



Keno Hill Silver District Dry Stack Tailings Facility Tailings Management Plan



October 2024

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Acronyms and Abbreviations

Acronym	Definition
AKHM	Alexco Keno Hill Mining Corp.
AOS	Apparent Opening Size
DCP	Dynamic Cone Penetration Test
DSTF	Dry Stack Tailings Facility
EOR	Engineer of Record
GCL	Geosynthetic Clay Liner
MARV	Mean Average Roll Value
OMS	Operations, Maintenance and Surveillance
QA	Quality Assurance
QC	Quality Control
QML	Quartz Mining License
SPT	Standard Penetration Test
TARP	Trigger Action Response Plan

TAILINGS MANAGEMENT PLAN REVISION HISTORY

Revision	Revision Date	Author(s)	Revision Notes
0	July 2023	AKHM / Tetra Tech Canada	Initial Version
2	October 2024	AKHM	Transition to Hecla letterhead; simplify document to reference relevant information, rather than include as appendices; updated with Phase 2 design information.

1 INTRODUCTION

The purpose of this Tailings Management Plan is to serve as an “index” to the various documents and plans that define design, construction, and management requirements for the Dry Stack Tailings Facility (DSTF) at the Keno Hill Silver District Mining Operations (Keno Hill) and has been prepared in general accordance with the Government of Yukon guidance document *Plan Requirement Guidelines for Quartz Mining Projects* (Government of Yukon 2013). Unless otherwise appropriate, this document will follow the table of contents outlined in the aforementioned guidance document and will include references to relevant documentation under each heading. New, or summarizing information will not be included unless necessary.

Referenced documents include:

- **Site description**, including the results of geotechnical site investigations for Phases I and II of the DSTF.
- **Design criteria**, including tailings quantities, tailings properties, geotechnical criteria, hydrologic criteria, tailings storage conditions, and liner criteria.
- **Operational requirements**, including an Operation, Maintenance, and Surveillance (OMS) manual, tailings placement requirements, air quality and dust control, and emergency management. As of the date of this document, the most current version of the OMS is dated September 2024.
- **Design details**, including foundation conditions, site preparation requirements, construction quality assurance/quality control requirements, stability analyses, construction schedules, surface water management designs, liner system designs, borrow sources, soil storage, and access management.

2 SITE DESCRIPTION

The following subsections summarize the surface and subsurface conditions within the DSTF area.

Phase 1 design is described in EBA 2011, included as Appendix A – Phase 1 Detailed Design. Phase 2 preliminary and designs are described in EBA 2015 and Tetra Tech 2024.

2.1 Surface Conditions

The site in the vicinity of the DSTF slopes generally west at approximately 5% to 20%, with a bedrock high crossing the site in a generally east-west direction. Northeast of the facility, the topography drops off towards Crystal Lake, 500 meters to the northwest, at a grade of 5% to 25%.

Phase I of the DSTF is located north/northeast of the Mill area, generally on the north side of the bedrock high, and Phase II is located east/southeast of the Mill area, south of the bedrock high.

A historic waste management facility for the town of Keno is located east of the DSTF. Duncan Creek road is located at the southern end of Phase II, and Keno Hill warehouse facilities are located northwest of Phase I.

Undisturbed areas are vegetated with shrubs and spruce trees. Vegetation is generally thicker and more mature to the east and southeast.

2.2 Subsurface Conditions

2.2.1 Soils

In general, overburden conditions within the DSTF footprint consist of a thin organic cover overlying a locally ice-rich silt/sand till with sand and gravel seams deposited throughout. Coarse-grained sands and gravels are present underlying the till above the bedrock interface in some areas. In general, there is lower ground ice and moisture contents within the Phase II footprint than within Phase I.

2.2.2 Groundwater

Groundwater has not been encountered during the Phase I or Phase II geotechnical investigations.

