-16-145C”) exceeded the rapid rise trigger between October 2017 and January 2018, attributed to rises in the impoundment level after cessation of Summer discharging operations. Rises are recorded again during the spring freshets of each year, with steady declines in measured phreatic surface attributed to improvements in tailings beach production.
- Piezometers P-16-145B and P-14-134 located on the upstream side of the dam have measured lower water elevations in 2018 and 2019 compared to 2017, also likely due to increased beaching efforts. However, downstream piezometers (underdrain and near underdrain) show similar elevations as previous years, indicating downstream drainages likely influence these piezometers rather than just seepage alone.
- P-16-146B is improperly identified in the O&M Manual as “P-16-146D.” Piezometer P-16-146B is non-operational and does not respond to the changes in water elevation as observed by the other VWPs in the same borehole. This instrument is likely damaged and is not shown in Figure D-2.
- P-08B exceeded the rapid rise trigger during intense precipitation events in the Summer of 2017. The piezometer maintained consistently null readings throughout much of the 2018 year, being only recently repaired in May 2019. This lack of data is not of major concern, as data trends in P-08B are generally historically corroborated by readings in P-08A.
- P-97-20 exceeded the rapid rise trigger during intense precipitation events in the Summer of 2017.
- P-14-130 exceeded the rapid rise trigger during a precipitation event in the Summer of 2018, however, this event was preceded by an uncharacteristic single reading local minimum phreatic surface elevation spike that is attributed to developing this rapid rise event. No other critical near underdrain piezometers show similar trends during this time period.
- P-16-151B has exceeded the rapid rise trigger during the spring freshets each year.
- P-97-28 exceeded the rapid rise trigger during the spring freshets each year in 2018 and 2019. These events are recorded as rapid spikes in phreatic surface elevation of about 7 feet and correspond with increased seepage pumping rates over the spring freshet. Following the spring freshet in 2018, the phreatic surface elevation rapidly decreased back to normal values, corresponding with reductions in seepage pumping rates. A similar decline is anticipated following the spring freshet in 2019. This piezometer may be influenced by westerly flows within bedrock as opposed to northerly flows near the underdrain during the spring freshet.

3.3.3 Critical Downstream Shell Piezometers Analysis

Seven VWPs are located in the downstream shell area below the dam crest. A plot of this VWP data is shown in Figure D-3 and significant findings from our data review are summarized below.

- P-14-129A, P-14-129B, and P-05-69 appear to be essentially dry with piezometric levels measured near their tip elevation, except P-14-129B does have a small rise during the spring freshet for each year.
- P-97-29 exceeded the rapid rise trigger during the spring freshet each year. Each event was marked as rapid spikes in phreatic surface elevation as opposed to gradual increases captured by other nearby piezometers. This piezometer may be influenced by westerly flows within bedrock as opposed to northerly flows near the underdrain during these events, in addition to the spring freshets.
- P-97-30 exceeded the rapid rise trigger during the spring freshets each year. During February 2019, P-97-30 recorded an uncharacteristic 10-foot increase in phreatic surface elevation across the month. The groundwater surface gradually decreased then stabilized at an elevation higher than previous records before rising again during the 2019 spring freshet.

  This February 2019 and subsequent stabilization trend in P-97-30 is similar to historic records around the same time periods in 2016 and 2017, but no other nearby piezometers shared similar trends prior to the 2019 spring freshet. During the same February 2019 time period, there are no uncharacteristic changes in seepage pumping rates, tailings pond elevations, or precipitation events. Potential causes for this behavior could be attributed to undocumented changes in water discharges from the pipeline corridor that pooled near the dam face. Westerly flows within bedrock, as opposed to northerly flows near the underdrain, could also be attributed to this response, but changes in downstream piezometers (P-97-28, P-97-29) and upstream piezometers (P-05-63 in Figure D-5) would also likely follow this trend if that were the case.

3.3.4 Noncritical Crest Piezometers beneath Tailings Main Dam Analysis

There are 5 VWPs at 4 locations beneath the crest of the TMD. A plot of their VWP data is shown in Figure D-4 and a summary of significant findings from our review are listed below.

- P-11 data readings were inconsistent (due to connectivity issues) through the beginning of 2018 until the spring freshet, with phreatic surface elevations measuring below the actual tip elevation of the instrument. Readings spiked during the spring freshet, then slowly decreased until inconsistent readings returned around the end of Summer 2018.

  Readings normalized in the Fall of 2018 and read semi-consistent elevations with localized maxima through to the Spring of 2019. These localized maxima (rises and falls in recorded phreatic surface elevation over short periods of time) occurred during periods of beaching in the area but are not captured by nearby instruments. The short duration peaks of over 20 feet of head may be related to the washed-out pipe bench near P-11 (Photo 8) that created a thawed zone within the active layer and allowed localized water head to develop within a leaking piezometer casing. Readings continuously decreased in May 2019, dropping to and then below the tip elevation of the instrument during the 2019 spring freshet.
- P12-A shows little response to seepage pumping, precipitation events, and the spring freshets each year. The instrument is likely not dry as readings place the phreatic surface elevation above the tip elevation of the instrument.
- P-12B and P-13 data readings were inconsistent (due to connectivity issues) through much of 2018 before the connection was re-established in Fall of 2018. Readings at P-12B slowly decrease from Fall 2018

through to 2019 until the rapid rise trigger is exceeded in response to the spring freshet. Readings at P-13 remained below the tip elevation of the instrument from Fall 2018 through the 2019 spring freshet, indicating that the instrument is likely in a dry condition.

- P-14A is improperly identified in O&M Manual as “P-14,” and shows little response to seepage pumping, precipitation events, and the spring freshets each year. However, the instrument is likely not dry as readings place the phreatic surface elevation above the tip elevation of the instrument.

3.3.5 Noncritical Piezometers near Wing Wall Analysis

There are 10 VWPs located in the Wing Wall area. VWPs P-05-65, CPT-16-13A, and CPT-19-13A are located within the impoundment and the others are located downstream of the Wing Wall. A plot of VWP data is shown in Figure D-5 and the significant findings from our review are summarized below.

- P-05-65 and CPT-16-13 have become disconnected prior to the monitoring period shown in Figure D-5 and are not presented.
- P-16-150 showed little response to seepage pumping, precipitation events, and the 2018 spring freshet prior to becoming non-operational in the Fall of 2018.
- CPT-19-13 exceeded the rapid rise trigger during a precipitation event in Summer 2017 and maintained consistent phreatic surface elevation readings until a rapid decrease at the end of August 2017 where after readings stabilized until the instrument became disconnected in November 2017.
- P-05-63 generally exceeded the rapid rise trigger during the spring freshets each year and during some precipitation events in 2017 and 2018.
- P-16-148A&B and P-16-149A&B show little response to seepage pumping, precipitation events, and the spring freshets each year. Temperatures recorded alongside the phreatic surface elevations indicate that these instruments are installed within the permafrost, so their readings are suspect.
- Since CPT-19-13, CPT-16-13, and P-05-65 are no longer being monitored there are currently no piezometers upstream of the Wing Wall that can be used to evaluate gradients across the Wing Wall.

3.3.6 Seepage Collection Dam Piezometers

Two VWPs are located within or downstream of the Seepage Collection Dam. A plot of VWP data is shown in Figure D-6 and there were no significant findings from the analysis. The 2 VWPs do not show a deviation from historical records.

During 2019, it was determined that piezometer P-96-10 is a subpermafrost installation (WMCI 1997). Therefore, this instrument may be recording a confined aquifer phreatic response that does not represent responses displayed in other nearby piezometer installations. The instrument has been recording temperatures at or below freeze (32°F) since August 2018 so the data is suspect and may no longer be reliable. To assure a gradient toward the SCP and that the seepage pumpback is capturing seepage through the Seepage Collection Dam another shallow piezometer should be installed downstream of SPP-97-002.

3.3.7 Additional Piezometers

Other than P-16-145B there are 23 additional VWPs upstream of the Main Embankment that are monitored but do not necessarily have a role within the current O&M Manual. These piezometers that were installed in 10 vertical series were separated into groups for evaluation by reviewing those near the upstream toe (P-16-145 and P-16-146 series), those on the east side of the Main Embankment (CPT-08-13, CPT-09-13, CPT-12-13, and CPT-13-13 series), and those on the west side of the Main Embankment.

The dam upstream toe group includes the vertical series piezometers P-16-145 (C, A, and B) and P-16-146 (C, A, and D) as shown in Figure D-7. Please note that the designated piezometer letter is in the order of elevation – highest to lowest. The P-16-146 series tends to follow a similar pattern and a similar vertical gradient that fluctuates with changing conditions within the impoundment related to beaching, precipitation, and the pond elevation. However, the P-16-145 series shows erratic behavior with the gradient typically going upward between the lowest piezometer P-16-145B and the middle piezometer P-16-145A and downward from the highest piezometer P-16-145C. On occasion the gradient between P-16-145B and P-16-145C reverses with an upward gradient from P-16-145B that occurred in early 2018 and during beaching and the spring freshet in 2019. This behavior is likely related to flow paths impacted by the tailings beach configuration, the changing impoundment water surface, and the seasonal active layer within the tailings beach.

The vertical cone penetration test (CPT) VWPs on the east side of the Main Embankment are shown in Figure D-8 with two piezometers for each of the four vertical series. The data from these piezometers generally indicate a vertical gradient down and toward the lowest area of the upstream dam toe and the P-16-145 and P-16-146 piezometers. The CPT-09-13 series piezometers that are closest to P-16-145 and P-16-146 appear to be decreasing with time, likely related to continued beach development. Piezometers CPT-08-13B and CPT-13-13B, which have a similar tip elevation show a pattern like the seepage pumpback rate, particularly prior to the spring freshet. The highest piezometer at CPT-12-13A has the most variability and is likely impacted by discharges from the pipeline corridor. The remaining piezometers generally have less variability over the time period and remain relatively constant with one anomaly noted at CPT-12-13B and CPT-13-13C on August 29, 2017. This anomaly of a 3-foot rise and decrease in these respective piezometers appears to be related to a change in their temperature readings and suggests the readings from these two piezometers have been switched.

The four vertical CPT series piezometers on the west side of the Main Embankment (CPT-03-13, CPT-04-13, CPT-05-13, and CPT-06-13) are shown in Figure D-9. Much of this data is more sporadic with longer periods of when the instruments were disconnected. Like the CPT series on the east side, the west side series generally indicate a downward vertical gradient with common heads at nearly the same tip elevation. Lateral gradients are generally toward the west but sometimes appear to change toward the east.

3.4 Air Temperature, Precipitation, Tailings Pond Elevation, and Seepage Pumpback Data

Teck monitors the daily flow volumes of seepage pumpback into the tailings pond with a flowmeter located in the seepage pumpback pipeline. The flowmeter is connected to Teck's PI Server system that uploads data to the intranet making it accessible in real-time from the mine offices. The daily pumpback volume returned to the tailings pond includes seepage through the TMD, precipitation, and surface flows from the associated downstream catchment area and secondary seepage pumpback that comes from water collected in a sump below

the SCP. Therefore, the pumpback volume is not a direct indicator of seepage from the tailings pond, but seepage pumpback rates do vary seasonally and with changes within the tailings pond, such as the beach width. Golder understands that the three pumps in the pumping chambers are activated automatically at prescribed water elevations that are detailed in the O&M Manual. Figures D-10 and D-11 (Appendix D) compares the daily seepage pumpback rates, tailings pond elevation, precipitation, and air temperature. Figures D-12 and D-13 compare the yearly seepage pumpback rates from 2016 through 2019, plotted as daily and cumulative values over the years presented. A summary of observations from these 4 figures is provided below.

- Figure D-10 shows the daily precipitation, seepage pumpback rate, and air temperature with respect to time beginning in July 2017. The greatest pumpback rate occurs during the spring freshet, which is typically coincident with the air temperature rising above freezing. The lowest pumpback rate typically occurs over the winter with a steady decrease until the spring freshet. Seepage pumpback rate is also generally coincident with increases in precipitation, as seen in the Fall of 2017.
- Figure D-11 shows the daily precipitation, seepage pumpback rate, and tailings pond elevation with respect to time beginning in July 2017. The tailings pond elevation generally rises throughout winter until after the freshet. After the freshet, the tailings pond elevation decreases as a result of water treatment discharge and generally remains stable throughout the summer. The tailings pond elevation has increased between 1 and 2 feet each year since July 2017 (measured as the elevation at the given time each year and not overall elevation).
- Figure D-12 shows daily seepage pumpback rate and tailings pond elevations over the Julian year since January 2016. The tailings pond elevation generally follows a similar trend each year, rising over the winter until the freshet and then declining until the onset of winter. The greatest average daily seepage pumpback rate occurred in early April 2017 at just over 1,700 gallons per minute, likely as a result of the January 2017 unusual occurrence (Golder 2018). In a given annual year discharge rates decrease into December and tend to decrease further until the next freshet, particularly since beaching efforts have improved over the last two years. TMD seepage collection pumpback rate has remained at a 3-year low of fewer than 400 gallons per minute over much of the 2018-19 winter, most likely due to increased beaching efforts.
- Figure D-13 shows the daily seepage pumpback rate and daily precipitation over the Julian year since January 2016 as a cumulative assessment. Cumulative seepage pumpback rates have generally decreased from year to year, with 2017 being uncharacteristic likely as a result of the January 2017 unusual occurrence (Golder 2018). This decrease in cumulative seepage pumpback rate is likely related to increased tailings beach production efforts. Cumulative precipitation follows similar trends year to year with larger increases in precipitation generally occur during the end of summer and into the fall of each year. An uncharacteristic rise in precipitation during the beginning of the year is apparent in 2019 as compared to previous years.

3.5 Ground Temperature Monitoring

Five thermistors are used to monitor subsurface thermal conditions and monitor changes in the active layer below the TMD Main Embankment and downstream of the Wing Wall. Two thermistors are located on the west abutment, and the remaining 3 are located downstream of the Wing Wall near the Mill Site (Figures 2 and 3). Currently, the thermistors are not connected to a data logger and temperatures are collected manually, generally 3 to 4 times per year. Data is collected as raw data then converted into temperatures. Temperature profiles and

select dates are shown in Figures E-1 through E-5 (Appendix E). The profiles include an initial reading, the warmest and coldest readings, select intermediate readings, and the most current reading(s). Significant findings from the data analysis are as follows:

- T-05-61 is located on the west abutment and indicates the top of permafrost has decreased from about 27 feet below the bedrock surface in 2018 to about 46 feet below the bedrock surface in April 2019.
- T-95-004 is located on the west abutment and east of T-05-61, is about 400 feet long, and measures the upper and lower bounds of the permafrost zone. The data shows that permafrost is within the bedrock in this area and the upper permafrost table has degraded from about elevation 930 feet to 880 feet between 2005 and 2015. After 2015, the upper permafrost elevation appears to have stabilized. The bottom of the permafrost has seen a slight increase in elevation between 2005 and 2017. Based on a review of the last two readings taken in August 2017 (not shown) and the last reading in January 2019, the data appears suspect and may indicate the thermistor nodes are failing.
- T-05-64 is located downstream of the Wing Wall next to the Concentrate Storage Building (CSB). The data suggests a slight warming trend since installation. The permafrost level remains near the native ground surface at this location and is likely maintained by the active convection cooling system used to stabilize the building foundation. No measurements have yet been recorded for 2019.
- T-05-66 is located downstream of the Wing Wall between the CSB and Fuel Tanks. The permafrost table appears to have remained relatively consistent with time at an elevation of about 960 feet, which is within apparent fill materials.
- T-05-67 is located downstream of the Wing Wall near where the haul road splits to either the Mill Site or the Crusher Pad. The data suggests the permafrost within the bedrock has degraded from about elevation 952 feet to 930 feet between 2005 and 2018.

3.6 Accelerographs

If an earthquake is significant enough to be felt by staff at the mine, earthquake parameters and accelerograph data is to be sent to the EoR for analysis. Earthquake parameters can be obtained from the Alaska Earthquake Information Center, and accelerograph data can be obtained from the two stations located at Red Dog Mine:

- UAF Station: Located on the ridgeline west of DD-2 Quarry located about 0.6 miles southwest of the tailings pond. This station was installed by the University of Alaska Fairbanks (UAF) as part of the Alaska Earthquake Information Center.
- Teck TMD Station: Located downstream of the right abutment of the TMD. This station that was installed by Teck should be set to record and save a record of any event with a peak ground acceleration greater than 0.04g.

Data from the UAA station can be retrieved by contacting UAF, and data from the Teck TMD station is saved on a computer onsite. There was no accelerograph data reviewed as part of this inspection.

3.7 Turbidity Sensors

As per the O&M Manual, 2 Campbell Scientific turbidity sensors are to be installed in the TMD to estimate and monitor the total suspended solids (TSS) within the seepage water passing through the underdrain. These two sensors are to be located:

- In the turbidity well located at Piezometer P-16-152, and
- In one of the pumpback chambers at the SCP.

We understand the turbidity sensor at P-16-152 was installed in December 2017 and data is typically recorded hourly and downloaded by mine staff monthly. Turbidity sensors were disconnected in May as part of the 2019 Stage XI dam raise construction, then reinstalled in October. To evaluate TSS from a turbidity sensor, an instrument-specific correlation between the two parameters is being developed through a laboratory testing program. This monitoring program is still under development and no turbidity data was reviewed as part of this inspection.

4.0 CONCLUSIONS

Based on Golder's observations during the site visit and a review of the monitoring data, the TMD and its appurtenant components appear to be in satisfactory condition. Additional conclusions regarding the safety of the dam and its performance are summarized below.

- During the field inspection, the TMD and its appurtenant components appeared to be in satisfactory condition. Other than the historic lateral cracking observed in the Wing Wall crest that appear to have decreased in size since they were initially observed over the last two years, no other signs of instability were observed. Teck should continue monitoring dam performance data in accordance with the O&M Manual.
- The historic lateral (perpendicular to the centerline) cracking observed at the Wing Wall is thought to be related to thaw consolidation of ice-rich native soils. As noted above, the cracks appeared smaller since they were first observed and do not appear to impact stability or freeboard but should continue to be monitored.
- Longitudinal (parallel to the centerline) cracking was observed at the Wing Wall crest near Station 55+50, but it was along the geomembrane anchor trench and attributed to the settlement of the anchor trench fill; therefore, it was not related to instability or movements of the embankment fill.
- The exposed upstream liner generally appeared to be in good condition, except for some liner damage observed near Stations 3+00, 19+00, and 51+00. Teck was aware of these deficiencies and Golder produced a technical memorandum recommending repair methods at these locations. At the time of this publication, the liner defects have been repaired with construction quality assurance monitoring performed by Golder.
- At the time of the field investigation, the downstream abutments of the TMD Main Embankment did not have signs of instability or seepage. Additionally, there were no signs of instability for the TMD Main Embankment buttress, such as cracking, slumps, or indications of lateral movement.

- Along the center of the downstream embankment buttress slope, an irregularity in the fill on the slope was noted. This was identified as a remnant of construction efforts from 2018 and was repaired as part of the 2019 construction efforts.
- The Seepage Collection Dam appeared to be in satisfactory condition with no observed signs of instability. The Seepage Seepage Pumpback located downstream of the Seepage Collection Dam was also observed and did not appear to be actively pumping at that time.
- Based on a review of the weekly, quarterly inspection reports, and monthly monitoring data assessments, Teck is performing inspections in accordance with the O&M Manual. The new system of collecting piezometer data is a vast improvement, and the system is working well. Upgrading of instruments, the infrastructure, and data presentation is ongoing.
- The SAA inclinometer data indicates there were no significant deformations or changes in deformation rate. Teck is currently in contact with Measurand, NavStar, and Golder to resolve data reduction discrepancies to ensure best practices are being adhered to and replicability of data manipulation can be maintained.
- Golder is tasked with updating the current TMD O&M Manual following completion of the 2019 construction efforts to capture recommendations and changes to the monitoring frequency program and addition of new instruments for monitoring purposes at the TMD and its appurtenant structures. This O&M Manual update will include a review of presently installed instruments and trigger level events to ensure that thresholds for monitoring dam performance are set based on historic precedence, projected pond level elevation rises, and tailing beach operating widths.
- Piezometric levels have generally behaved as anticipated in response to tailings pond levels, tailings beach production, and precipitation events. None of the critical piezometers exceeded their trigger elevations or hydraulic gradients. Several piezometers exceeded their rapid rise triggers, but they generally were related to anticipated conditions, such as during the spring freshet, tailings beach production, and precipitation events.
- Piezometer P-96-10 was installed very deep within the bedrock to monitor the subpermafrost groundwater and does not reflect the piezometric surface downstream of SPP-97-002 located downstream of the SCP.
- An anomaly in piezometers CPT-12-13B and CPT-13-13C on August 29, 2017 with a 3-foot rise and decrease in these respective piezometers appears to be related to a change in their temperature readings and suggests the readings from these two piezometers have been switched.
- Generally, the greatest seepage pumpback rate occurs during the spring freshet, which is typically coincident with the air temperature rising above freezing. The greatest average daily sump pumping rate occurred in late May 2019 at just over 1,100 gallons per minute (considering the standard monitoring period reviewed for most instrumentation). Improved tailings beach production has decreased seepage pumpback rates and those beaching practices should continue.
- The tailings pond elevation generally rises throughout winter until spring. After the freshet, the tailings pond elevation decreases as a result of discharging and generally remains stable throughout the summer. The tailings pond elevation has increased between 1 and 2 feet each year since 2016, with an increase of just over 1 foot occurring between January 2018 and January 2019.

- Temperatures beneath the TMD show degradation of the permafrost location in some locations and thermal stability being maintained in others. Since the subsurface temperatures indicate that permafrost thaw has progressed below the bedrock surface at the west abutment, these instruments do not provide significant monitoring data related to possible thaw subsidence and that cannot already be captured in the upstream and downstream piezometers.

5.0 RECOMMENDATIONS

The following sections summarize Golder's recommendations from this APR and recommendations provided by Klohn Crippen Berger Ltd. (KCB) after their periodic safety inspection (PSI) in 2017.

5.1 2019 Golder APR Recommendations

The following recommendations were developed by Golder during the preparation of this 2019 APR including the field inspection and our review of the monitoring data and inspections. Recommendations from Golder's 2018 APR that were not reproduced below have been completed.

- Continue monitoring the TMD in accordance to the O&M Manual until it is revised.
- Continue monitoring for lateral cracks on the crest of the Wing Wall. Identify changes in length, width, or depth. Then survey, photograph, and document in writing any increase observed.
- Continue working with Measurand, NavStar, and Golder to determine best practices for SAA inclinometer data reduction and replicability procedures.
- 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 pumpback is capturing seepage through the Seepage Collection Dam.
- 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.
- 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.

5.2 2017 KCB PSI Recommendations

Recommendations provided by KCB 2017 are summarized below in Table 3 along with Golder's target completion date, and current status.