2.2.3 Permafrost

Keno Hill is located near the boundary between “extensive discontinuous” and “continuous” permafrost (Natural Resources Canada, 1995), meaning that 50% to 100% of the surface is expected to be underlain by permafrost in this region.

Permafrost has been observed to be discontinuous in the DSTF area. In most historical boreholes, permafrost was encountered at less than 1 m depth and typically extended to about 15 to 20 m depth. Outside of the DSTF area, permafrost has been encountered as deep as 76 m at Keno Hill (Ensero, 2023). Some boreholes in the DSTF area did not encounter permafrost, primarily near the bedrock high and within the southeast ridge near Duncan Creek Road. The top 3.5 m of permafrost is generally considered to be ice rich and contains a combination of horizontally stratified ice lenses, randomly oriented ice inclusions, and non-visible excess ice (EBA, 2011). Massive ice has been encountered in several boreholes outside of the DSTF footprint, with thickness ranging between 4 m and 15 m.

The active layer near the DSTF has been observed to be as thin as 200 mm in thickness in some locations, protected by a thick organic cover.

2.2.4 Underground Workings

No underground workings are currently or planned beneath Phase 2 of the DSTF, as depicted in Figure 2-1. The approximate Phase 2 boundary is shown in blue.

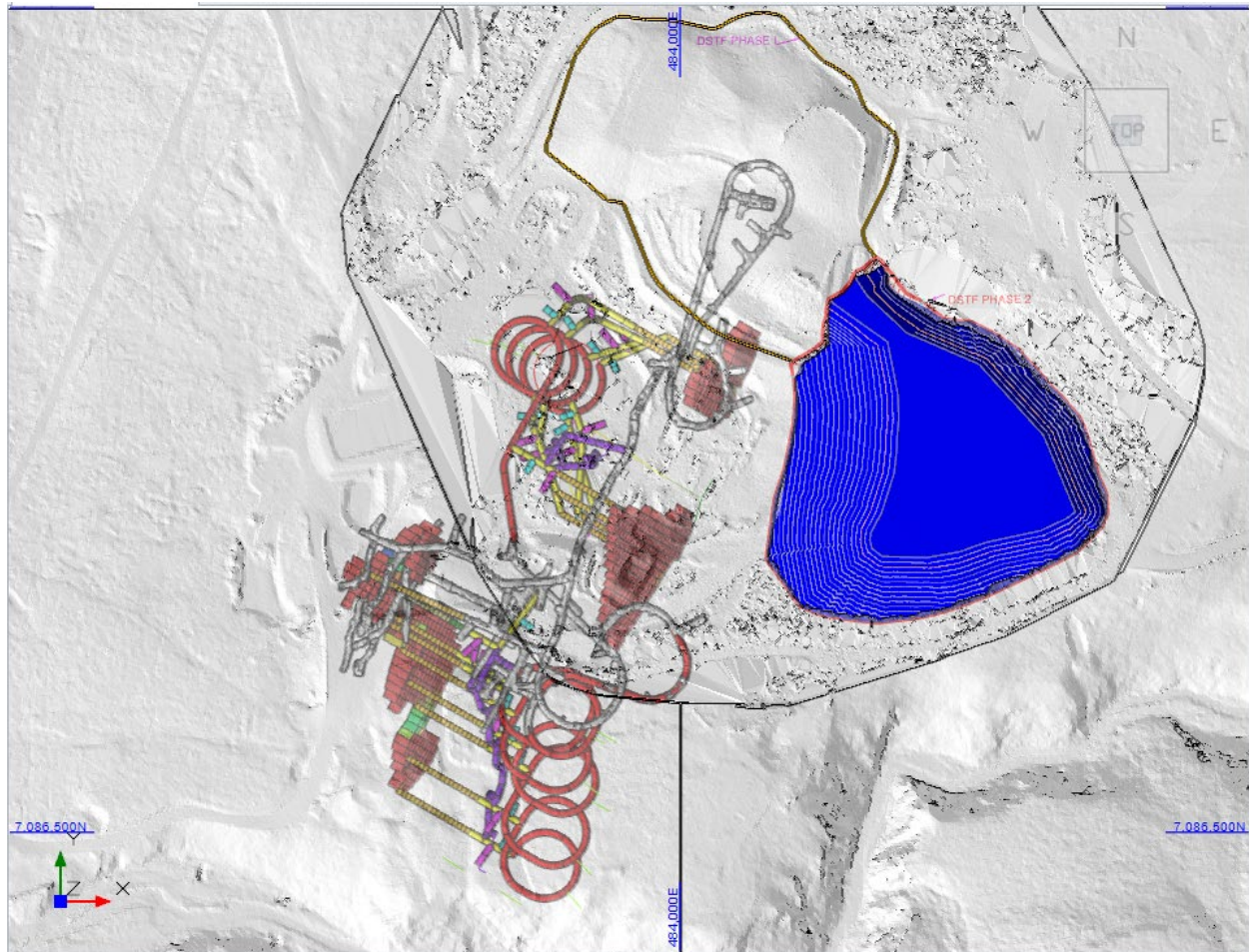


Figure 2-1: Flame & Moth – Plan of Mine Workings

3 DESIGN CRITERIA

3.1 Tailings Quantities

As of August 2024, approximately 342,000 dry tonnes (190,000 m³) of tailings are stored in the DSTF¹ and cover an area of approximately 3.3 hectares. The ultimate proposed DSTF capacity is approximately 450,000 m³ or 855,000 tonnes and will cover an area of approximately 6.5 hectares. Tailings are planned to be placed in the DSTF at a rate of approximately 11,160 tonnes (6,200 m³) per month (372 tonnes per day).

QML-0009 provides approval for up to 907,000 tonnes of dewatered tailings to be placed in the DSTF.

¹ Tailings volumes were not reliably tracked prior to 2024, thus the estimate of approximately 190,000 m³ is based on an average dry density of 1.8 tonnes/m³, consistent with placing tailings at about 95% of the maximum dry density reported in Table 3-2.

3.2 Tailings Properties & Design Criteria

Key DSTF Design Criteria are summarized in Table 3-1. Additional details pertaining to Phase 2 are included in Appendix B – Phase 2 Design Basis. Hecla is currently evaluating options for improving Phase 1 to meet the more stringent Phase 2 design criteria.

Assumed tailings, tailings production, and placement parameters are shown in Table 3-2. The hydraulic properties of the lining system, which consists of a layer of geosynthetic clay liner (GCL) overlain by a geonet and non-woven geotextile, are summarized in Table 3-3 and Table 3-4, respectively.

Table 3-1: DSTF Design Criteria

Category	Design Criteria	Phase 1	Phase 2
General Characteristics	Ultimate design capacity	286,000 tonnes (125,000 m ³)	569,000 tonnes (325,000 m ³)
	Area	2.4 ha	4.1 ha
	Maximum height (toe to crest)	approximate 25 m	Approximately 30 m
	Approximate Crest elevation	945 m above sea level (a.s.l.)	940 m a.s.l.
	Typical slope	Varies between 2.5H:1V and 3.5H:1V	3.25H:1V
Hydrology	Peak flow	1/200-year 10-day freshet	Larger of: -200-yr critical duration event -500-yr peak instant. flow
Seismicity	Design earthquake	1/475-year	1/2475
	Peak ground acceleration	0.146g	0.278g
Stability – static analysis	Minimum factor of safety	1.2 to 1.3	1.3 during construction 1.5 long-term
Stability – pseudo-static analysis	Minimum factor of safety	1.05 to 1.0	1.0
Stability – Post Earthquake	Minimum factor of safety	N/A	1.0 to 1.2

Table 3-2: Tailings Parameters (Tetra Tech 2024)