Table 3: KCB PSI Recommendations

No.	Recommendation Description	Target Date	Status
PSI-R-01	As part of any dam raise above existing crest, EI. 986 ft., Teck and EoR should review the Hazard Potential Classification, specifically related to the three seasonally occupied cabins that are in the downstream inundation zone and whether they should be considered as "temporarily" populated.	Complete	Inundation analysis completed in October 2019.
PSI-R-02	Standalone reports are recommended that summarize key project information applicable to the TMD, specifically for (refer to description in text): • 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.	12/31/2019	Both documents are currently in progress
PSI-R-03	Review and action, as appropriate, recommendations and opportunities (refer to Table 3.2 of report text)[1] to improve implementation of the Observational Method at the TMD.	12/31/2021	Once Stage XI construction has been completed
PSI-R-04	The basis for selection of undrained shear strength ratio (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 (TMD28, TMD30)[1] and should be clarified.	Complete	Have reverted to the shear strength ratio of 0.22, which is deemed appropriate for NC materials
PSI-R-05	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.	NA	The material properties of the native coarse and fine materials have been reassessed by Golder
PSI-R-06	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)[1] is a useful reference when reviewing analyses methods and applicability of 3D stability analyses.	Completed	Stability of the Stage XI and XII dams have been reassessed by Golder
PSI-R-07	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.[1]	NA	Completing an independent deformation analysis as part of the Stage XI design
PSI-R-08	Record document should be prepared or approved by the EoR that summarizes actions taken to address recommendations from Stage IX review (TMD37)[1] to bring the Stage IX Raise into design compliance.	Completed	AECOM June 2018
PSI-R-09	The risk reduction measures identified by AECOM during the filter workshop (TMD11)[1], 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.	12/31/2021	Once Stage XI construction has been completed
PSI-R-10	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	This will be a complicated model, with much of the input information still being developed. This task may be completed at a future date once the input data has been properly defined and calibrated

No.	Recommendation Description	Target Date	Status
PSI-R-11	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.[1] • 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.	12/31/2020	O&M Manual to be updated in 2019 if possible
PSI-R-12	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.	12/31/2020	Will be done after PSI-R-02, O&M Manual update, and in coordination with the closure plan update
PSI-R-13	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.	12/31/2020	Date provided is to make recommendations; date for installation to be coordinated with Teck after construction of Stage XI is complete
PSI-R-14	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[1] 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."	12/31/2020	Partially complete - to be fully incorporated when the O&M manual is updated
PSI-R-15	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.	12/31/2020	Once Stage XI construction has been completed
PSI-R-16	Teck is recommended to plot tailings beach widths, include historic where available, and pumpback rates to identify whether a correlation can be identified.	Complete	
PSI-R-17	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.	Completed	

Notes: 1) Refer to Table 10.1 KCB 2017

6.0 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.

Sincerely,

Golder Associates Inc.

Matthew S. Gillaspy, EIT
Project Engineer

Steven L. Anderson, PE
Associate and Senior Geotechnical Engineering Consultant

MSG/SLA/TGK/sla

Attachments: Figure 1 – Project Location
Figure 2 – Main Embankment and Seepage Collection Dam View
Figure 3 – Wing Wall View
Figure 4 – Main Embankment Sections
Figure 5 – Wing Wall Sections
Figure 6 – Selected Site Observations of Main Embankment, Wing Wall, and Seepage Collection Dam

Appendix A – 2019 Site Inspection Photographs
Appendix B – ADNR Visual Inspection Checklist
Appendix C – SAA Inclinometer Data
Appendix D – Piezometer, Air Temperature, Precipitation, Tailings Pond Elevation, and Seepage Pumpback Data
Appendix E – Thermistor Data

https://golderassociates.sharepoint.com/sites/101201/technical work/_tailings main dam annual report/rev0/18113464-005-l-rev0-2019 tmd apr-20191024.docx

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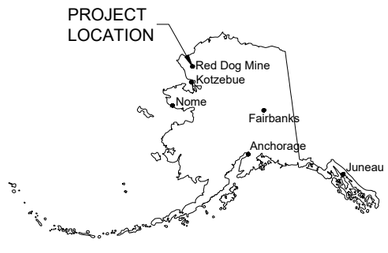
Figures



NOT TO SCALE

REFERENCES

1. AERIAL IMAGERY ACQUIRED BY PHOTOSAT INFORMATION LTD ON JUNE 13, 2019; FILENAMES: red_dog_wo4032a_wv2_2019jun13_mine_grid_east.tif AND red_dog_wo4032a_wv2_2019jun13_mine_grid_west.tif

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

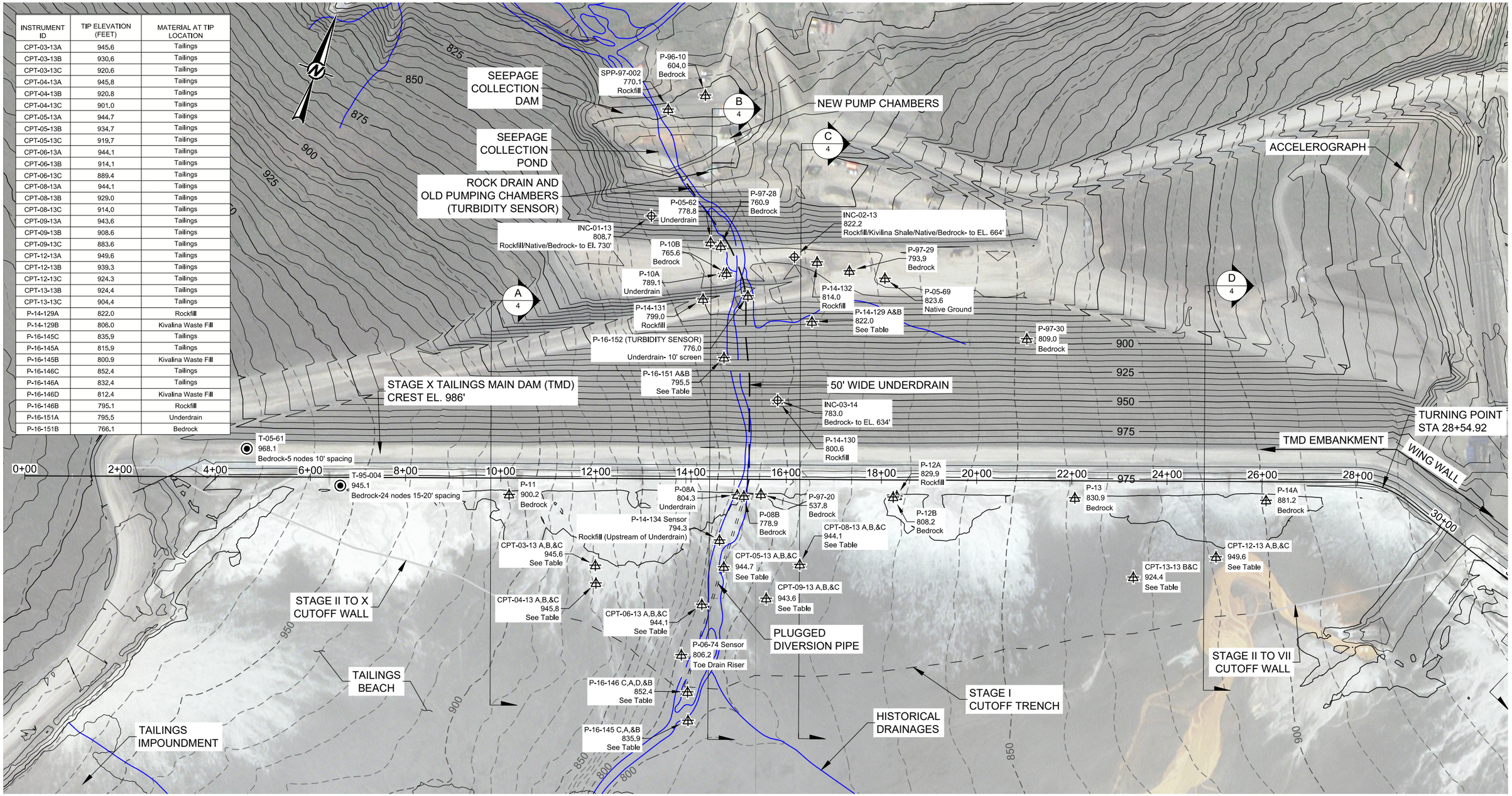
YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
SITE OVERVIEW

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	1

INSTRUMENT ID	TIP ELEVATION (FEET)	MATERIAL AT TIP LOCATION
CPT-03-13A	945.6	Tailings
CPT-03-13B	930.6	Tailings
CPT-03-13C	920.6	Tailings
CPT-04-13A	945.8	Tailings
CPT-04-13B	920.8	Tailings
CPT-04-13C	901.0	Tailings
CPT-05-13A	944.7	Tailings
CPT-05-13B	934.7	Tailings
CPT-05-13C	919.7	Tailings
CPT-06-13A	944.1	Tailings
CPT-06-13B	914.1	Tailings
CPT-06-13C	889.4	Tailings
CPT-08-13A	944.1	Tailings
CPT-08-13B	929.0	Tailings
CPT-08-13C	914.0	Tailings
CPT-09-13A	943.6	Tailings
CPT-09-13B	908.6	Tailings
CPT-09-13C	883.6	Tailings
CPT-12-13A	949.6	Tailings
CPT-12-13B	939.3	Tailings
CPT-12-13C	924.3	Tailings
CPT-13-13B	924.4	Tailings
CPT-13-13C	904.4	Tailings
P-14-129A	822.0	Rockfill
P-14-129B	806.0	Kivalina Waste Fill
P-16-145C	835.9	Tailings
P-16-145A	815.9	Tailings
P-16-145B	800.9	Kivalina Waste Fill
P-16-146C	852.4	Tailings
P-16-146A	832.4	Tailings
P-16-146D	812.4	Kivalina Waste Fill
P-16-146B	795.1	Rockfill
P-16-151A	795.5	Underdrain
P-16-151B	766.1	Bedrock



LEGEND

1000	2018 TOPOGRAPHY (5 AND 25 FOOT CONTOURS)
1000	ORIGINAL TOPOGRAPHY (10 AND 50 FOOT CONTOURS)
T-05-61 968.1 Bedrock-5 nodes 10' spacing	THERMISTOR STRING (T) TOP NODE ELEVATION SOIL UNIT AND NUMBER OF NODES AND SPACING
P-12B 808.2 Bedrock	VIBRATING WIRE PIEZOMETER (P, CPT) INSTRUMENT ELEVATION (HIGHEST IF TABULATED) SOIL UNIT
INC-01-13 808.7 Rockfill/Native/Bedrock- to EL. 730'	SAA INCLINOMETER (INC) HIGHEST SENSOR ELEVATION SOIL UNIT(S) AND BOTTOM SENSOR ELEVATION

REFERENCES

1. EXISTING TOPOGRAPHY PROVIDED BY TAK, FILENAME: 2018 As-built Topo Surface-EG.dwg
2. ORIGINAL TOPOGRAPHY AND HISTORIC DRAINAGES SHOWN FROM 1984 TOPOGRAPHIC CONTOURS PROVIDED BY TAK.
3. AERIAL IMAGERY ACQUIRED BY PHOTOSAT INFORMATION LTD ON JUNE 13, 2019; FILENAMES: red_dog_wo4032a_wv2_2019jun13_mine_grid_east.tif AND red_dog_wo4032a_wv2_2019jun13_mine_grid_west.tif
4. DAM FEATURES INCLUDING STATIONING, CUTOFF WALL AND TRENCH, UNDERDRAIN, AND DIVERSION PIPE FROM STAGE X AS-BUILT DRAWINGS IN "CONSTRUCTION COMPLETION REPORT, STAGE X WIDENING AND RAISE, TAILINGS MAIN DAM, RED DOG MINE, ALASKA," BY AECOM, DATED NOVEMBER 4, 2016.

0 100 200 300
SCALE FEET

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

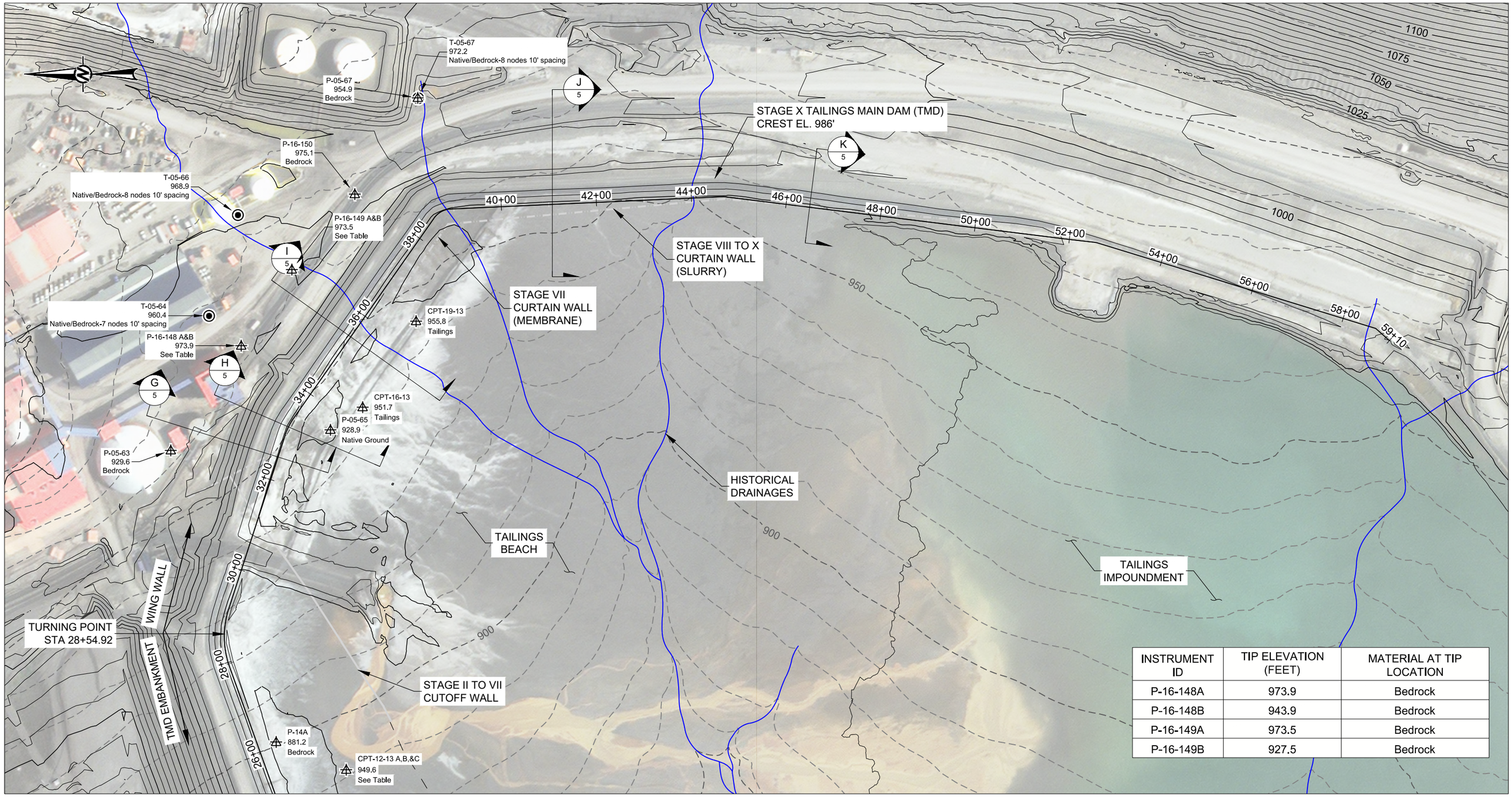
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
MAIN EMBANKMENT AND SEEPAGE COLLECTION DAM VIEW

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\Anchorage\Public\Geomatics\Teck\Red Dog\99_PROJECTS\18113464 TAK 2019 Red Dog Dam Inspections\02_PRODUCT\CN\DWG\Main Dam\ | File Name: RD MD APR 2019 Plan View.dwg



INSTRUMENT ID	TIP ELEVATION (FEET)	MATERIAL AT TIP LOCATION
P-16-148A	973.9	Bedrock
P-16-148B	943.9	Bedrock
P-16-149A	973.5	Bedrock
P-16-149B	927.5	Bedrock

LEGEND

1000	2018 TOPOGRAPHY (5 AND 25 FOOT CONTOURS)
1000	ORIGINAL TOPOGRAPHY (10 AND 50 FOOT CONTOURS)
T-05-61 968.1 Bedrock-5 nodes 10' spacing	THERMISTOR STRING (T) TOP NODE ELEVATION SOIL UNIT AND NUMBER OF NODES AND SPACING
P-12B 808.2 Bedrock	VIBRATING WIRE PIEZOMETER (P, CPT) INSTRUMENT ELEVATION (HIGHEST IF TABULATED) SOIL UNIT

REFERENCES

1. EXISTING TOPOGRAPHY PROVIDED BY TAK, FILENAME: 2018 As-built Topo Surface-EG.dwg
2. ORIGINAL TOPOGRAPHY AND HISTORIC DRAINAGES SHOWN FROM 1984 TOPOGRAPHIC CONTOURS PROVIDED BY TAK.
3. AERIAL IMAGERY ACQUIRED BY PHOTOSAT INFORMATION LTD ON JUNE 13, 2019; FILENAMES: red_dog_wo4032a_wv2_2019jun13_mine_grid_east.tif AND red_dog_wo4032a_wv2_2019jun13_mine_grid_west.tif
4. DAM FEATURES INCLUDING STATIONING, CUTOFF WALL AND TRENCH, UNDERDRAIN, AND DIVERSION PIPE FROM STAGE X AS-BUILT DRAWINGS IN "CONSTRUCTION COMPLETION REPORT, STAGE X WIDENING AND RAISE, TAILINGS MAIN DAM, RED DOG MINE, ALASKA," BY AECOM, DATED NOVEMBER 4, 2016.

0 100 200 300
SCALE FEET

CLIENT
TECK ALASKA INCORPORATED
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PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
WING WALL VIEW

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	3

Path: \\Anchorage\Public\Geomatics\Teck\Red Dog\99_PROJECTS\18113464 TAK 2019 Red Dog Dam Inspections\02_PRODUCTION\DWG\Main Dam\ | File Name: RD MD APR 2019 Plan View.dwg

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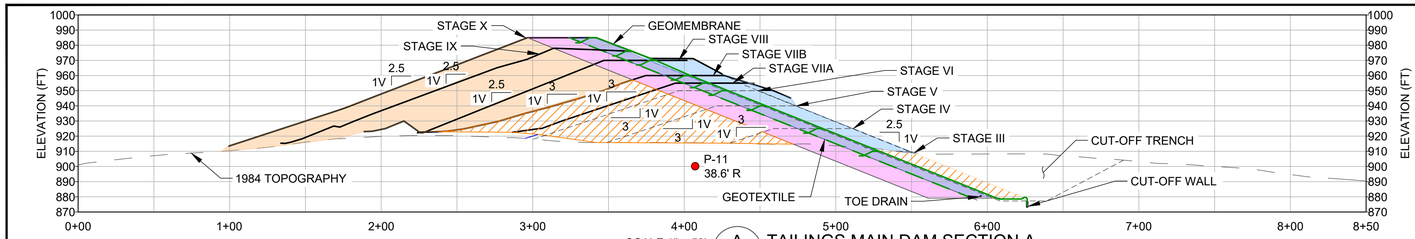
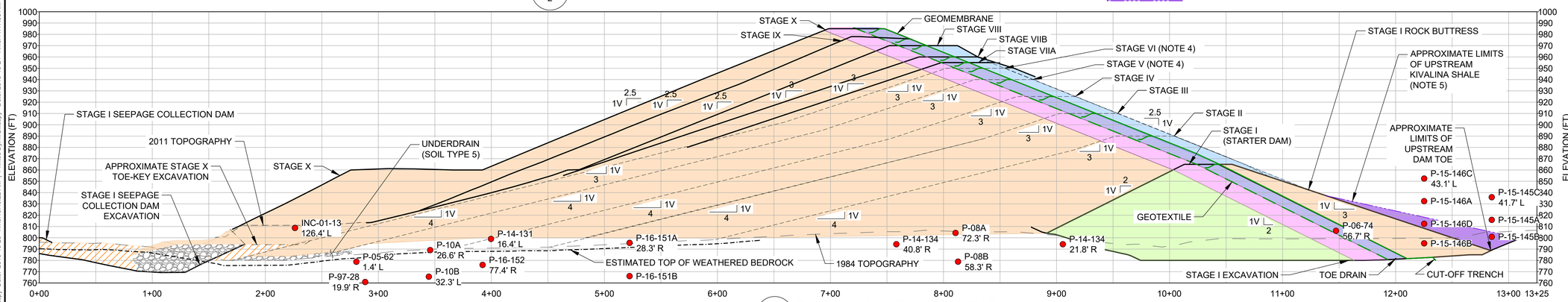


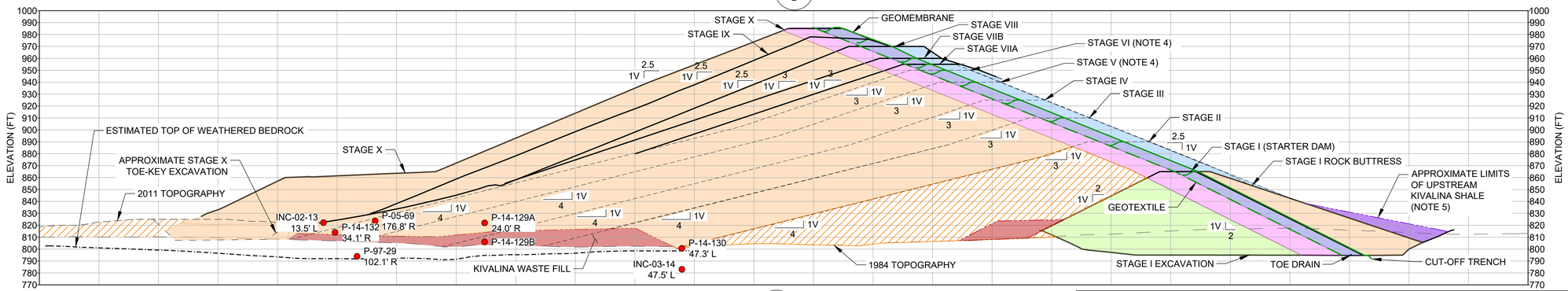
SCALE 1" = 50' — A/2 — TAILINGS MAIN DAM SECTION A