Criteria	Value
Tailings Production Rate	See Section 3.1
Percentage of Tailings Stored in DSTF	Currently 100%; see Section 3.1
Typical Particle Size Description	SILT, sandy to and SAND, trace clay
Bulk Density	2250 kg/m ³
Moisture Content	10-20%
Maximum Dry Density / Optimum Moisture	1885 – 1960 kg/m ³ at 17% - 12%
Permeability, k	9.65E-8 m/s
Effective friction angle, ϕ'	30-32°
Effective cohesion, c'	8-30 kPa

Table 3-3: Geosynthetic Clay Liner – Bentomat ST Properties (Tetra Tech 2024)

Material Property	Test Standard	Test Frequency	Required Values
Bentonite Swell Index	ASTM D 5890	1 per 50 tonnes	24 ml/2g min
Bentonite Fluid Loss	ASTM D 5891	1 per 50 tonnes	18 ml max
Bentonite Mass/Area	ASTM D 5993	40,000 ft ² (4,000 m ²)	0.75 lb/ft ² (3.6 kg/m ²) min
GCL Grab Strength	ASTM D 6768	200,000 ft ² (20,000 m ²)	30 lbs/in (53 N/cm) MARV
GCL Peel Strength	ASTM D 6496	40,000 ft ² (4,000 m ²)	3.5 lbs/in (6.1 N/cm) min
GCL Index Flux	ASTM D 5887	Weekly	1 x 10 ⁻⁸ m ³ /m ² sec max
GCL Hydraulic Conductivity	ASTM D 5887	Weekly	5 x 10 ⁻⁹ cm/sec max
GCL Hydrated Internal Shear Strength	ASTM D5321 ASTM D 6243	Periodic	500 psf (24kPa) typ @ 200 psf

Table 3-4: Geonet Properties (Tetra Tech 2024)

Material Property	Test Standard	Material Specification
Fabric Weight	ASTM D 5261	270 g/m ² (8 oz/yd ²)
Grab Tensile	ASTM D 4632	1001 N (225 lb)
Gab Elongation	ASTM D 4632	0.5
Trapezoid Tear	ASTM D 4533	289 N (65 lb)
CBR Puncture	ASTM D 6241	2670 N (600 lb)
Water Flow	ASTM D 4491	4075 l/min/m ² (100 gpm/ft ²)
Permittivity	ASTM D 4491	1.26 sec ⁻¹
Permeability	ASTM D 4491	0.30 m/sec
AOS	ASTM D 4751	0.180 mm (80 US Sieve)

4 DESIGN AND CONSTRUCTION DETAILS

4.1 General – Design

4.1.1 Design History

Detailed Phase 1 design was completed in 2011 (EBA 2011).

Preliminary design for Phase 2 of the DSTF was completed in 2015 (Tetra Tech 2015). Detailed designs were finalized in September 2024 (Tetra Tech 2024). Issued for Construction (IFC) drawings for the eastern portion of Phase 2 are included in Appendix C – DSTF Phase 2 East Issued for Construction Drawings, and Construction Specifications are included in Appendix D – DSTF Phase 2 East Construction Specifications.

Issued for construction drawings and specifications for the western portion of Phase 2 are anticipated to be finalized in early 2025, with construction beginning shortly thereafter.

4.1.2 Geothermal Analysis

Geothermal analysis was carried out for DSTF design Phases 1 and 2 by Tetra Tech (operating as EBA Engineering Consultants Ltd., for Phase 1). Analyses were carried out using GEOTHERM, Tetra Tech's proprietary 2D finite element modelling software. GEOTHERM simulates transient, two-dimensional heat conduction with change of phase for multiple boundary conditions. Heat exchange modelling considered air temperatures, wind velocity, snow depth, and solar radiation. Geothermal modelling for Phase 1 design predicted that the frozen overburden and ice would thaw in approximately 50 years. Ground temperature monitoring data since Phase 1 construction has indicated a slower rate of thaw, and Phase 2 geothermal modelling parameters were adjusted based on Phase 1 measurements. Geothermal modelling was used

as the basis for construction of the DSTF on ice-rich permafrost. The design intent is to allow permafrost within the foundation to thaw at a slow rate, allowing time for porewater pressure dissipation.