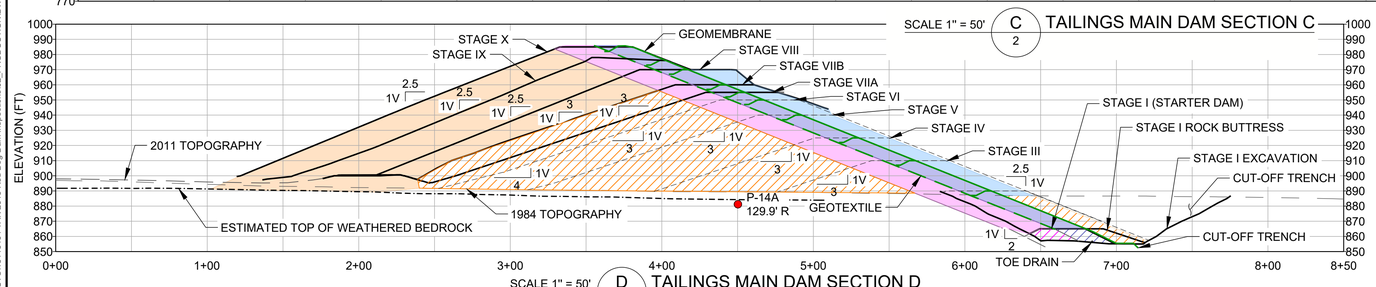
LEGEND

- 1984 PRE-MINE TOPOGRAPHY
- TAILINGS MAIN DAM STAGES I AND VII THROUGH X (NOTE 1)
- TAILINGS MAIN DAM STAGES II THROUGH VI (NOTE 1)
- ASSUMED, PROJECTED GRADES (NOTE 3)
- HDPE GEOMEMBRANE LINER SYSTEM (NOTE 6)
- 16 OZ GEOTEXTILE
- KIVALINA SHALE WASTE FILL (NOTE 2)
- UPSTREAM KIVALINA SHALE (NOTE 5)
- SOIL TYPE 1 (NOTE 2)
- SOIL TYPE 2 (NOTE 2)
- SOIL TYPE 3 (NOTE 2)
- SOIL TYPE 7 (NOTE 2)
- SOIL TYPE 9 (NOTE 2)
- ASSUMED SOIL TYPE 1 (NOTE 3)
- ASSUMED SOIL TYPE 2 (NOTE 3)
- ASSUMED SOIL TYPE 3 (NOTE 3)
- ASSUMED SOIL TYPE 7 (NOTE 3)
- ASSUMED SOIL TYPE 9 (NOTE 3)
- P-15-145C 41.7' L — PIEZOMETER OR INCLINOMETER # AND OFFSET (RIGHT OR LEFT)



SCALE 1" = 50' — B/2 — TAILINGS MAIN DAM SECTION B





SCALE 1" = 50' — C/2 — TAILINGS MAIN DAM SECTION C

SCALE 1" = 50' — D/2 — TAILINGS MAIN DAM SECTION D

NOTE(S)

1. STAGES I, VIIA, VIIB, AND VIII THROUGH X TAILINGS MAIN DAM GRADES AND SEEPAGE COLLECTION DAM GRADES FROM AS-BUILT DRAWING SETS. STAGES II THROUGH VI TAILINGS MAIN DAM GRADES ASSUMED FROM DESIGN DRAWING SETS.
2. MATERIAL TYPES SHOWN IN SOLID COLORS, INCLUDING KIVALINA SHALE WASTE FILL, ARE EXTRACTED FROM SHEET DRAWING T10R-6 "LAYOUT-TAILINGS MAIN DAM" FROM AECOM CONSTRUCTION DRAWINGS TECK ALASKA INCORPORATED NATIONAL INVENTORY OF DAMS IDENTIFICATION NUMBER - AK 00201 RED DOG MINE TAILINGS MAIN DAM, STAGE X RAISE RED DOG MINE, ALASKA, REVISION 1 DATED OCTOBER 31, 2016.
3. MATERIAL TYPES SHOWN IN STRIPED COLORS ARE ASSUMED MATERIAL REGIONS. GRADE LINES SHOWN IN BLUE, DASHED LINETYPES ARE ASSUMED, PROJECTED GRADES.
4. SELECT SHALE WAS UTILIZED AS FILL IN VARIOUS REGIONS OF THE STAGE V AND VI LIFTS. THESE REGIONS WILL BE FURTHER DEFINED UPON ADDITIONAL DATA REVIEW.
5. APPROXIMATE LIMITS OF UPSTREAM PLACED KIVALINA SHALE EXTRACTED FROM FIGURE 4-2 "TAILINGS MAIN DAM EMBANKMENT PLAN VIEW" FROM URS SUPPLEMENTAL GEOTECHNICAL REPORT, VOLUME 1 OF 2 - TEXT, FIGURES, TABLES & PHOTOS, RED DOG TAILINGS MAIN DAM, RED DOG MINE, ALASKA PREPARED FOR TECH ALASKA, INCORPORATED, DATED MARCH 15, 2013. KIVALINA SHALE PLACED SUB-AQUEOUSLY UPSTREAM OF STAGE I. HOWEVER, EXACT LIMITS AND THICKNESS OF PLACED MATERIAL NOT DOCUMENTED WITH AS-BUILT DATA.
6. HDPE GEOMEMBRANE LINER SYSTEM FOR STAGES I THROUGH VII CONSISTS OF (FROM TOP DOWN) 1.5 FEET THICK OF PROCESS SELECT $\frac{3}{8}$ INCH MINUS MATERIAL, 100-MILL HDPE GEOMEMBRANE, 1 FOOT THICK OF PROCESS SELECT $\frac{3}{8}$ INCH MINUS MATERIAL, AND 16 OZ GEOTEXTILE.
7. HDPE GEOMEMBRANE LINER SYSTEM FOR STAGE XII CONSISTS OF (FROM TOP DOWN) 1.5 FEET THICK OF PROCESS SELECT $\frac{3}{8}$ INCH MINUS MATERIAL, 100-MILL HDPE GEOMEMBRANE, AND 1 FOOT THICK OF PROCESS SELECT $\frac{3}{8}$ INCH THICK OF PROCESS SELECT $\frac{3}{8}$ INCH MINUS MATERIAL.
8. HDPE GEOMEMBRANE LINER SYSTEM FOR STAGE IX CONSISTS OF (FROM TOP DOWN) 100-MILL HDPE GEOMEMBRANE, AND 1 FOOT THICK OF PROCESS SELECT $\frac{3}{8}$ INCH MINUS MATERIAL.
9. HDPE GEOMEMBRANE LINER SYSTEM FOR STAGE X CONSISTS OF (FROM TOP DOWN) 100-MILL HDPE GEOMEMBRANE, 1 FOOT THICK OF PROCESS SELECT $\frac{3}{8}$ INCH MINUS MATERIAL, AND 16 OZ GEOTEXTILE.

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DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

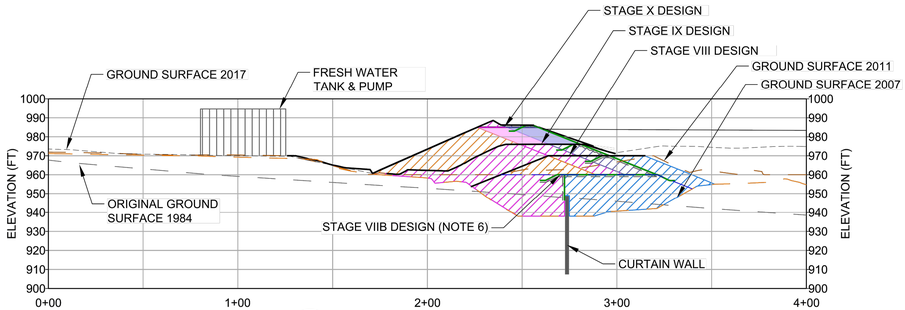
TITLE
MAIN EMBANKMENT SECTIONS

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	4

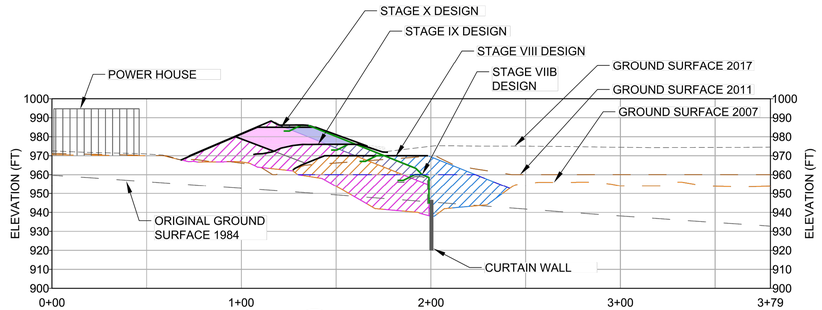
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

0 1 in

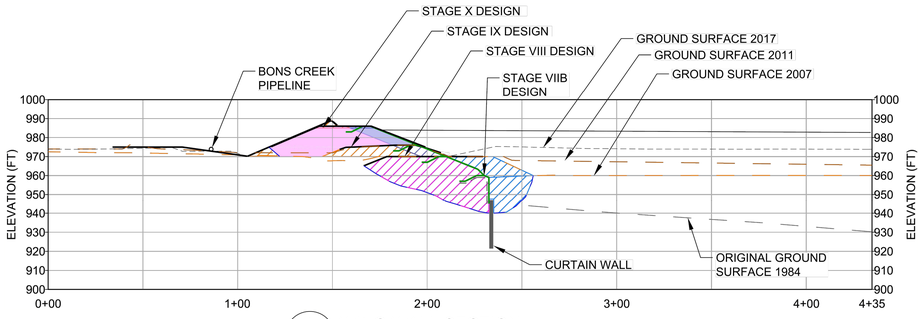
Path: \\Anchorage\Public\Geomatics\Teck\Red Dog\99_PROJECTS\18113464 TAK 2019 Red Dog Dam Inspections\02_PRODUCTION\DWG\Main Dam\ | File Name: RD IMD APR 2019 Main Embankment Sections.dwg | Last Edited By: mgillaspy Date: 2019-10-23 Time:10:40:22 AM | Printed By: MGillaspy Date: 2019-10-24 Time:11:17:58 AM



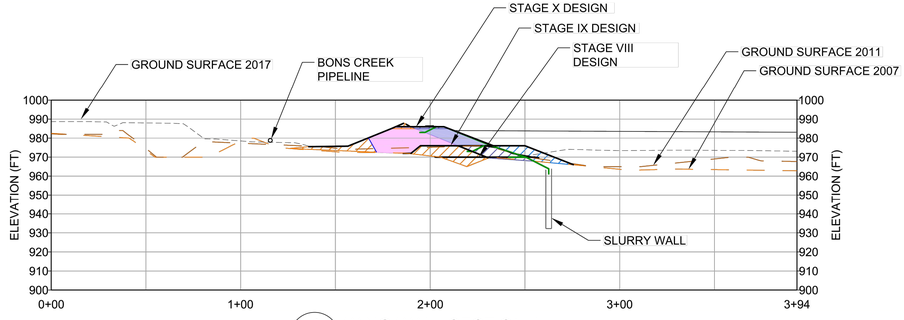
SCALE 1" = 40' — G/3 — WING WALL SECTION G



SCALE 1" = 40' — H/3 — WING WALL SECTION H



SCALE 1" = 40' — I/3 — WING WALL SECTION I

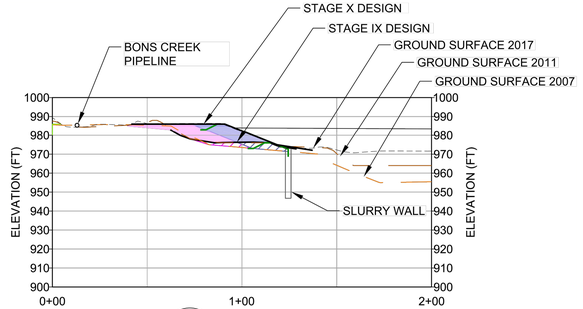


SCALE 1" = 40' — J/3 — WING WALL SECTION J

LEGEND

- 1984 PRE-MINE TOPOGRAPHY
- 2007 TOPOGRAPHY
- 2011 TOPOGRAPHY
- 2017 TOPOGRAPHY (NOTE 4)
- TAILINGS MAIN DAM STAGES I AND VII THROUGH X (NOTE 1)
- ASSUMED, PROJECTED GRADES (NOTE 2)
- HDPE GEOMEMBRANE LINER SYSTEM (NOTE 5)
- SOIL TYPE 3 (NOTE 2)
- SOIL TYPE 7 (NOTE 2)
- ASSUMED SOIL TYPE 1 (NOTE 2)
- ASSUMED SOIL TYPE 3 (NOTE 2)
- ASSUMED SOIL TYPE 7 (NOTE 2)
- ASSUMED SOIL TYPE 9 (NOTE 2)

0 40 80
1" = 40' FEET



SCALE 1" = 40' — K/3 — WING WALL SECTION K

NOTE(S)

1. ORIGINAL SECTIONS DEVELOPED BY GOLDER AS PRESENTED IN TECK ALASKA INCORPORATED, RED DOG MINE TAILINGS MAIN DAM, CONSOLIDATED AS-BUILT DRAWINGS, RED DOG MINE, ALASKA, ISSUED FOR CLIENT DATED MARCH 4, 2019.
2. STAGES I, VIIA, VIIB, AND VIII THROUGH X TAILINGS MAIN DAM GRADES AMD SEEPAGE COLLECTION DAM GRADES FROM AS-BUILT DRAWING SIETS. STAGES II THROUGH VI TAILINGS MAIN DAM GRADES ASSUMED FROM DESIGN DRAWING SETS.
3. MATERIAL TYPES SHOWN IN SOLID COLORS, INCLUDING KIVALINA SHALE WASTE FILL, ARE EXTRACTED FROM SHEET DRAWING T10R-6 "LAYOUT-TAILINGS MAIN DAM" FROM AECOM CONSTRUCTION DRAWINGS TECK ALASKA INCORPORATED NATIONAL INVENTORY OF DAMS IDENTIFICATION NUMBER - AK 00201 RED DOG MINE TAILINGS DAM, STAGE X RAISE RED DOG MINE, ALASKA REVISION 1 DATED OCTOBER 16, 2016.
4. MATERIAL TYPES SHOWN IN STRIPED COLORS ARE ASSUMED MATERIAL REGIONS. GRADE LINES SHOWN IN BLUE, DASHED LINETYPES ARE ASSUMED, PROJECTED GRADES.
5. EXISTING CONTOURS (2017) SHOWN IN PROFILE SECTION VIEWS BASED ON LIDAR INFORMATION PREPARED BY KODIAK MAPPING INC., ON NOVEMBER 13, 2017.
6. HDPE GEOMEMBRANE LINER SYSTEM ALONG CURTAIN WALL AND SLURRY WALL GENERALLY CONSIST OF SOIL TYPE NUMBER 4 INSTALLED ON BOTH SIDES OF THE 100-MIL HDPE GEOMEMBRANE.
7. STAGE VIIB CONSTRUCTION RAISED THE TAILINGS MAIN DAM TO ELEVATION 960 FT. STAGE VIII CONSTRUCTION REALIGNED THE WING WALL UPSTREAM.

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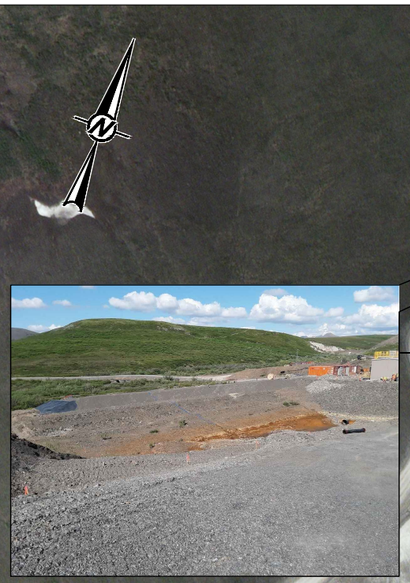
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
WING WALL SECTIONS

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

0 1 in



IRON STAINING NEAR BUTTRESS TOE AND SCP

DAMAGE TO HDPE GEOMEMBRANE LINER

HISTORIC CRACK AT DAM CREST

HISTORIC CRACK ALONG STAGE X UPSTREAM SLOPE TOE

50' WIDE UNDERDRAIN

5+00

10+00

15+00

20+00

30+00

35+00

40+00

45+00

50+00

55+00

59+10

STAGE II TO X CUTOFF WALL

PLUGGED DIVERSION PIPE

STAGE I CUTOFF TRENCH

TAILINGS BEACH

STAGE II TO VII CUTOFF WALL

STAGE VII CURTAIN WALL (MEMBRANE)

STAGE VIII TO X CURTAIN WALL (SLURRY)

TAILINGS IMPOUNDMENT

0 200 400 600

SCALE FEET

LEGEND

- SURVEYED CRACKS IN 2018
- SURVEYED CRACKS IN 2017

REFERENCES

1. AERIAL IMAGERY ACQUIRED BY PHOTOSAT INFORMATION LTD ON JUNE 13, 2019; FILENAMES: red_dog_wo4032a_wv2_2019jun13_mine_grid_east.tif AND red_dog_wo4032a_wv2_2019jun13_mine_grid_west.tif
2. DAM FEATURES INCLUDING STATIONING, CUTOFF WALL AND TRENCH, UNDERDRAIN, AND DIVERSION PIPE FROM STAGE X AS-BUILT DRAWINGS IN "CONSTRUCTION COMPLETION REPORT, STAGE X WIDENING AND RAISE, TAILINGS MAIN DAM, RED DOG MINE, ALASKA," BY AECOM, DATED NOVEMBER 4, 2016.
3. FIELD PHOTOGRAPHS TAKEN ON JUNE 21, 2019. NO NEW CRACKING WAS OBSERVED DURING 2019 ANNUAL INSPECTION.

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PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
SELECTED SITE OBSERVATIONS OF MAIN EMBANKMENT, WING WALL, AND SEEPAGE COLLECTION DAM

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

1 in

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APPENDIX A

2019 Site Inspection Photographs

Appendix A: Photographs

PHOTO 1

TAILINGS BEACH, LOOKING SE

June 21, 2019

PHOTO 2

UPSTREAM LINER AT TMD EMBANKMENT, LOOKING SW FROM PIPELINE CORRIDOR

June 21, 2019

Appendix A: Photographs

PHOTO 3 LINER CUTOFF AT TMD EMBANKMENT WEST ABUTMENT, LOOKING E-NE June 21, 2019	
PHOTO 4 TMD EMBANKMENT WEST ABUTMENT, LOOKING W June 21, 2019	

Appendix A: Photographs

PHOTO 5 LINER DAMAGE AT TMD EMBANKMENT, LOOKING W June 21, 2019	
PHOTO 6 CLOSEUP OF LINER DAMAGE June 21, 2019	

PHOTO 7 TAILINGS DISCHARGE AREA, LOOKING SE **June** 21, 2019	
PHOTO 8 PIPE BENCH WASHOUT NEAR PIEZOMETER P-11, LOOKING SW June 21, 2019	

Appendix A: Photographs

PHOTO 9

WING WALL CREST AND UPSTREAM FACE, LOOKING SE

June 21, 2019

Appendix A: Photographs

PHOTO 10

WING WALL DOWNSTREAM SLOPE NEAR POWER HOUSE, LOOKING NE

June 21, 2019

PHOTO 11

HISTORIC TRANSVERSE CRACK AT WING WALL CREST, LOOKING NE

June 22, 2018

Appendix A: Photographs

PHOTO 12 UPSTREAM WING WALL LINER, LOOKING NW June 21, 2019	
PHOTO 13 UPSTREAM WING WALL LINER, LOOKING S June 21, 2019	

Appendix A: Photographs	
PHOTO 14 HISTORIC TRANSVERSE CRACK AT WING WALL CREST, LOOKING E June 21, 2019	
PHOTO 15 HISTORIC CRACK ALONG STAGE X WING WALL UPSTREAM TOE, LOOKING N June 21, 2019	

Appendix A: Photographs

PHOTO 16 CLOSEUP OF CRACK ALONG STAGE X WING WALL UPSTREAM TOE, LOOKING N June 21, 2019	
PHOTO 17 WING WALL DOWNSTREAM SLOPE, LOOKING SE June 21, 2019	

Appendix A: Photographs

PHOTO 18 TMD EMBANKMENT WEST ABUTMENT, LOOKING DOWN SLOPE FROM CREST June 21, 2019	
PHOTO 19 TMD EMBANKMENT WEST ABUTMENT, LOOKING UP SLOPE FROM BUTTRESS June 21, 2019	

Appendix A: Photographs

PHOTO 20 TMD EMBANKMENT EAST ABUTMENT, LOOKING NW DOWN SLOPE June 22, 2018	
PHOTO 21 TMD EMBANKMENT DOWNSTEAM SLOPE FACE, LOOKING W June 21, 2019	

Appendix A: Photographs

PHOTO 22

TMD EMBANKMENT DOWNSTREAM SLOPE AND EAST ABUTMENT, LOOKING SE FROM BUTRESS

June 21, 2019

PHOTO 23

TMD EMBANKMENT DOWNSTREAM SLOPE AND WEST ABUTMENT, LOOKING W FROM BUTTRESS

June 21, 2019

Appendix A: Photographs

PHOTO 24

TMD EMBANKMENT DOWNSTREAM BUTTRESS SLOPE, LOOKING S

June 21, 2019

PHOTO 25

TMD SEEPAGE COLLECTION POND AND DAM, LOOKING E

June 21, 2019

Appendix A: Photographs

PHOTO 26

SEEPAGE COLLECTION DAM AND POND, LOOKING NE

June 21, 2019

PHOTO 27

SEEPAGE-SEEPAGE PUMPBACK, LOOKING N

June 21, 2019

APPENDIX B

ADNR Visual Inspection Checklist

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

GENERAL INFORMATION

NAME OF DAM: Tailings Main Dam	POOL ELEVATION: 972
NATIONAL INVENTORY OF DAMS ID#: AK00201	TAILWATER ELEVATION: 789 Feet (SCP)
OWNER: Teck Alaska Inc.	CURRENT WEATHER: Partly Cloudy
HAZARD POTENTIAL CLASSIFICATION: Class II (Signific	PREVIOUS WEATHER: Partly Cloudy
SIZE CLASSIFICATION: N/A	INSPECTED BY: Steven L. Anderson, PE and Matthew S. Gillaspy, EIT
PURPOSE OF DAM: Tailings Storage Facility	INSPECTION FIRM: Golder Associates Inc.
O & M MANUAL REVIEWED: Yes	DATE OF INSPECTION: June 21, 2019
EMERGENCY ACTION PLAN REVIEWED: Yes	

ITEM	YES	NO	REMARKS
RESERVOIR			
1. Any upstream development?	✓		Tailings Back Dam Rockfill Widening
2. Any upstream impoundments?	✓		Tailings Beach
3. Shoreline slide potential?		✓	
4. Significant sedimentation?	✓		Stored Tailings
5. Any trash boom?		✓	
6. Any ice boom?		✓	
7. Operating procedure changes?	✓		Stage XI Raise DS Toe Work Planned
DOWNSTREAM CHANNEL			
1. Channel			Seepage Collection Pond Fish Weir
a. Eroding or Backcutting		✓	
b. Sloughing?		✓	
c. Obstructions?	✓		Seepage Collection Dam and Fish Weir
2. Downstream Floodplain			
a. Occupied housing?		✓	
b. Roads or bridges?	✓		Fish Weir Road, Future Exploration Road
c. Businesses, mining, utilities?		✓	
d. Recreation Area?	✓		Staff Recreational Area
e. Rural land?	✓		
f. New development?		✓	
EMERGENCY ACTION PLAN			
1. Class I or Class II Dam?	✓		Class II Dam
2. Emergency Action Plan Available?	✓		In Operations and Maintenance Manual
3. Emergency Action Plan current?	✓		
4. Recent emergency action plan exercise?	✓		**DATE:** Tabletop exercise 9/19/2018
INSTRUMENTATION			
1. Are there			
a. Piezometers?	✓		
b. Weirs?		✓	
c. Observation wells?	✓		
d. Settlement Monuments?		✓	currently removed but will be replaced
e. Horizontal Alignment Monuments?	✓		
f. Thermistors?	✓		
2. Are readings			
a. Available?	✓		
b. Plotted?	✓		
c. Taken periodically?	✓		In accordance with O&M Manual

ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

SAFETY

ITEM	YES	NO	REMARKS
SAFETY			
1. ACCESS			**TYPE:**
a. Road access?	✓		
b. Trail access?		✓	
c. Boat access?	✓		Boat Ramp available for Teck use
d. Air access?	✓		Air access restricted by Teck
e. Access safe?	✓		
f. Security gates and fences?		✓	Remote Secured Site
g. Restricted access signs?	✓		
2. PERSONNEL SAFETY			
a. Safe access to maintenance and operation areas?	✓		
b. Necessary handrails and ladders available?			N/A
c. All ladders and handrails in safe condition?			N/A
d. Life rings or poles available?	✓		Available at Mine offices
e. Limited access and warning signs in place?	✓		
f. Safe walking surfaces?	✓		
3. DAM EMERGENCY WARNING DEVICES			
a. Emergency Action Plan required?	✓		
b. Emergency warning devices required by EAP?	✓		**TYPE(S):** Monitored Instruments
c. Emergency warning devices available?	✓		
d. Emergency warning devices operable?	✓		
e. Emergency warning devices tested?	✓		
f. Emergency warning devices tested by owner?	✓		**WHEN:** monthly during instrumentation review
g. Emergency procedures available at dam?	✓		Mine offices
h. Dam operating staff familiar with EAP?	✓		
4. OPERATION AND MAINTENANCE MANUAL			
a. O & M Manual reviewed?	✓		
b. O & M Manual current?	✓		**DATE:** Rev 12, November 4, 2016
c. Contains routine inspection schedule?	✓		
c. Contains routine inspection checklist?	✓		

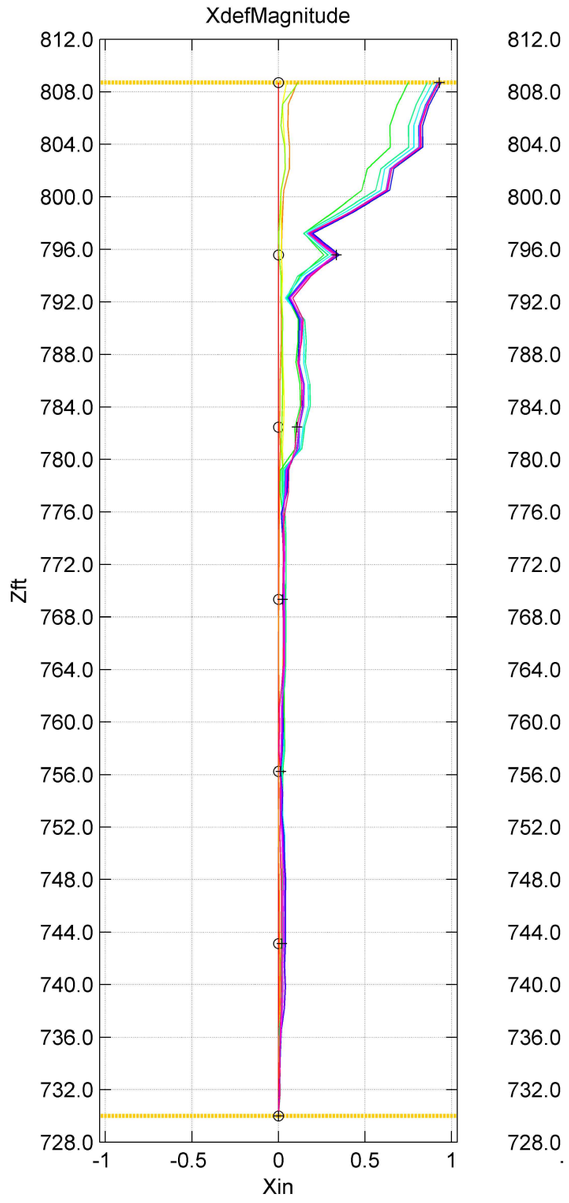
ALASKA DAM SAFETY PROGRAM
VISUAL INSPECTION CHECKLIST

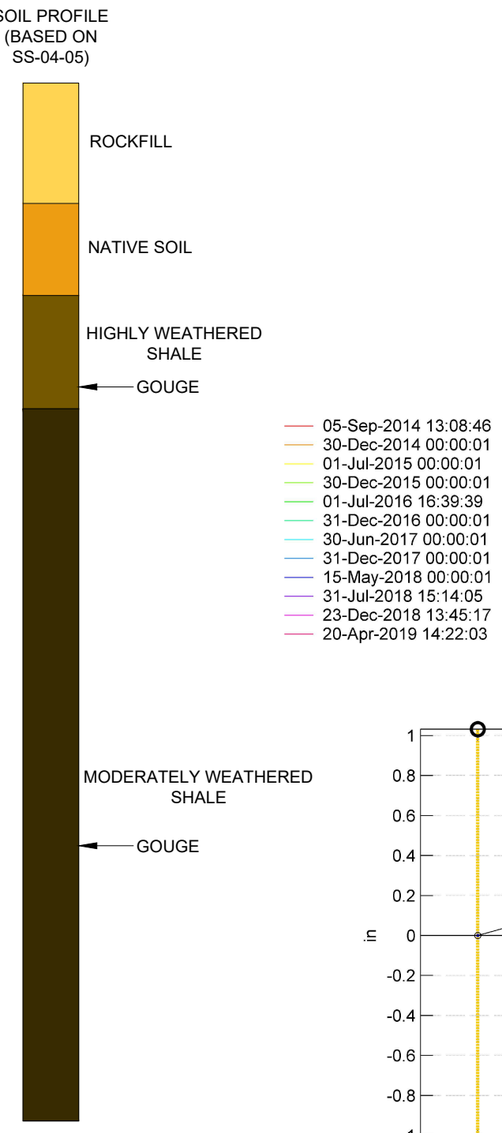
EMBANKMENT DAMS

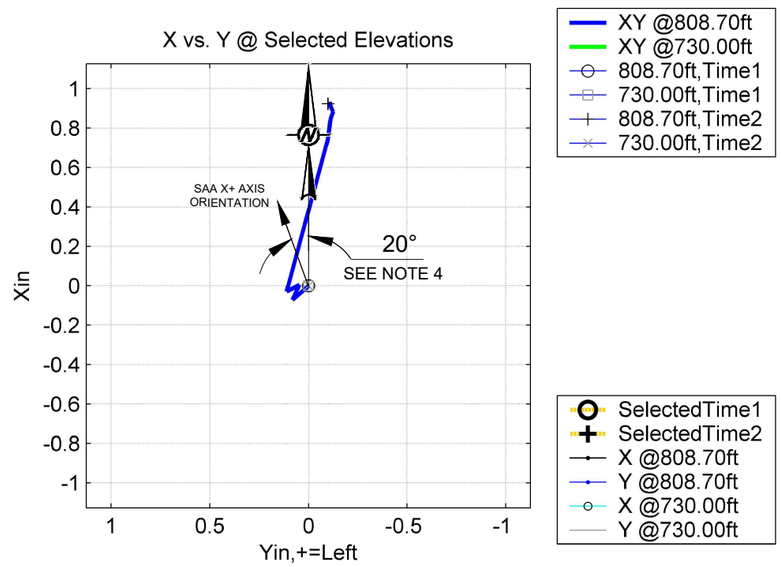
ITEM	YES	NO	REMARKS
EMBANKMENT DAMS			**TYPE:** Rockfill with upstream geomembrane
1. CREST			
a. Any settlement?	☐	✓	
b. Any misalignment?	☐	✓	
c. Any cracking?	✓	☐	Crest of Wing Wall (Lateral, Shallow)
d. Adequate freeboard?	✓	☐	
2. UPSTREAM SLOPE			
a. Adequate slope protection?	✓	☐	
b. Any erosion or beaching?	✓	☐	Beaching approved to El. 985
c. Trees or brush growing on slope?	☐	✓	
d. Deteriorating slope protection?	☐	✓	
e. Visual settlement?	☐	✓	
f. Any sinkholes?	☐	✓	
3. DOWNSTREAM SLOPE			**TYPE:** Exposed fill slope
a. Adequate slope protection?	✓	☐	
b. Any erosion?	☐	✓	
c. Trees or brush growing on slope?	☐	✓	
d. Animal burrows?	☐	✓	
e. Sinkholes?	☐	✓	
f. Visual settlement?	☐	✓	
g. Surface seepage?	☐	✓	
h. Toe drains dry?	☐	✓	Clear seep into Seepage Collection Pond
i. Relief wells flowing?	☐	☐	(N/A) Relief Wells not present
j. Slides or slumps?	☐	✓	
4. ABUTMENT CONTACTS			
a. Any erosion?	☐	✓	
b. Seepage present?	☐	✓	
c. Boils or springs downstream?	☐	✓	
5. FOUNDATION			**TYPE:** Alluvial and colluvial deposits
a. If dam is founded on permafrost			
(1) Is fill frozen?	☐	✓	Extent of instrumentation indicates thawed
(2) Are internal temperatures monitored?	✓	☐	
b. If dam is founded on bedrock			**TYPE:** Stage 1 - Starter Dam
(1) Is bedrock adversely bedded?	☐	✓	
(2) Does rock contain gypsum?	☐	✓	
(3) Weak strength beds?	✓	☐	Clay Gouge
c. If dam founded on overburden			**TYPE:** Subsequent Stages
(1) Pipeable?	✓	☐	Addressed in design
(2) Compressive?	✓	☐	Addressed in design
(3) Low shear strength?	✓	☐	Addressed in design

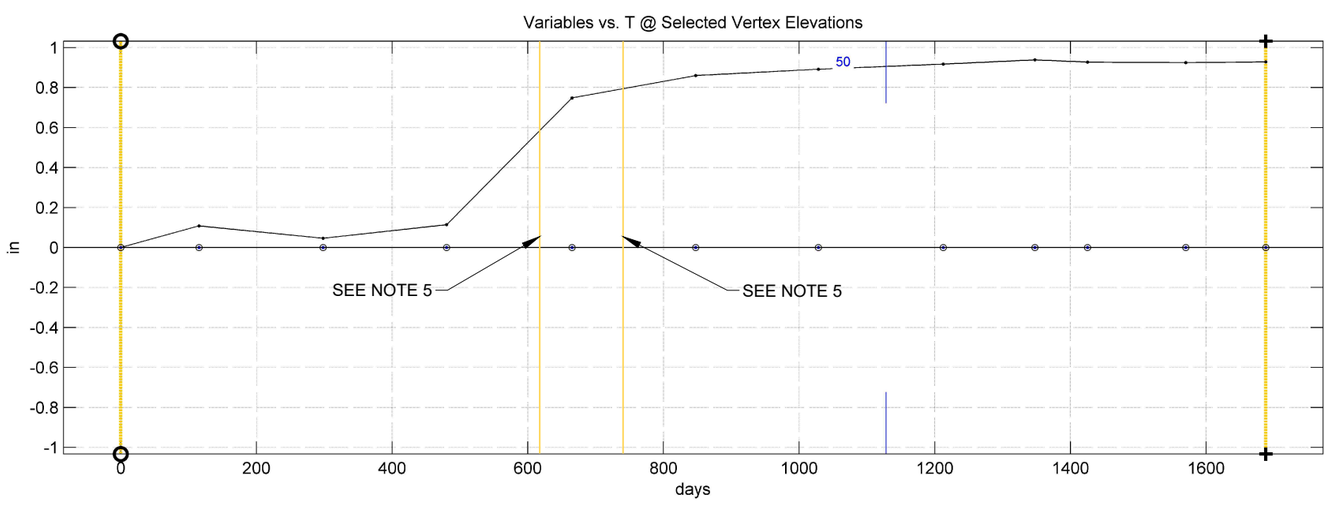
APPENDIX C

SAA Inclinometer Data









CUMULATIVE SAA INCLINOMETER DATA COLLECTED FROM SEPTEMBER 2014 BASELINE

NOTES

1. DISPLACEMENT PLOTTED VERSUS TIME AT LOCATION OF MAXIMUM DISPLACEMENT WITHIN VERTICAL ARRAY.
2. INC-01-13 LIES BURIED UNDERNEATH APPROXIMATELY 25 FEET OF FILL.
3. SENSORIZED INSTRUMENTATION TOLERANCE ERROR AS PER MEASURAND SPECIFICATIONS IS +/- 0.06 INCHES.
4. AZIMUTH ADJUSTMENT OF 20 DEGREES (COUNTER CLOCKWISE) IS ESTIMATED FROM THE URS PHASE II GEOTECHNICAL REPORT THAT STATES THE POSITIVE X-DISPLACEMENT DIRECTION IS NORTH-NORTHWEST
5. APPROXIMATE DATES OF STAGE X BUTTRESS CONSTRUCTION (MAY 15, 2016 TO SEPTEMBER 15, 2016.)

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

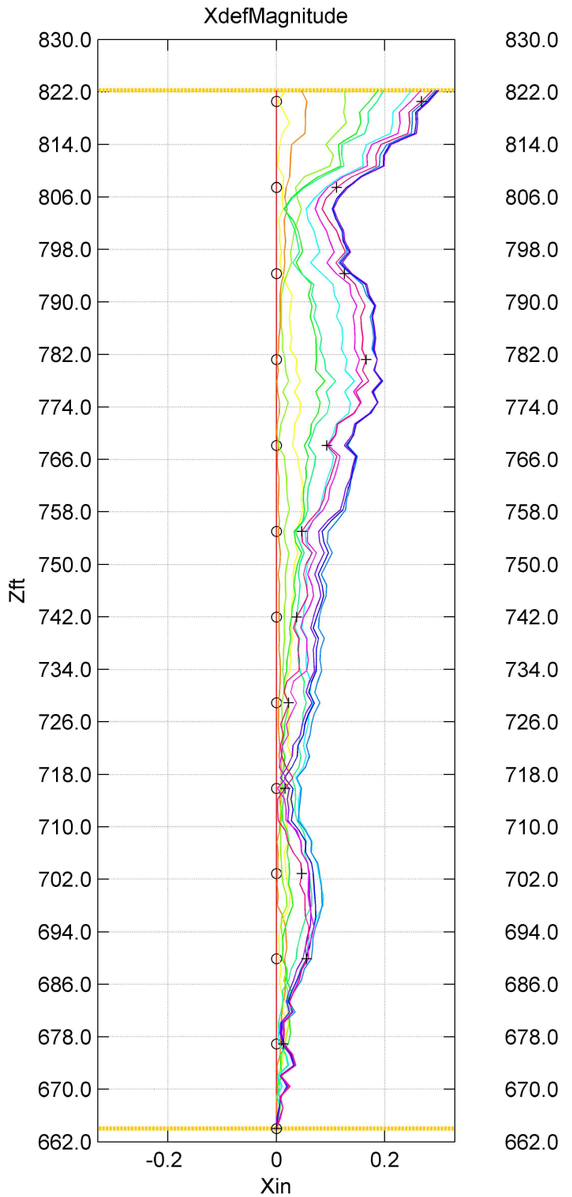
TITLE
SAA INC-01-13

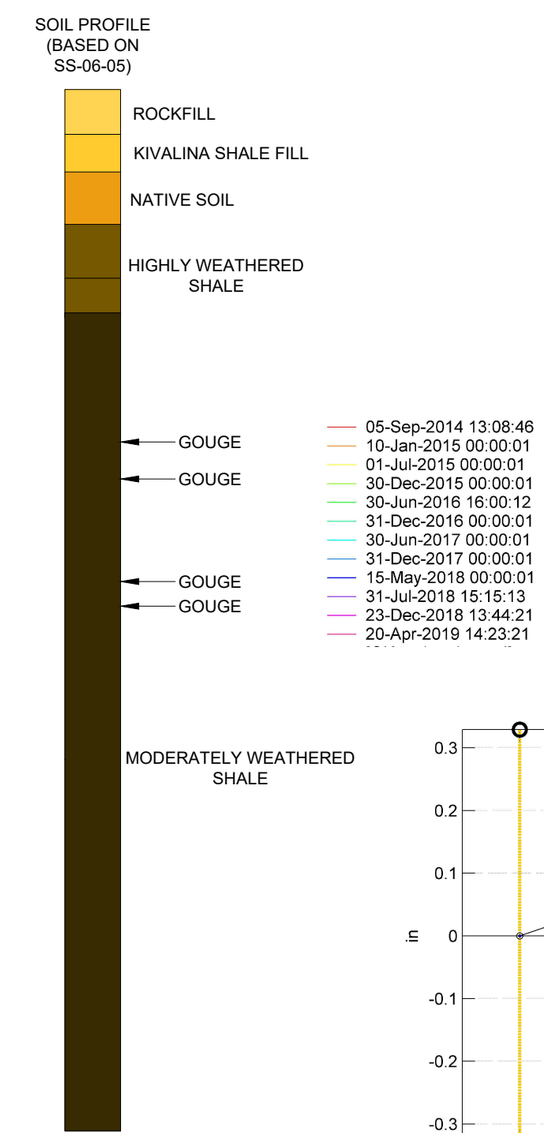
PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	C-1

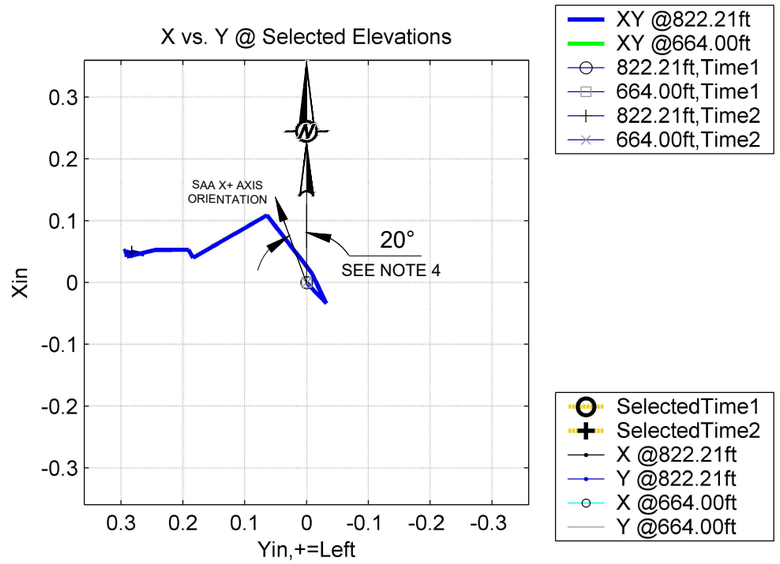
Path: \\Anchorage\Public\Geomatics\Teck\Red Dog\09_PROJECTS\18113464 TAK 2019 Red Dog Dam Inspections\02_PRODUCTION\DWG\Main Dam\ | File Name: RD MD APR 2019 Inclinometers.dwg

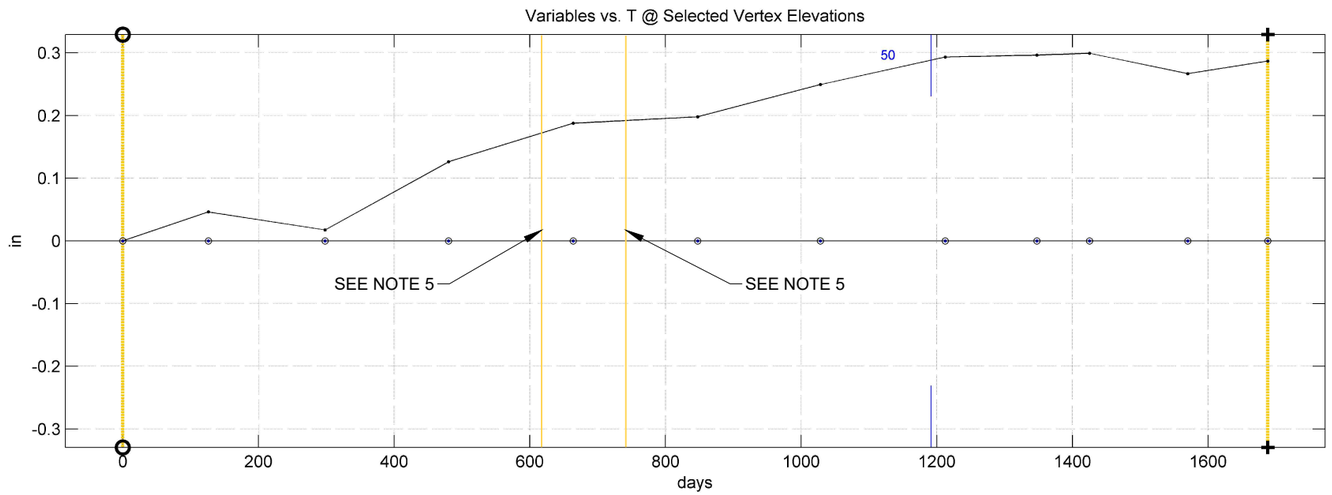
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

1 in
0









CUMULATIVE SAA INCLINOMETER DATA COLLECTED FROM SEPTEMBER 2014 BASELINE

NOTES

1. DISPLACEMENT PLOTTED VERSUS TIME AT LOCATION OF MAXIMUM DISPLACEMENT WITHIN VERTICAL ARRAY.
2. INC-02-13 LIES BURIED UNDERNEATH APPROXIMATELY 35+ FEET OF FILL.
3. SENSORIZED INSTRUMENTATION TOLERANCE ERROR AS PER MEASURAND SPECIFICATIONS IS +/- 0.06 INCHES.
4. AZIMUTH ADJUSTMENT OF 20 DEGREES (COUNTER CLOCKWISE) IS ESTIMATED FROM THE URS PHASE II GEOTECHNICAL REPORT THAT STATES THE POSITIVE X-DISPLACEMENT DIRECTION IS NORTH-NORTHWEST
5. APPROXIMATE DATES OF STAGE X BUTTRESS CONSTRUCTION (MAY 15, 2016 TO SEPTEMBER 15, 2016.)