4.1.3 Liquefaction Assessment and Stability Analysis

Liquefaction assessment was carried out using the NCEER method (Youd et al., 2001) based on SPT N-values (for Phase 1) and using the method described by Idriss and Boulanger (2008) based on SPT N-values (for Phase 2). Liquefaction analyses indicate that foundation soils are not highly liquefiable. The tailings are considered drained and unsaturated, and therefore non-liquefiable.

DSTF stability was analyzed using GeoStudio software SLOPE/W 2007 (for Phase 1) and SLOPE/W 2021 (for Phase 2). Several scenarios were analyzed to assess short and long-term stability under static and pseudostatic conditions. Stability was modelled based on three permafrost conditions: fully frozen, thawed to 1 m depth, and fully thawed. Stability analyses are described in the design reports.

4.1.4 Considerations from Phase I Performance

Some movements and distortions have been observed in the Phase 1 area and have manifested as several longitudinal tension cracks perpendicular to the slope, and several small sinkholes.

Constructed slopes in Phase 1 are generally 2H:1V to 2.5H:1V, with some localized steeper areas. The observed localized instabilities may be attributed to these steeper slopes, combined with occurrences of inconsistent placement and compaction procedures, as well as possible consolidation due to thaw of the underlying ice-rich permafrost. Steepened slopes will be regraded to design as required for closure.

Phase 2 design included modifications including flattened slopes to account for more stringent seismic design standards, incorporating the removal of ice rich permafrost underlying critical facility components, as well as an emphasis on operational and quality controls such as standard operating procedures being implemented by AKHM.

The Phase II facility will be constructed and operated to a higher standard than historically observed in Phase I. AKHM is currently planning a geotechnical investigation of Phase I to better characterize the in-situ tailings and foundation conditions.

4.1.5 OMS Updates

The OMS manual for the Keno Hill DSTF was prepared in 2010 by EBA Engineering Consultants Ltd. (EBA), updated in 2023 by Tetra Tech (Revision 1), and updated and superseded by AKHM in 2024 (Revision 2).

4.2 Ground Preparation and Foundation Conditions

Foundation preparation requirements for Phase I are described in EBA 2011. Phase II foundation preparation and construction is described in Tetra Tech 2024 and generally includes:

- Removal of imported material within the footprint such as waste rock, access road fill, or other deleterious materials, to ensure these materials are not present within the foundation.
- Removal of organics and ice-rich permafrost within the footprint of the toe buttress and interior shear berms.
- Removal of all trees and vegetation larger than 50 mm in diameter with minimal disturbance to the organic surface.
- An as-built survey of the existing ground surface.

- Construction and placement of the foundation components comprising a 0.6 m thick granular drainage blanket, GCL, geocomposite drain, and ballast material. The installation details are described in the Construction Specifications.
- The liner materials should be installed on drainage blanket material at grades no steeper than 4H:1V, unless otherwise approved by the engineer.
- An as-built survey of the surface of the foundation components.

Ground and foundation preparation is completed per Issued for Construction designs. Tailings are stacked on the prepared foundation on an ongoing basis.

5 OPERATIONAL REQUIREMENTS

The DSTF is operated as described in the OMS (AKHM 2024).

5.1 Tailings Placement

Tailings are generally placed in 500 mm lifts, track-walked several times with the dozer, and sealed with a smooth-drum compactor, completing a minimum of two overlapping passes with the vibratory roller. Placement quality control (QC) activities include periodic inspections, field testing such as dynamic cone penetration (DCP) tests, and laboratory testing. Quality assurance (QA) activities include a review of QC data and quarterly Engineer of Record (EOR) visual inspections.