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

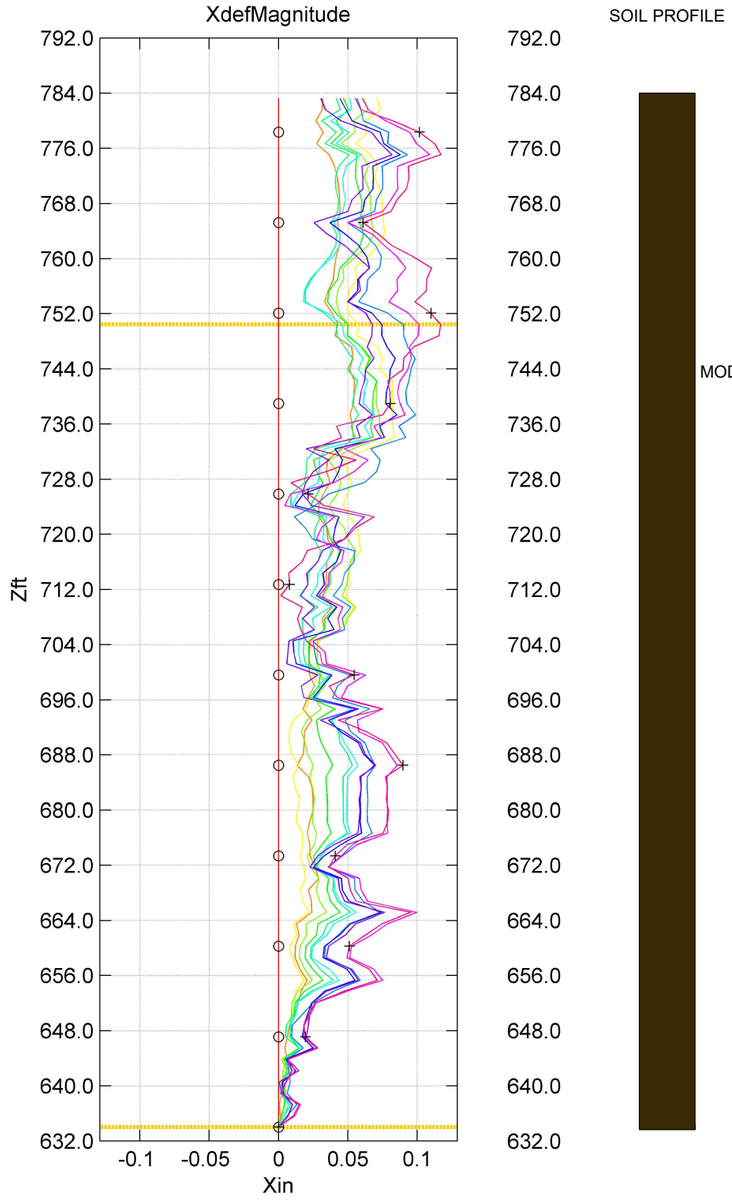
CONSULTANT
GOLDER

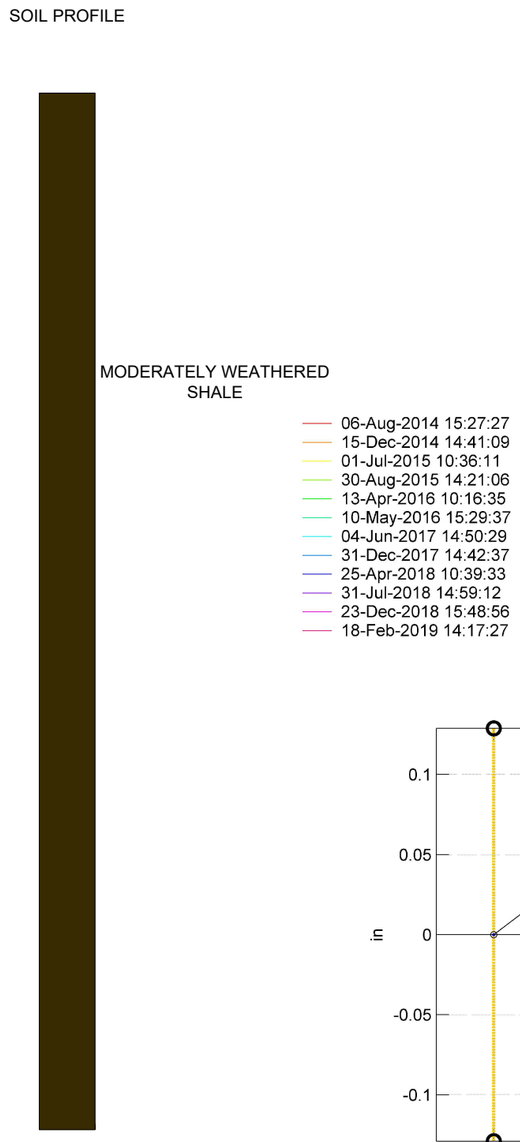
YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

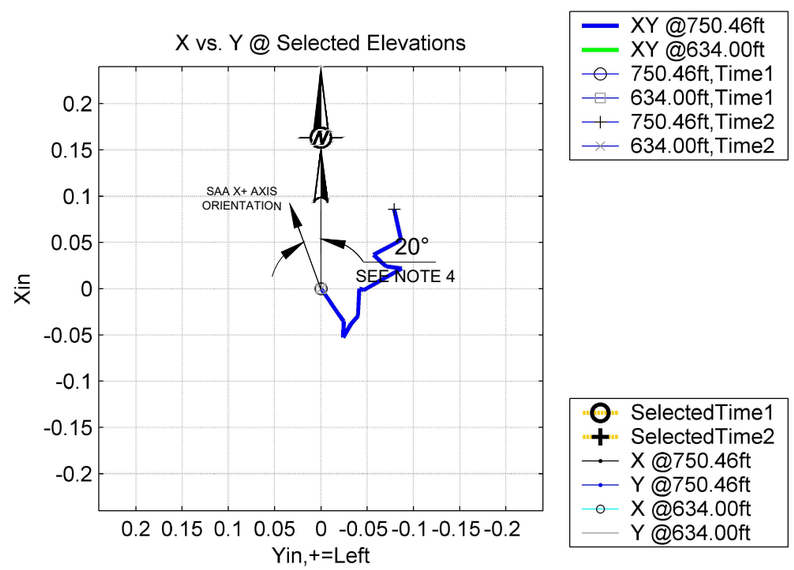
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

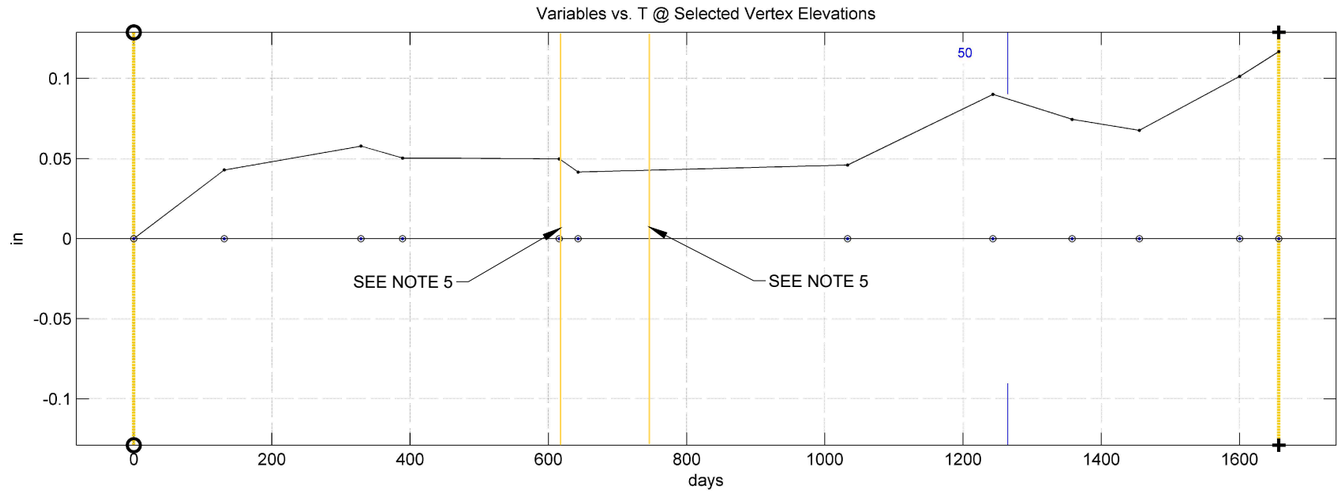
TITLE
SAA INC-02-13

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	C-2









CUMULATIVE SAA INCLINOMETER DATA COLLECTED FROM AUGUST 2014 BASELINE

NOTES

1. DISPLACEMENT PLOTTED VERSUS TIME AT LOCATION OF MAXIMUM DISPLACEMENT WITHIN VERTICAL ARRAY.
2. INC-03-14 LIES BURIED UNDERNEATH APPROXIMATELY 17 FEET OF FILL.
3. SENSORIZED INSTRUMENTATION TOLERANCE ERROR AS PER MEASURAND SPECIFICATIONS IS +/- 0.06 INCHES.
4. AZIMUTH ADJUSTMENT OF 20 DEGREES (COUNTER CLOCKWISE) IS ESTIMATED FROM THE URS PHASE II GEOTECHNICAL REPORT THAT STATES THE POSITIVE X-DISPLACEMENT DIRECTION IS NORTH-NORTHWEST
5. APPROXIMATE DATES OF STAGE X BUTTRESS CONSTRUCTION (MAY 15, 2016 TO SEPTEMBER 15, 2016.)

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

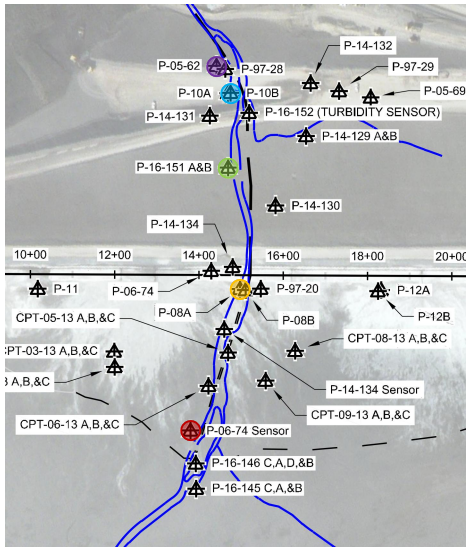
TITLE
SAA INC-03-14

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	C-3

APPENDIX D

Piezometer, Air Temperature, Precipitation, Tailings Pond Elevation, and Seepage Pumpback Data

GENERAL VICINITY MAP

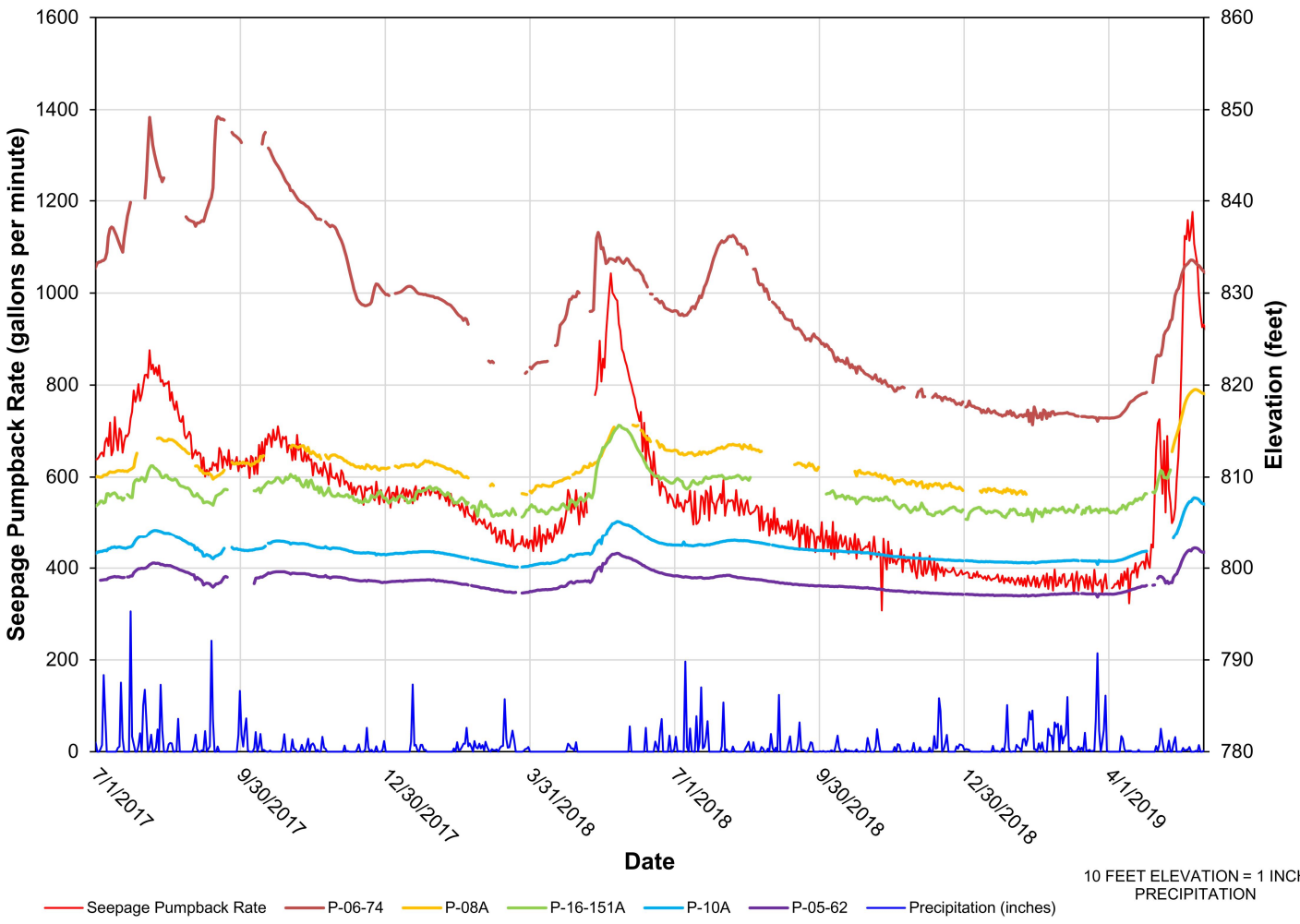


NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS

P-06-74 = 806.2 FEET
P-08A = 804.3 FEET
P-16-151A = 795.5 FEET
P-10A = 789.1 FEET
P-05-62 = 778.8 FEET



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

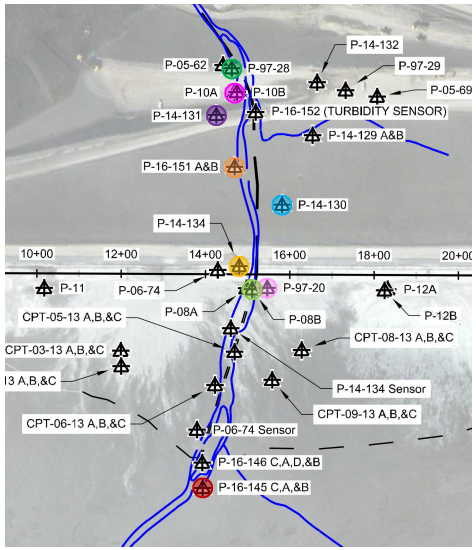
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
CRITICAL UNDERDRAIN PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0

GENERAL VICINITY MAP

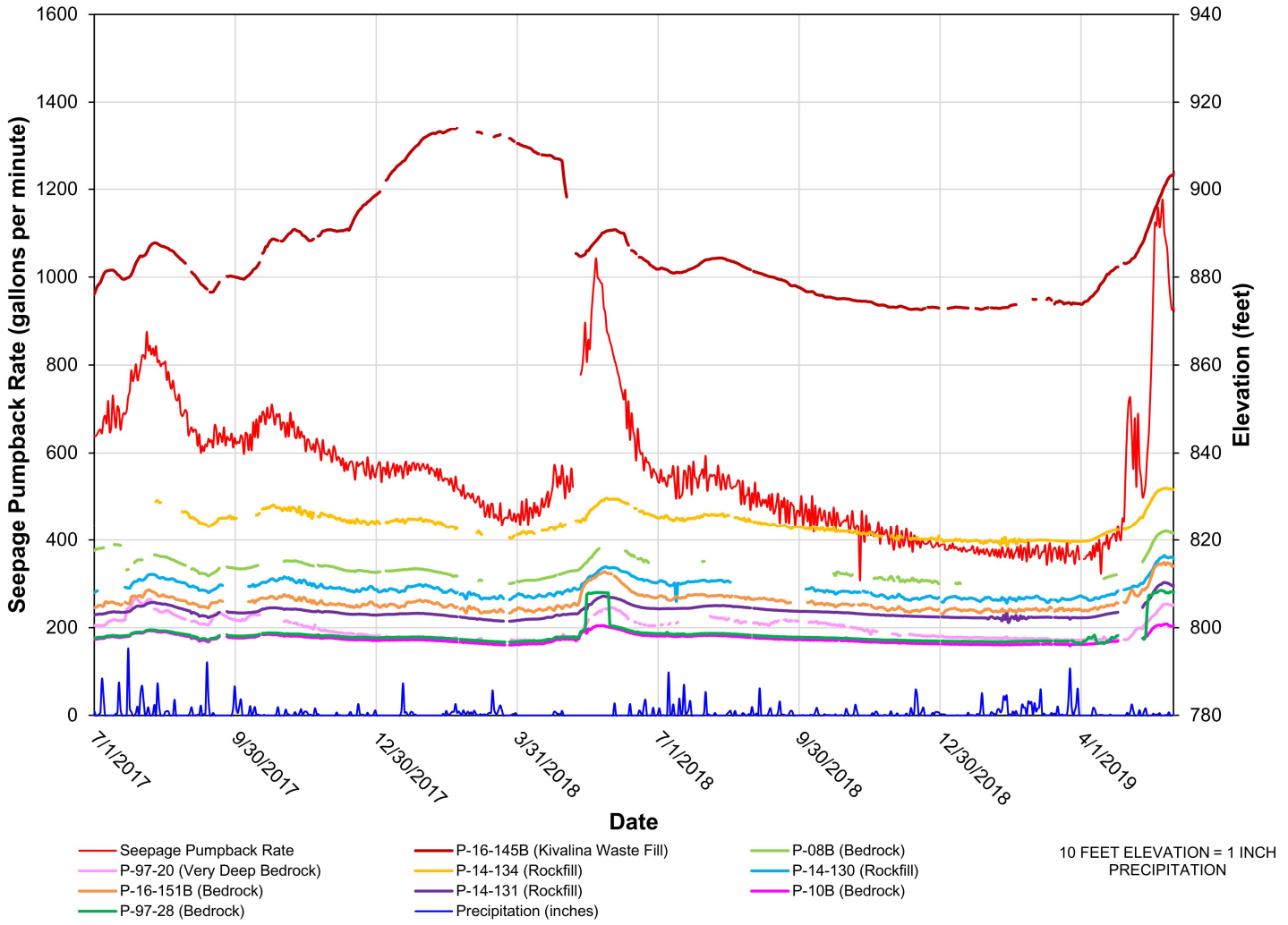


NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS

P-16-145B = 800.9 FEET	P-16-151B = 766.1 FEET
P-08B = 778.9 FEET	P-14-131 = 799.0 FEET
P-97-20 = 537.8 FEET	P-10B = 765.6 FEET
P-14-134 = 794.3 FEET	P-97-28 = 760.9 FEET
P-14-130 = 800.6 FEET	



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

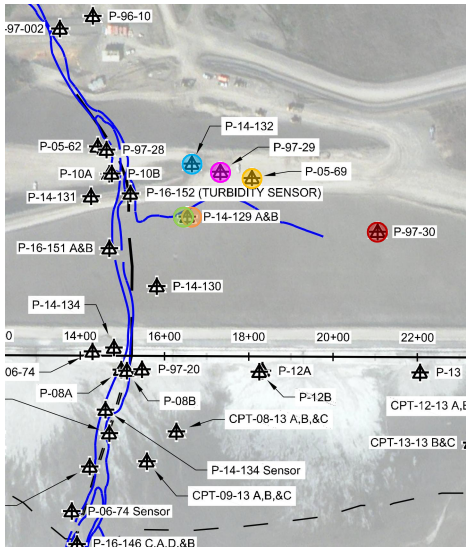
YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
CRITICAL NEAR UNDERDRAIN PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-2

GENERAL VICINITY MAP

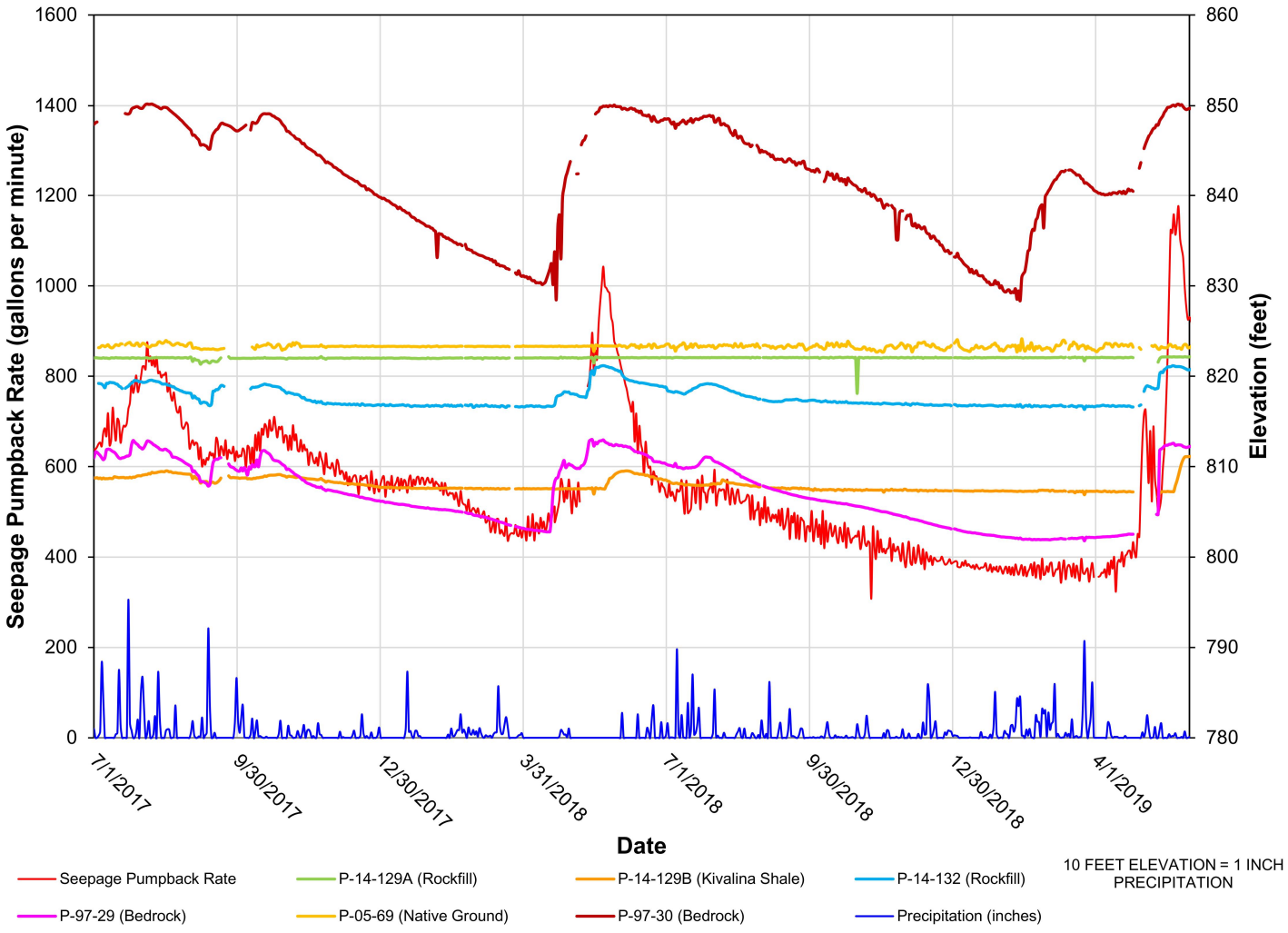


NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS

P-14-129A = 822.0 FEET	P-97-29 = 793.9 FEET
P-14-129B = 806.0 FEET	P-05-69 = 823.6 FEET
P14-132 = 814.0 FEET	P-97-30 = 809.0 FEET



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

NOTES

1. PIEZOMETERS P-14-129A AND P-05-69 APPEAR TO BE GENERALLY DRY WITH READINGS NEAR OR BELOW THEIR TIP ELEVATION.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

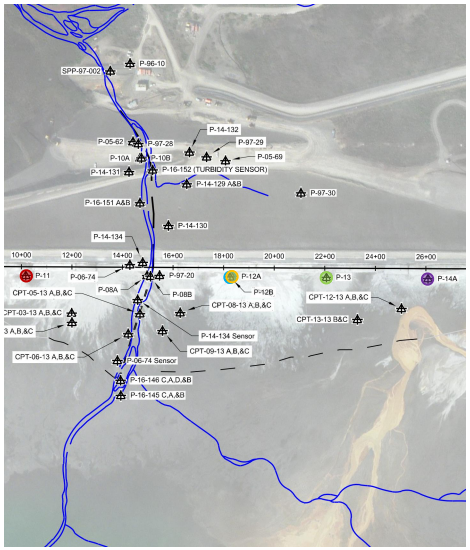
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
CRITICAL SHELL PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0

GENERAL VICINITY MAP

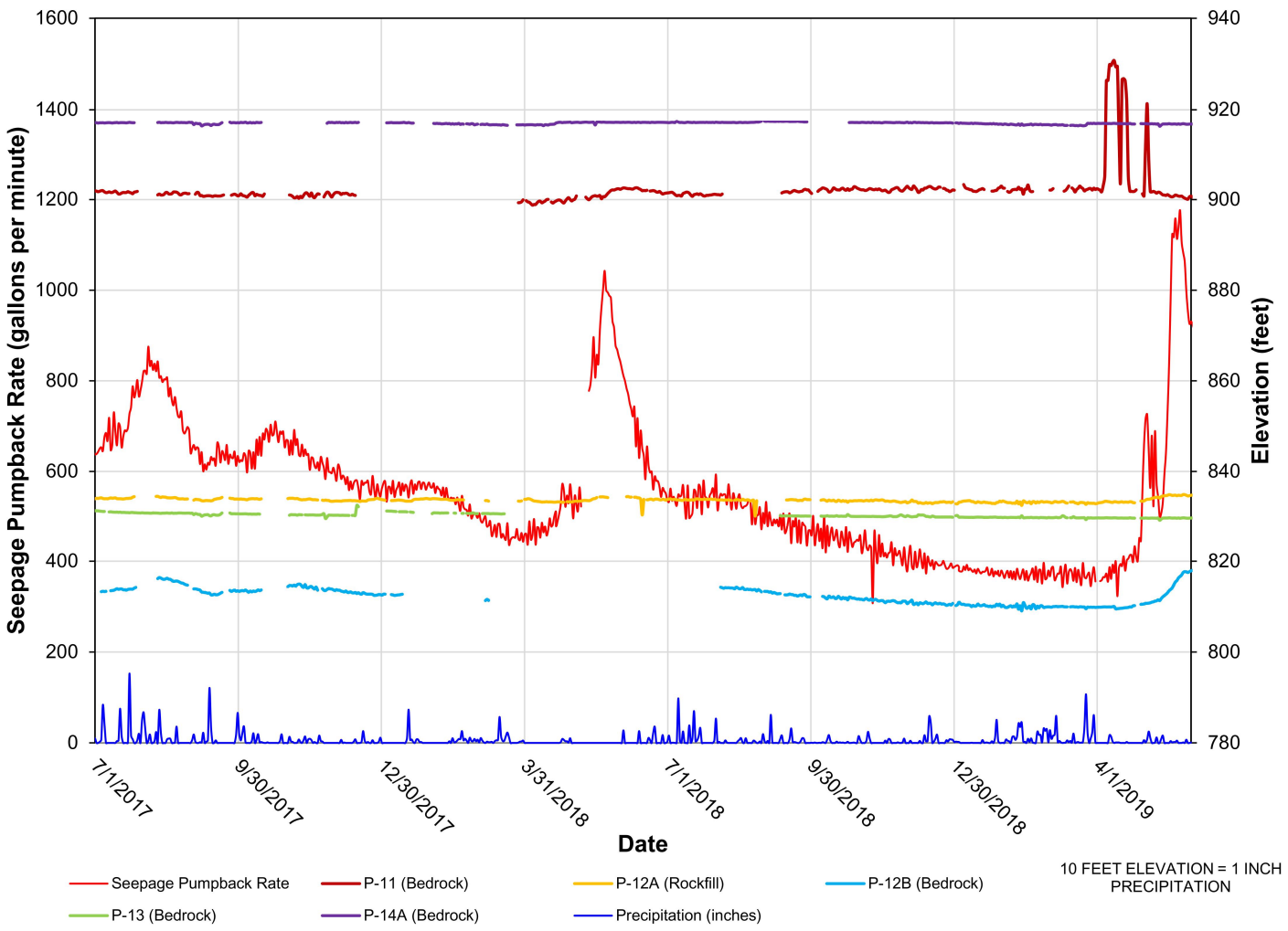


NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS

P-11 = 900.2 FEET
P-12A = 829.9 FEET
P12B = 808.2 FEET
P-13 = 830.9 FEET
P-14A = 881.2 FEET



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

NOTES

1. PIEZOMETER P-11 APPEARS TO BE OCCASIONALLY DRY WITH A TIP ELEVATION OF 900.2 FEET.
2. PIEZOMETER P-13 APPEARS TO BE DRY WITH A TIP ELEVATION OF 830.9 FEET.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

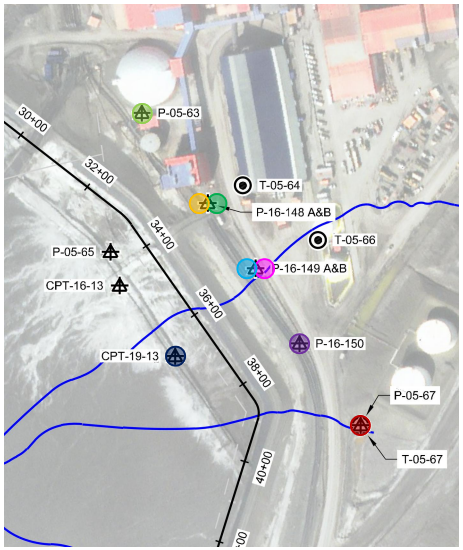
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
NONCRITICAL DOWNSTREAM PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0

GENERAL VICINITY MAP

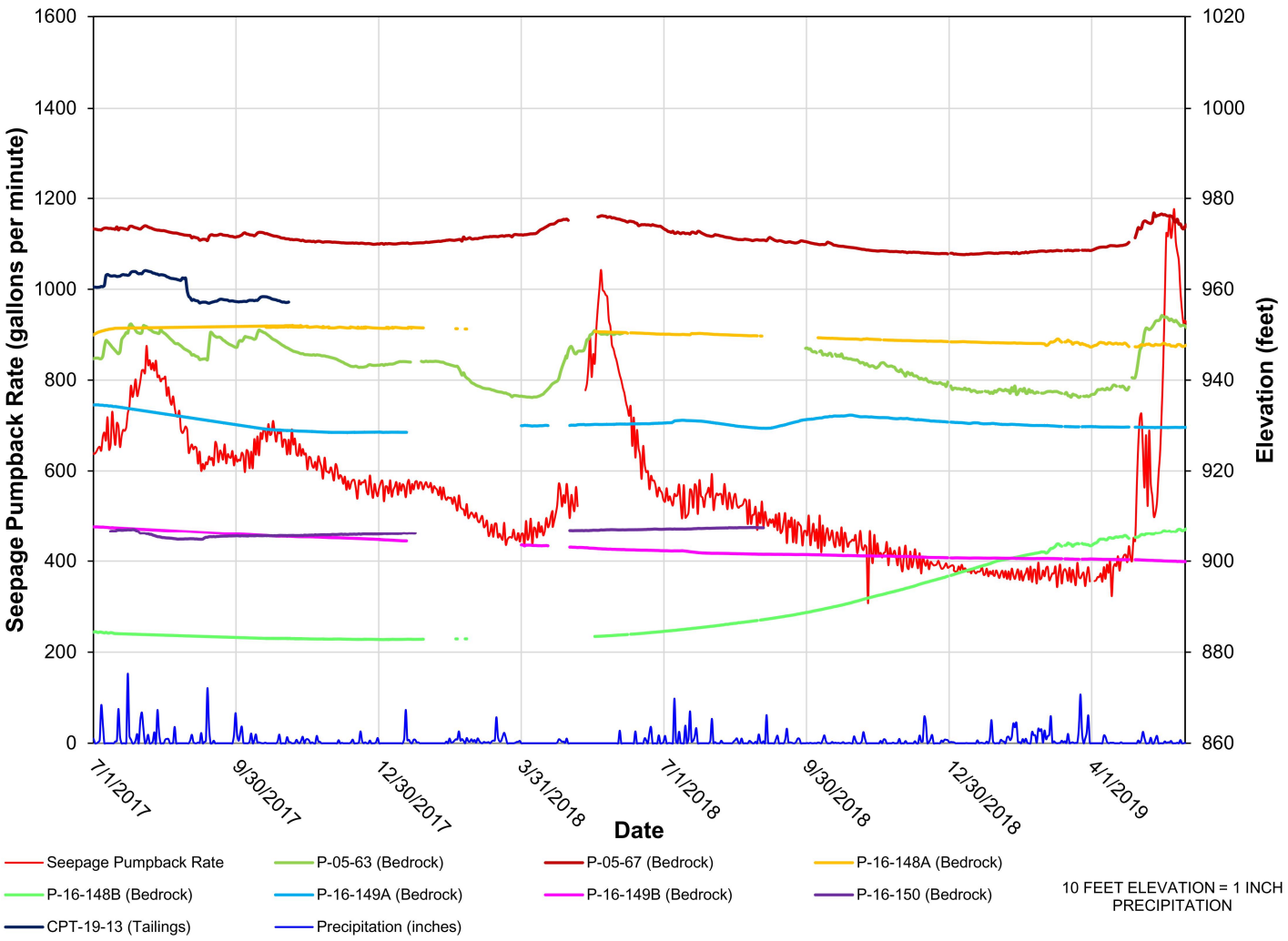


NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS

P-05-63 = 929.6 FEET	P-16-149A = 973.5 FEET
P-05-67 = 954.9 FEET	P-16-149B = 927.5 FEET
P-16-148A = 973.9 FEET	P-16-150 = 975.1 FEET
P-16-148B = 943.9 FEET	CPT-19-13 = 955.8



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

NOTES

1. PIEZOMETERS P-16-148A&B AND P-16-149A&B ARE ALL FROZEN; THEREFORE, THEIR DATA IS INACCURATE.
2. PIEZOMETERS P-05-65, CPT-16-13, AND CPT-19-13 ARE NOT OPERATING (CABLES DISCONNECTED).

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

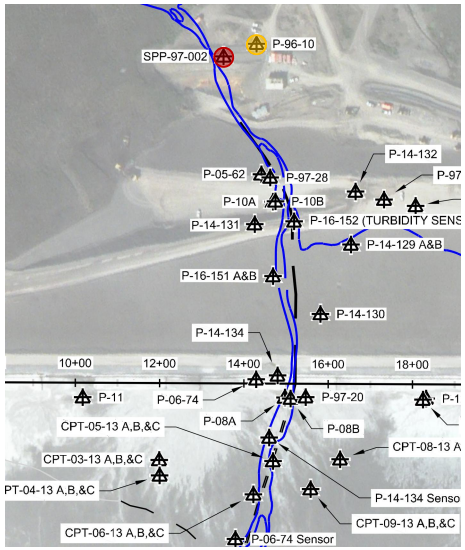
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
NONCRITICAL WING WALL PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0

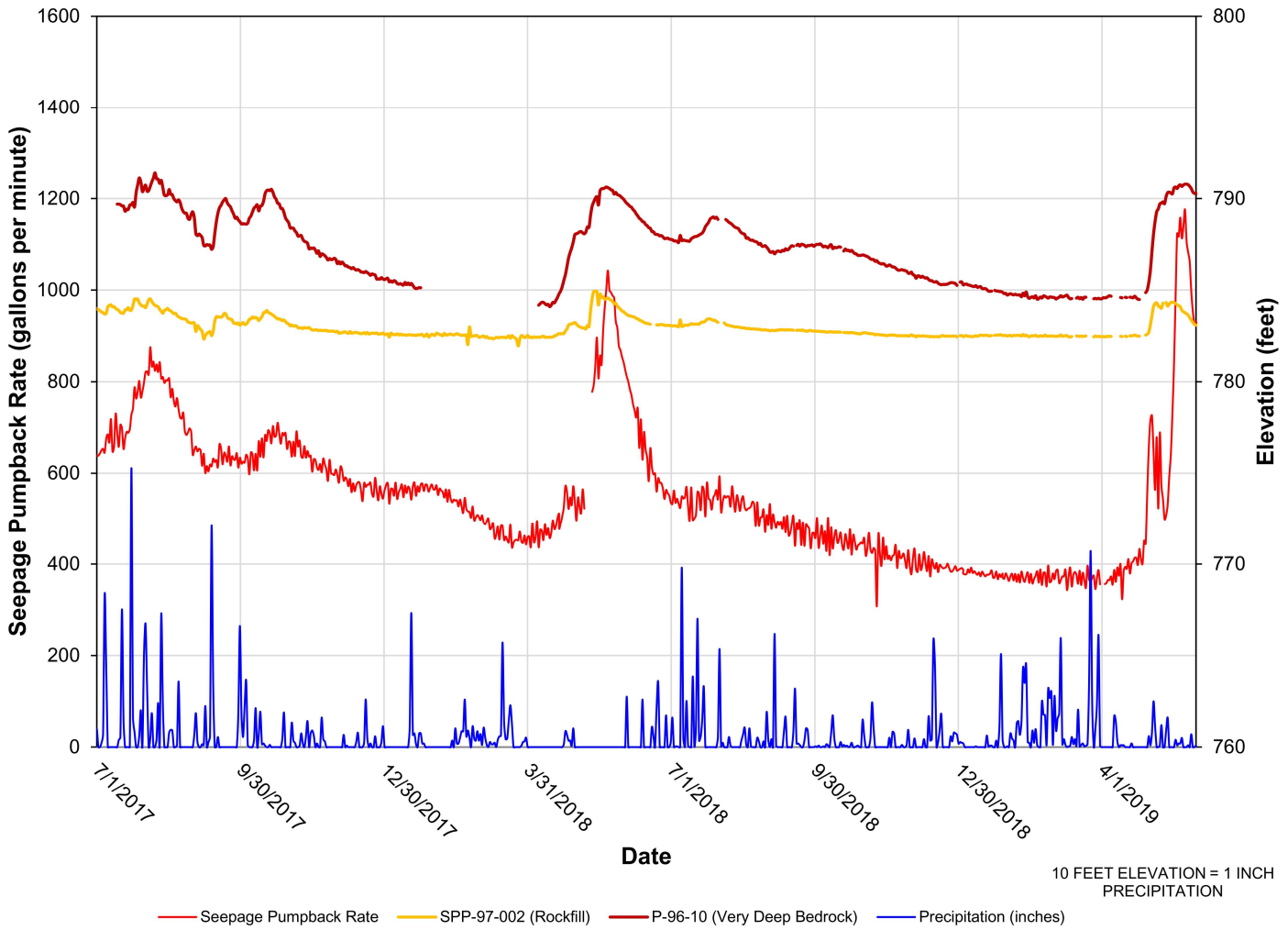
GENERAL VICINITY MAP



NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS
SPP-97-002 = 770.1 FEET
P-96-10 = 604.0 FEET



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

NOTES

1. PIEZOMETER P-96-10 INITIALLY INSTALLED TO MONITOR SUBPERMAFROST GROUNDWATER.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

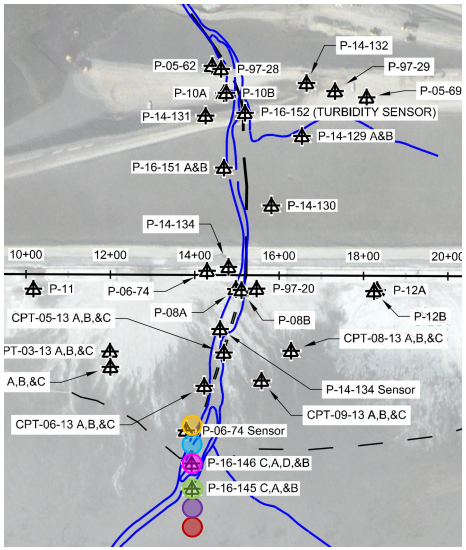
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
SEEPAGE COLLECTION DAM PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0

GENERAL VICINITY MAP

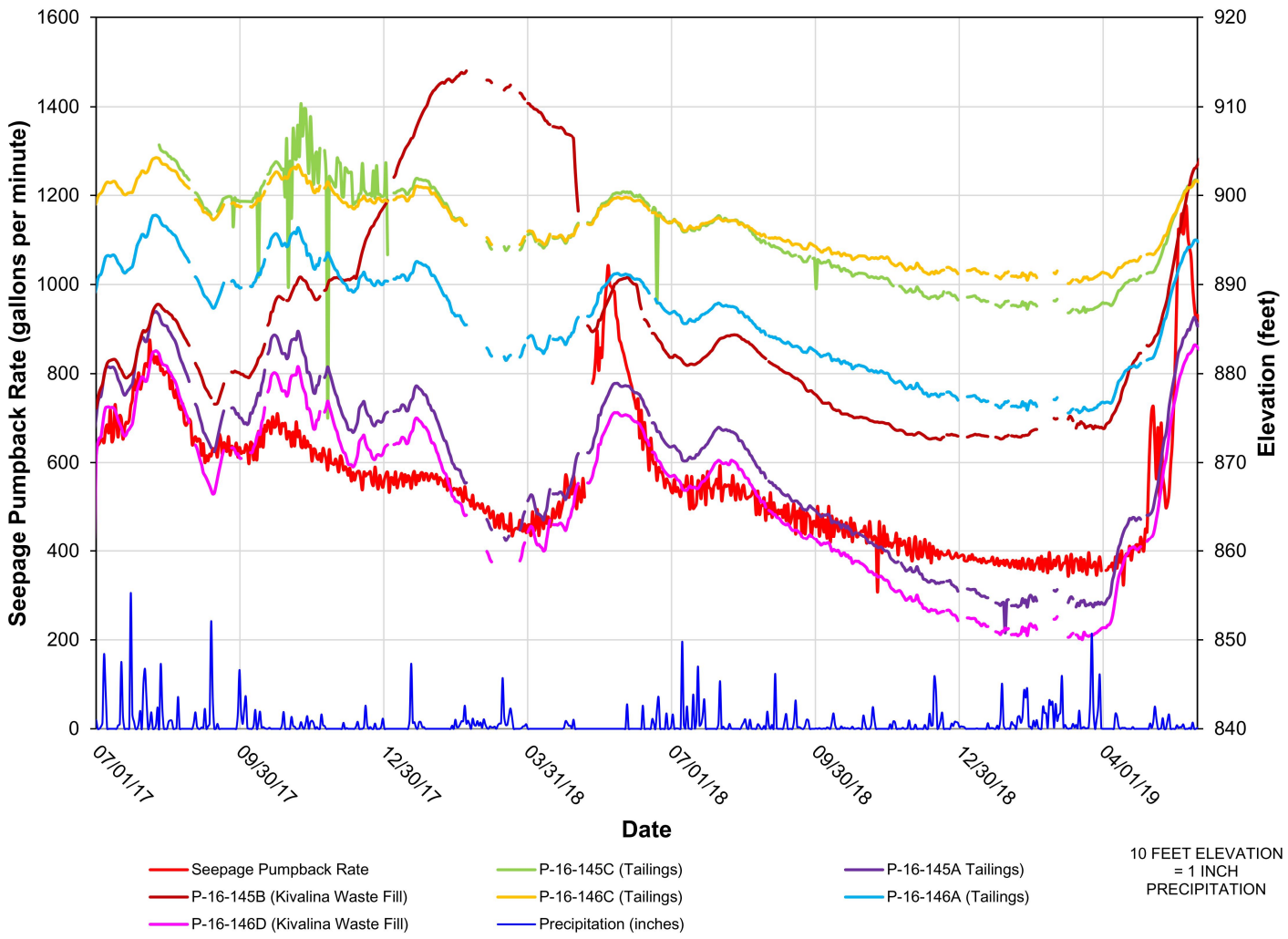


NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3

TIP ELEVATIONS

P-16-145C = 835.9 FEET	P-16-146C = 852.4 FEET
P-16-145A = 815.9 FEET	P-16-146A = 832.4 FEET
P-16-145B = 800.9 FEET	P-16-146D = 812.4 FEET



LEGEND

VIBRATING WIRE PIEZOMETER LOCATION

NOTES

1. PIEZOMETER P-16-145B IS NON-FUNCTIONAL.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

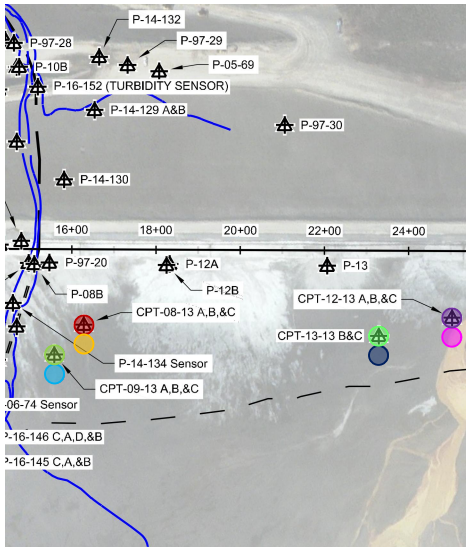
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
UPSTREAM 145 AND 146 SERIES PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-7

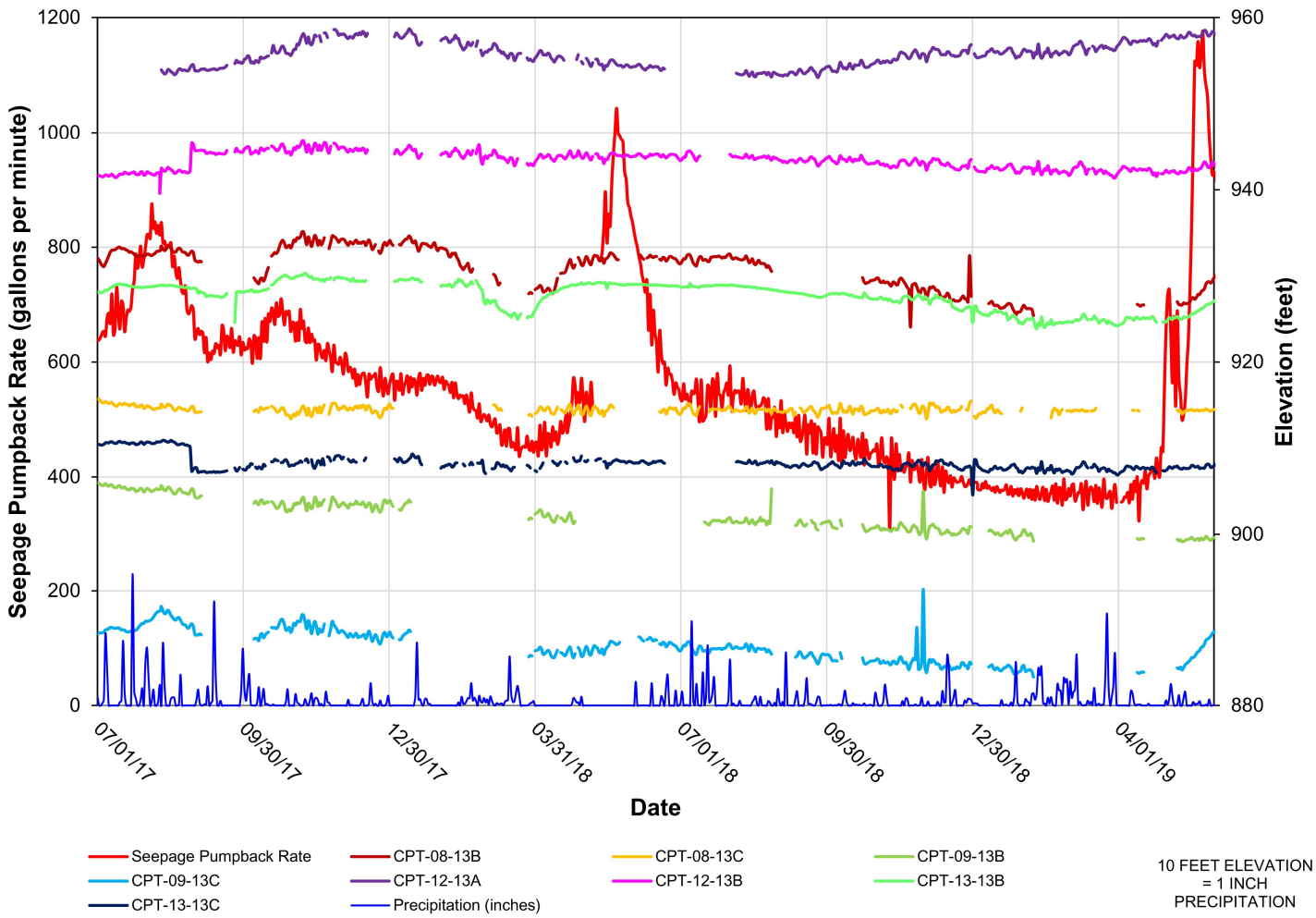
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0

GENERAL VICINITY MAP



NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3



TIP ELEVATIONS

CPT-08-13B = 929.0 FEET	CPT-12-13A = 949.6 FEET
CPT-08-13C = 914.0 FEET	CPT-12-13B = 939.3 FEET
CPT-09-13B = 908.6 FEET	CPT-13-13B = 924.4 FEET
CPT-09-13C = 883.6 FEET	CPT-13-13C = 904.4 FEET

LEGEND

VIBRATING WIRE PIEZOMETER LOCATIONS AND SEQUENCE

NOTES

1. PIEZOMETERS CPT-08-13A, CPT-09-13A, AND CPT-12-13C ARE NON-FUNCTIONAL.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
UPSTREAM TMD EAST CPT SERIES PIEZOMETERS

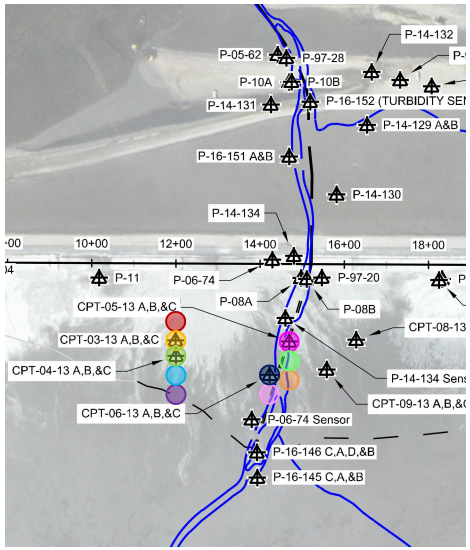
PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in

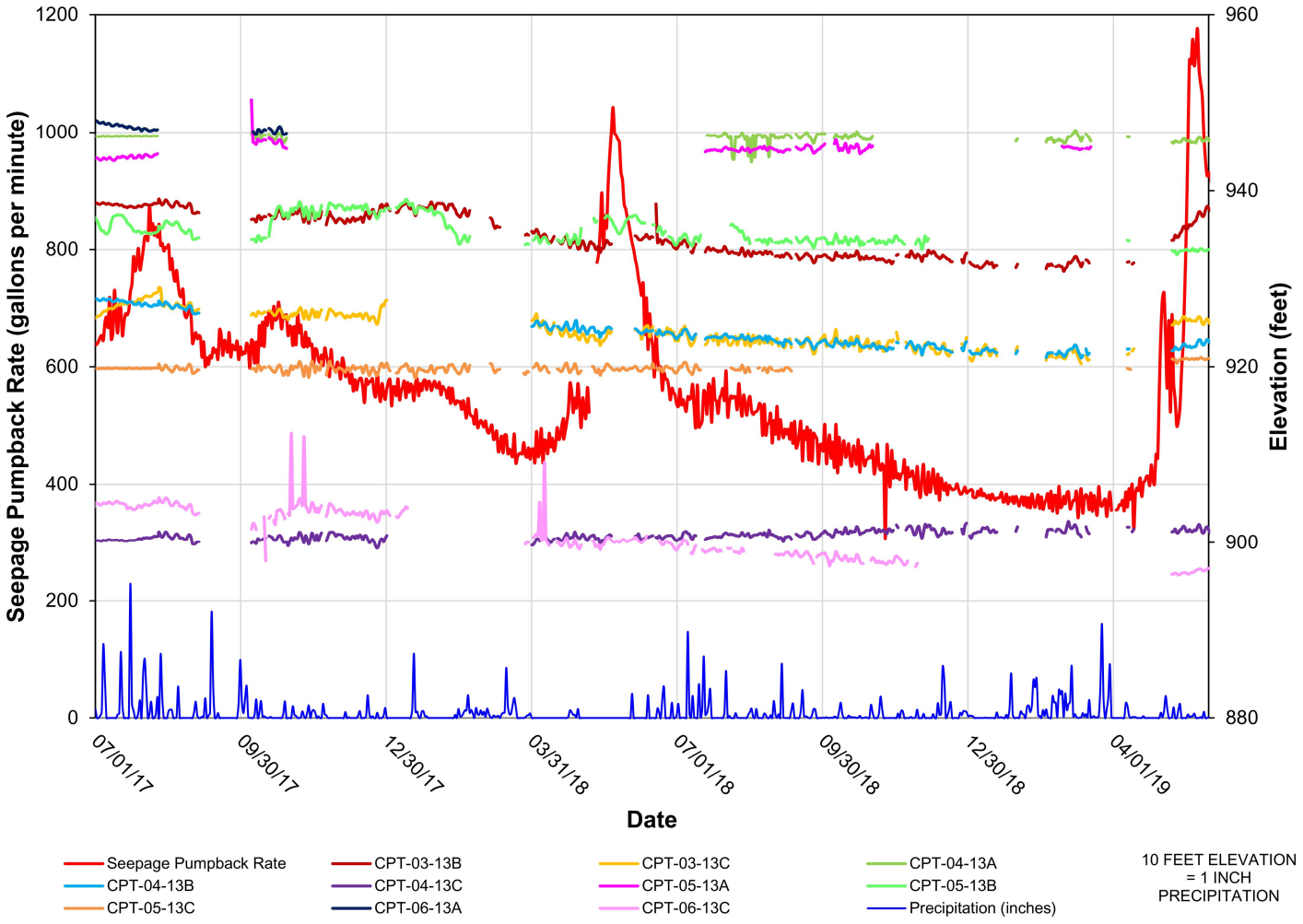
0

GENERAL VICINITY MAP



NOT TO SCALE

REFERENCE: SEE FIGURES 2 AND 3



TIP ELEVATIONS

CPT-03-13B = 930.6 FEET	CPT-05-13A = 944.7 FEET
CPT-03-13C = 920.6 FEET	CPT-05-13B = 934.7 FEET
	CPT-05-13C = 919.7 FEET
CPT-04-13A = 945.8 FEET	
CPT-04-13B = 920.8 FEET	CPT-06-13A = 944.1 FEET
CPT-04-13C = 901.0 FEET	CPT-06-13C = 889.4 FEET

LEGEND

VIBRATING WIRE PIEZOMETER LOCATIONS AND SEQUENCE

NOTES

1. PIEZOMETERS CPT-03-13A AND CPT-06-13B ARE NON-FUNCTIONAL.

CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

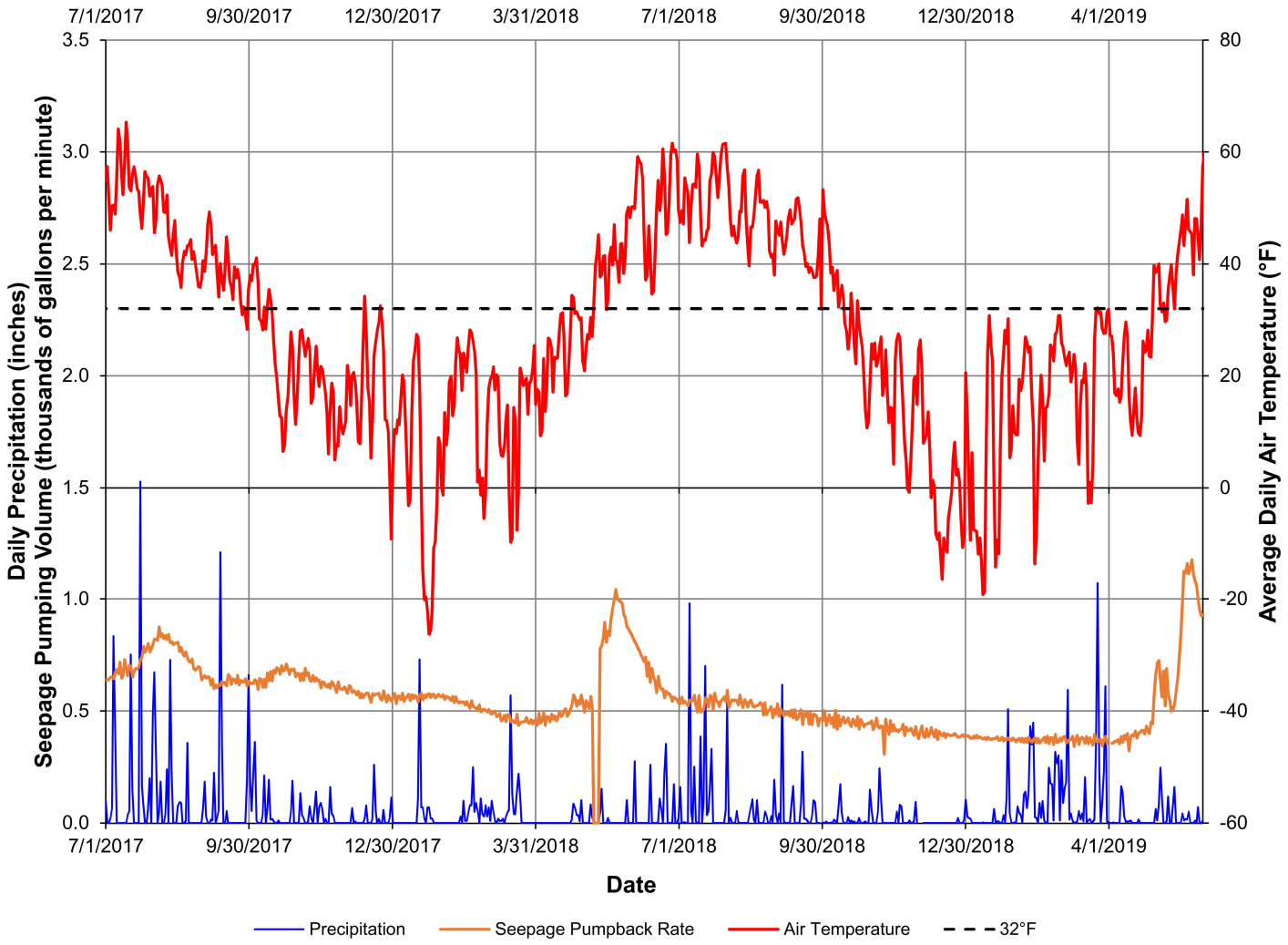
YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
UPSTREAM TMD WEST CPT SERIES PIEZOMETERS

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-9

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

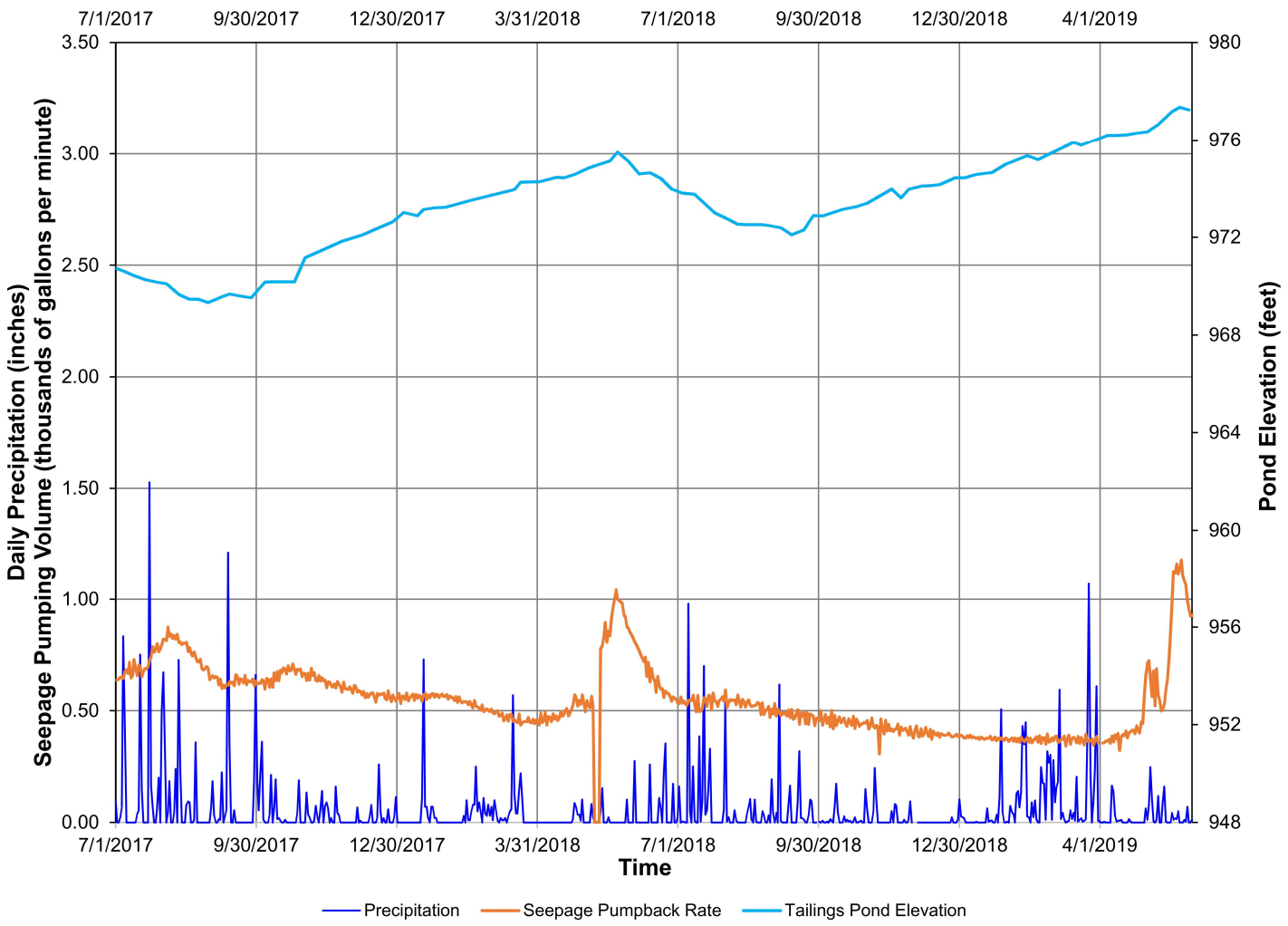
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
PRECIPITATION, SEEPAGE PUMPBACK, AND AIR TEMPERATURE

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-10



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

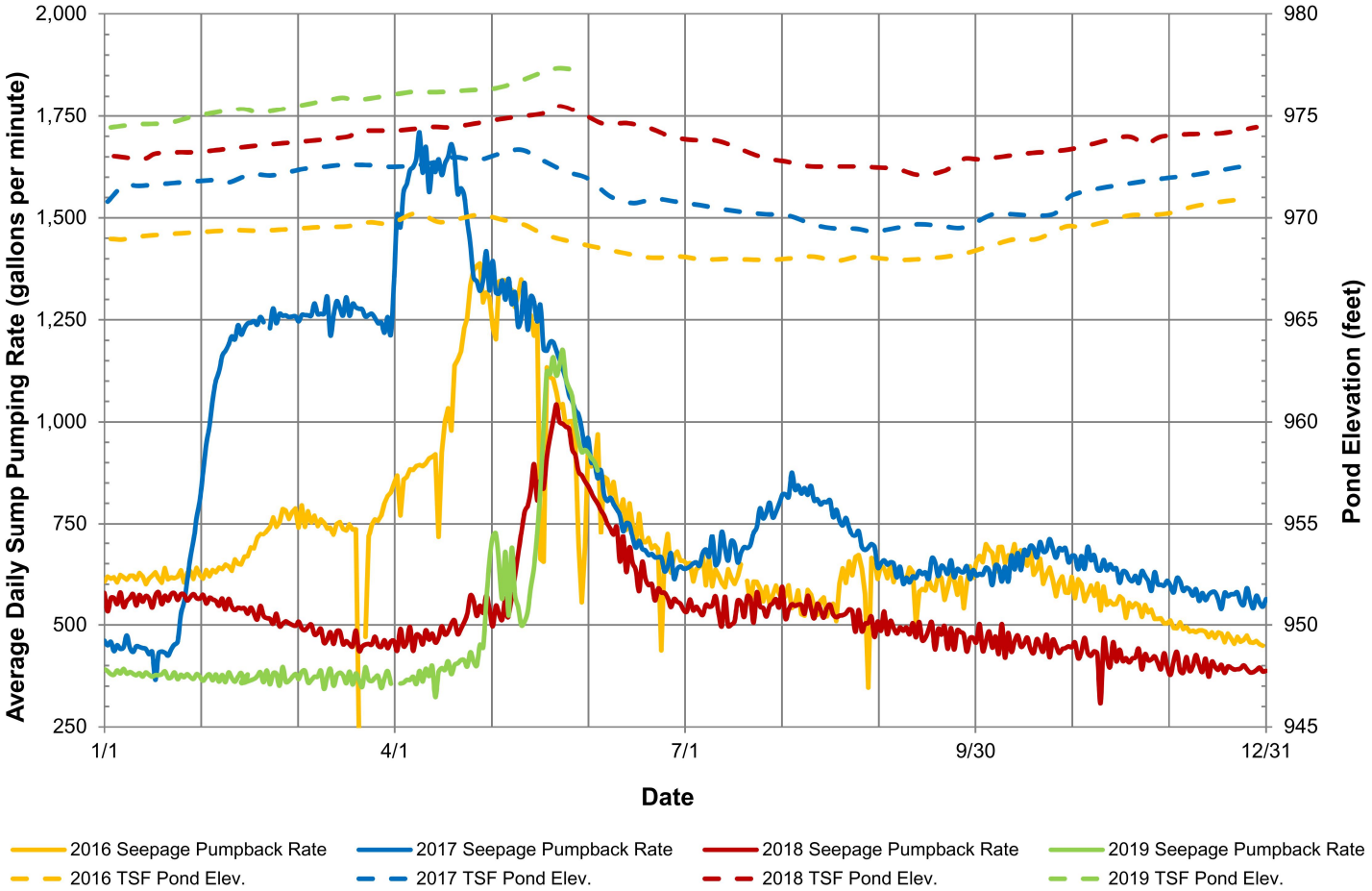
YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
PRECIPITATION, SEEPAGE PUMPBACK, AND POND ELEVATION

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-11

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

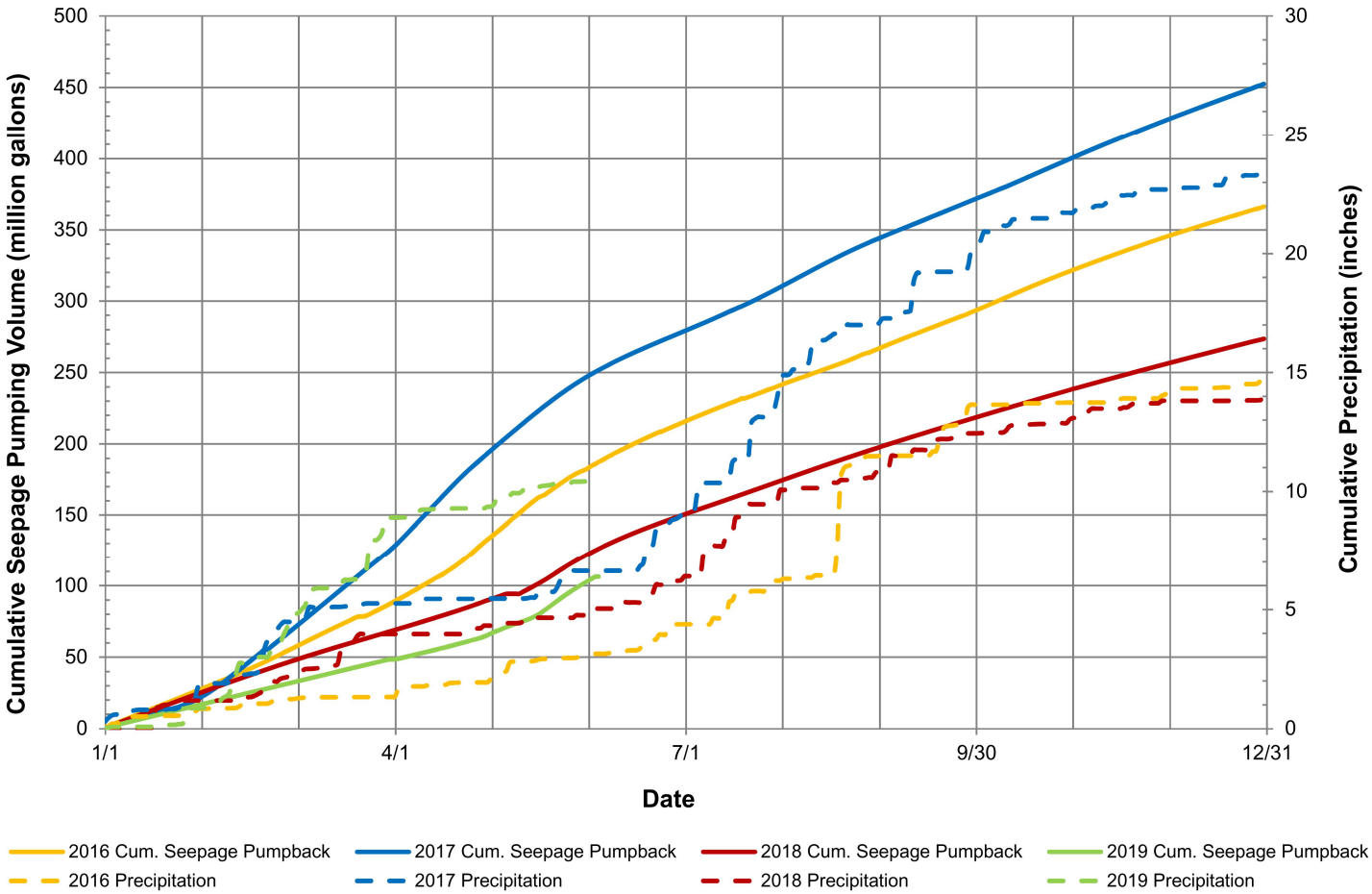
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
SEEPAGE PUMPBACK AND POND ELEVATION BY YEAR

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-12



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
PREPARED	BAH
DESIGN	N/A
REVIEW	SLA
APPROVED	TGK

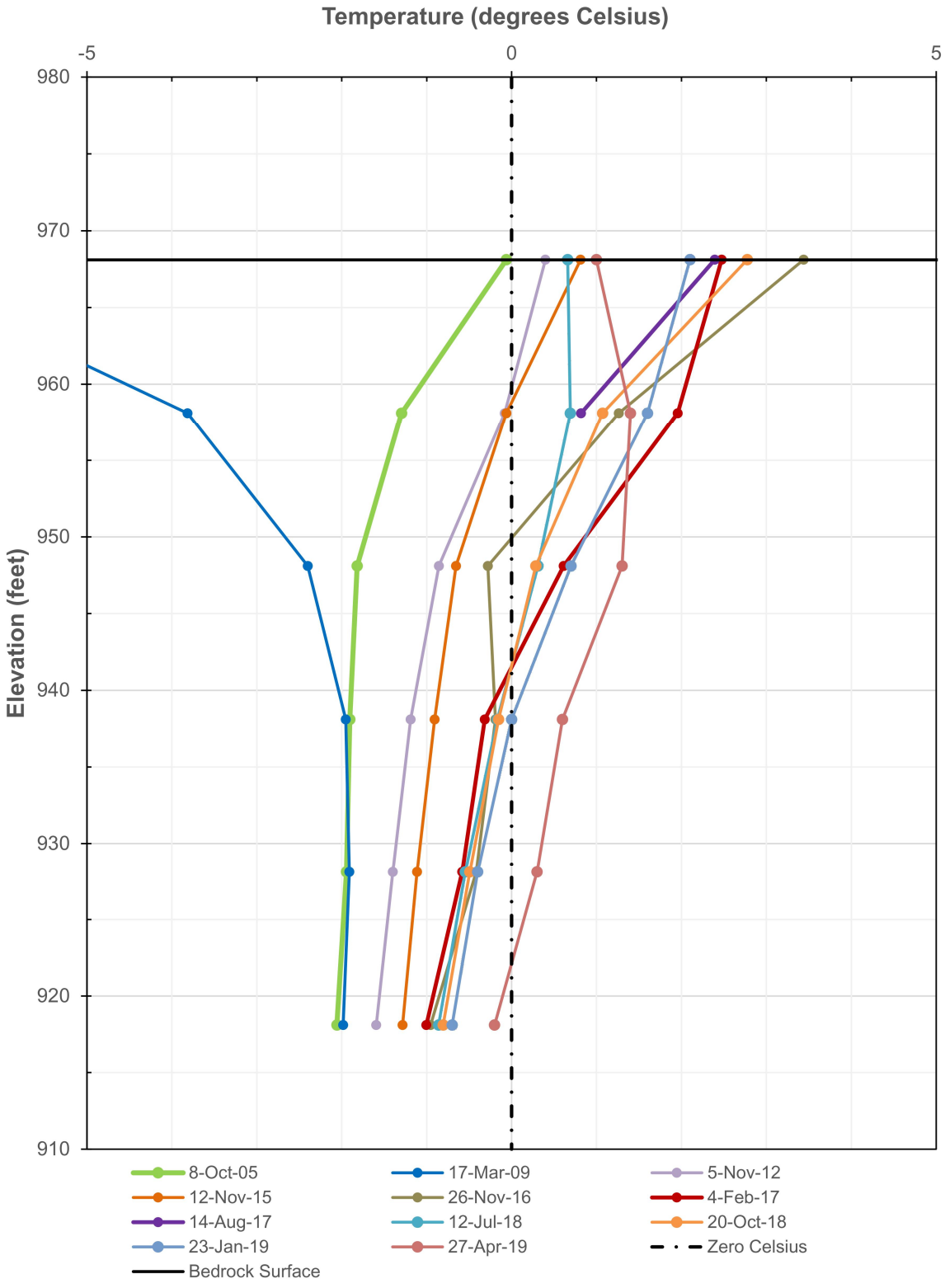
PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
CUMULATIVE SEEPAGE PUMPBACK AND PRECIPITATION BY YEAR

PROJECT No.	PHASE	Rev.	FIGURE
18113464	3000	0	D-13

APPENDIX E

Thermistor Data



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

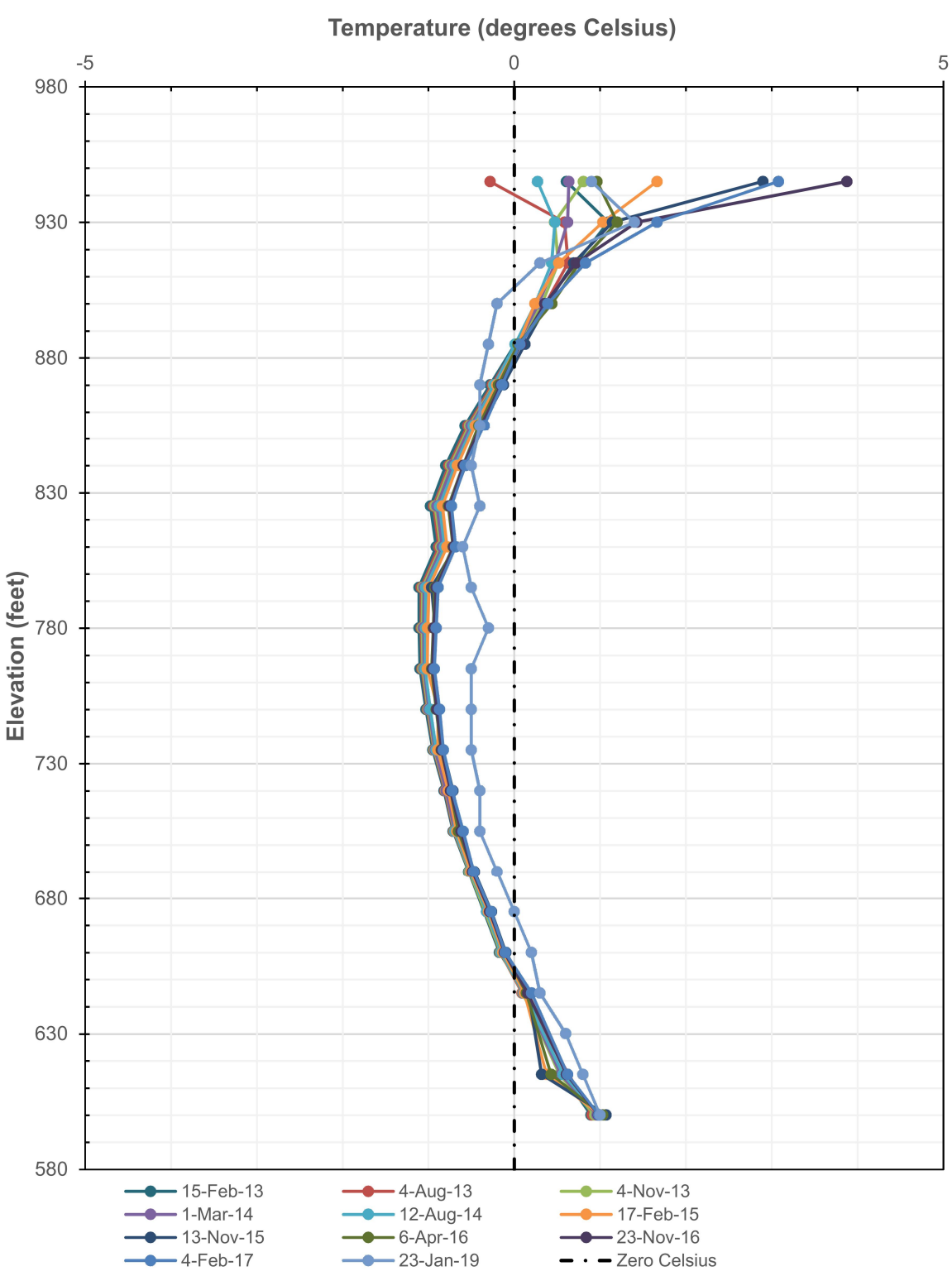
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
GROUND TEMPERATURE DATA AT T-05-61

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	E-1



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

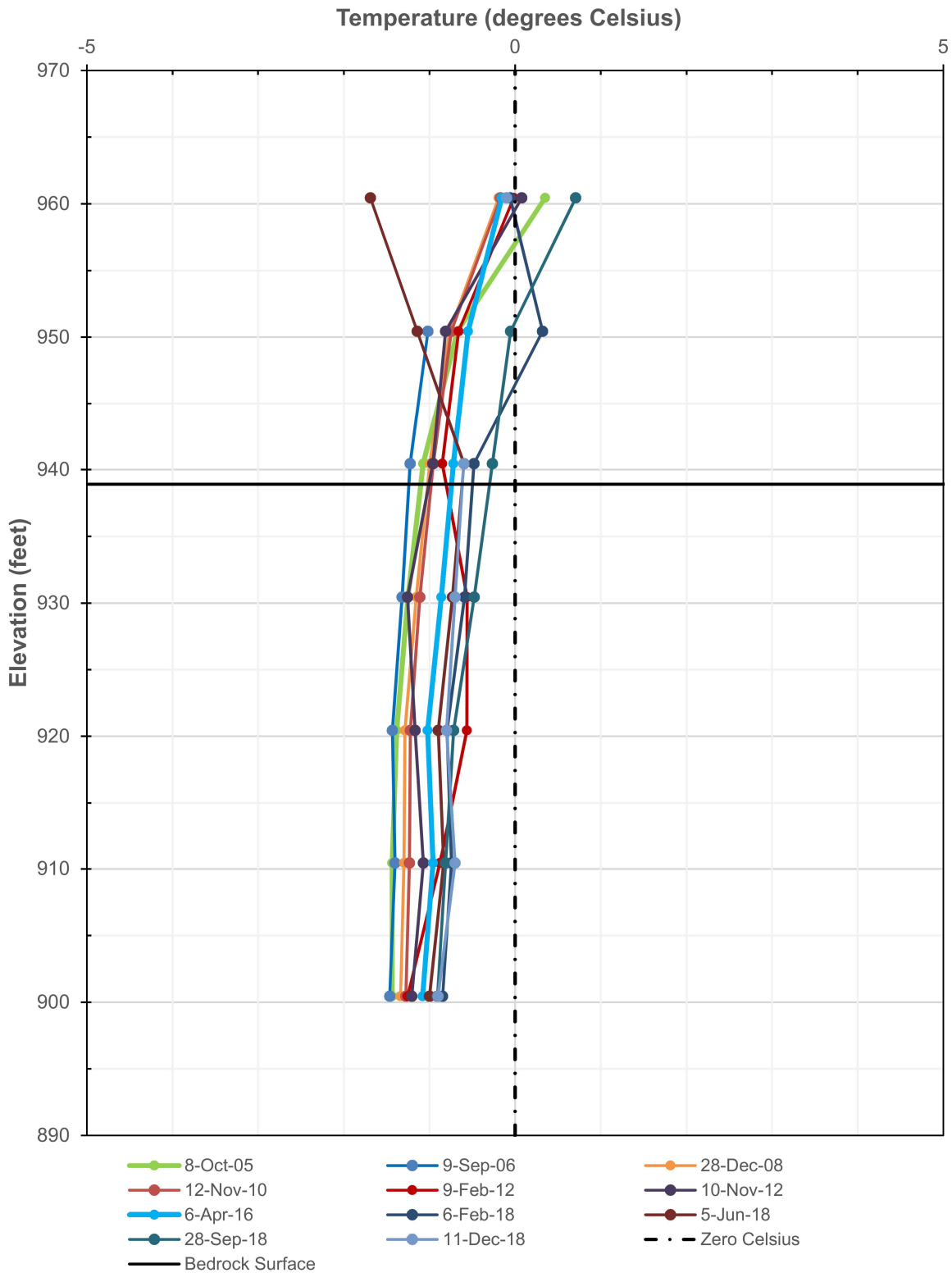
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
GROUND TEMPERATURE DATA AT T-95-004

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	E-2



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

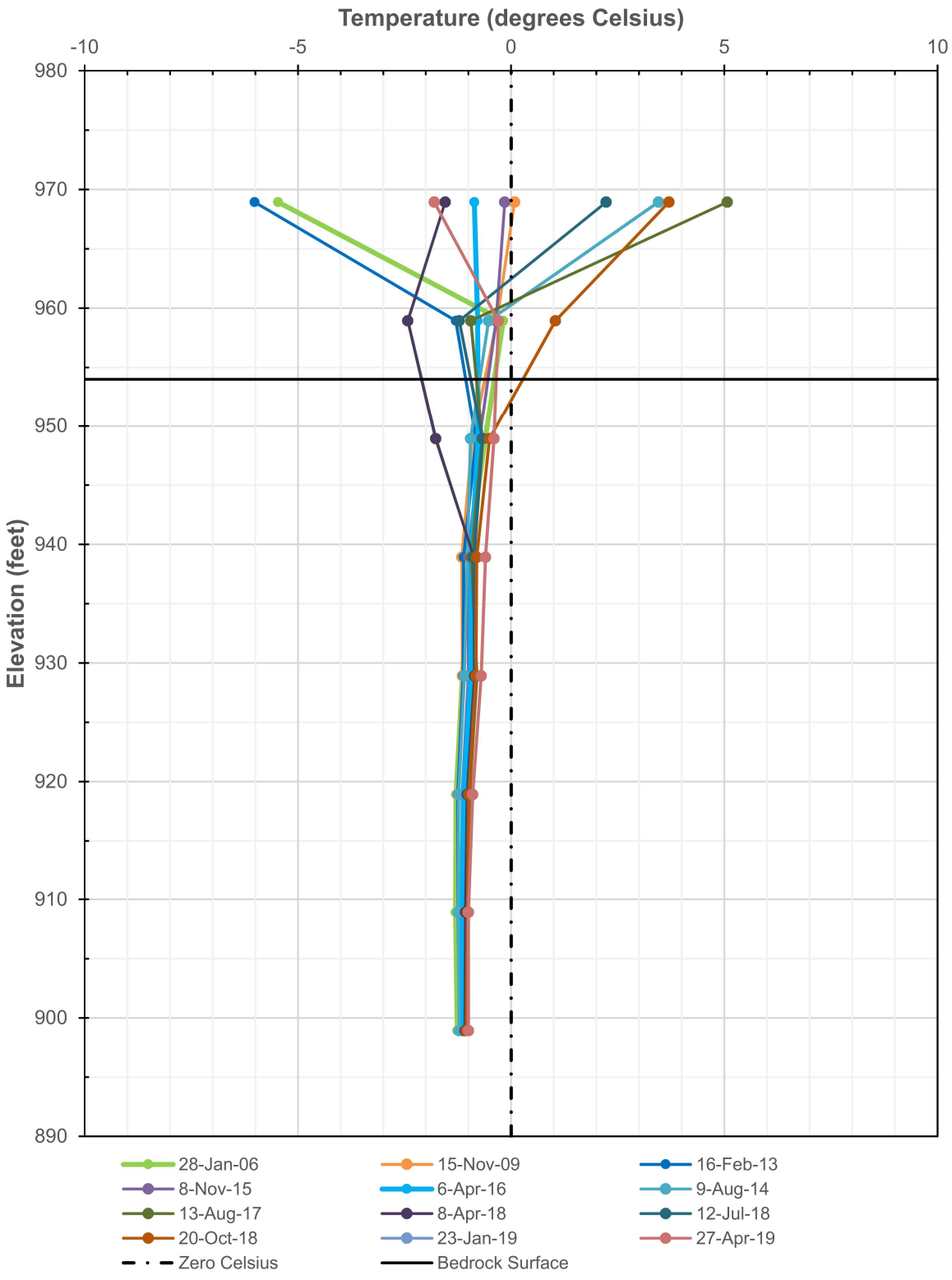
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
GROUND TEMPERATURE DATA AT T-05-64

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	E-3



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

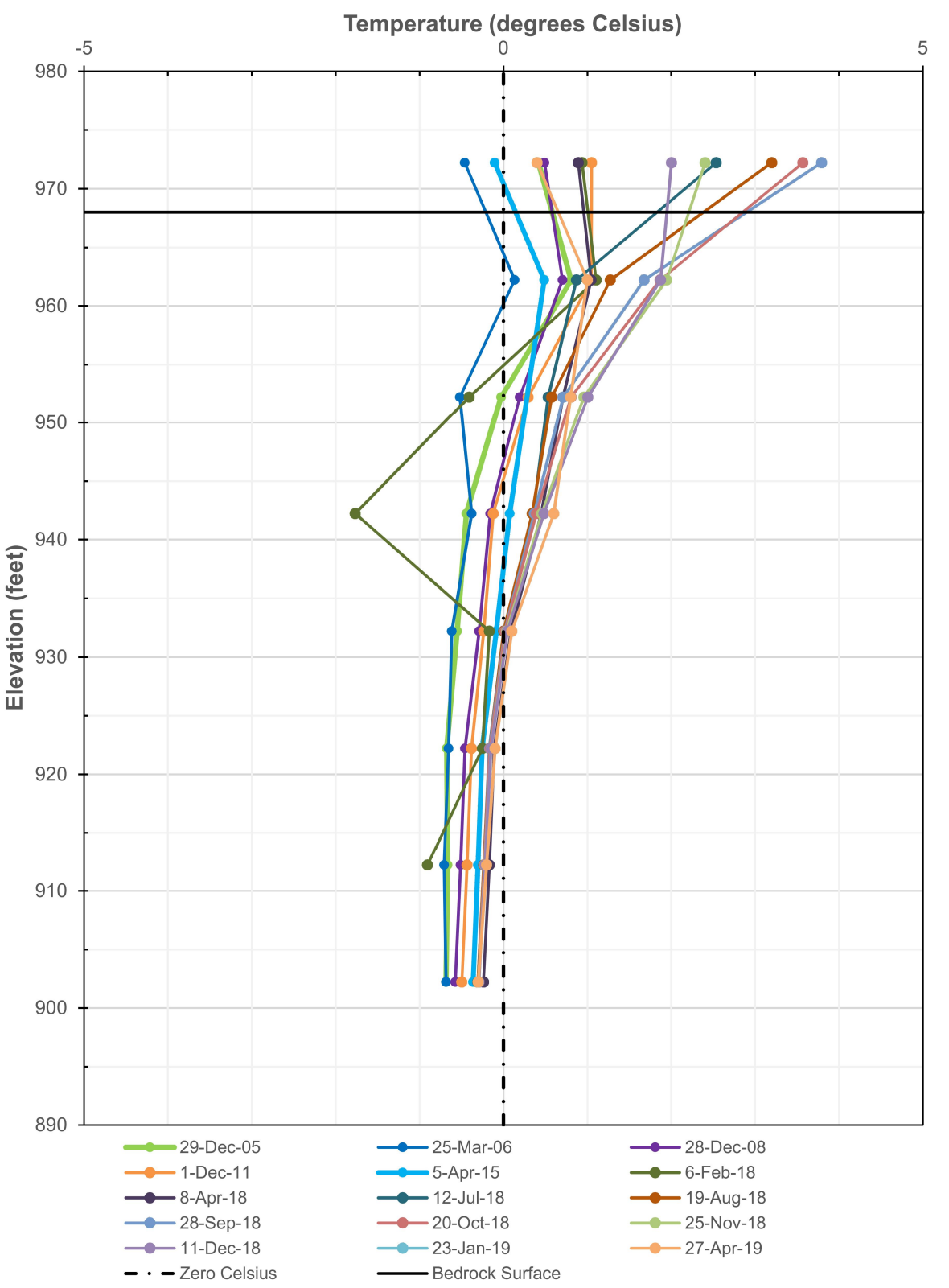
CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
GROUND TEMPERATURE DATA AT T-05-66

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	E-4



CLIENT
TECK ALASKA INCORPORATED
3105 LAKESHORE DRIVE, BUILDING A, SUITE 101
ANCHORAGE, ALASKA 99517

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-24
DESIGNED	N/A
PREPARED	BAH
REVIEWED	SLA
APPROVED	TGK

PROJECT
2019 ANNUAL PERFORMANCE REPORT
TAILINGS MAIN DAM
RED DOG MINE, ALASKA

TITLE
GROUND TEMPERATURE DATA AT T-05-67

PROJECT NO.	PHASE	REV.	FIGURE
18113464	3000	0	E-5