5.2 Off-Spec Tailings Management

If the EOR determines that the results of QC and QA activities show that the tailings characteristics and/or performance are materially different from design expectations, the EOR will complete additional shear strength testing, and provide recommended changes in operating procedures as necessary to ensure the tailings can be placed in the DSTF without compromising design criteria.

5.3 Water Recycle

Water collected in the runoff collection ditch is transferred to the water collection pond and mill pond for reuse in milling operations.

5.4 Air Quality and Dust Control

Air quality and dust control measures are described in the Keno Hill Silver District Mining Operations Dust Abatement and Monitoring Plan under a separate cover. Generally, dust at the DSTF is mitigated by progressively placing an evapo-transpirative cover over finished areas of the tailings stack. Dust suppressants (e.g., tackifiers) will be used if additional mitigation is required.

5.5 Emergency Management

Site-wide emergency preparedness and response for Keno Hill is described in the Keno Hill Silver District Mining Operations Mine Emergency Response Plan under a separate cover. DSTF-specific emergency response is described in the OMS manual and associated Trigger Action Response Plan (TARP) in Appendix C of the OMS.

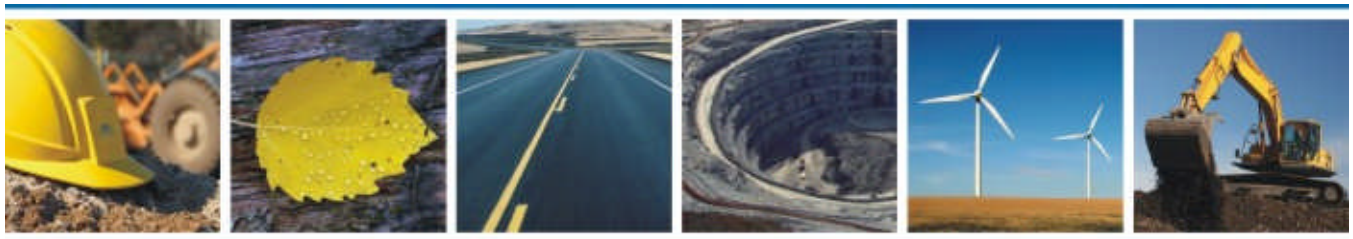
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- EBA. (2011). Detailed Design – Dry Stacked Tailings Facility – Keno Hill District Mine Site, Yukon. Report prepared for Alexco Resources Corporation, issued May 2011. EBA File No. W14101178.011. **See Appendix A – Phase 1 Detailed Design.**
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Appendix A – Phase 1 Detailed Design

ALEXCO RESOURCE CORP

DETAILED DESIGN DRY-STACKED TAILINGS FACILITY KENO HILL DISTRICT MILL SITE, YUKON



REPORT

MAY 2011
ISSUED FOR USE
EBA FILE: WI4101178.011

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1.0 INTRODUCTION

Alexco Resource Corp. (Alexco) is operating a silver, lead, zinc concentrating mill in the Keno Hill Silver District, Yukon. Alexco retained EBA, a Tetra Tech Company (EBA), to provide a detailed design for the Dry-Stacked Tailings Facility (DSTF) at the Keno Hill District Mill Site.

2.0 BACKGROUND

Alexco began preparatory earthworks and foundation work for the Keno Hill District Mill in the summer of 2009. EBA conducted a preliminary geotechnical investigation, consisting of thirty-one testpits excavated to varying depths, and a detailed geotechnical investigation consisting of drilling eleven boreholes with a mini-sonic drill rig. The preliminary investigation is summarized in the letter “Geotechnical Evaluation – Proposed Mill (Option 3) and DSTF” dated August 7, 2009. The detailed investigation is summarized in the report “Preliminary Engineering Design and Management Plan, Dry-Stacked Tailings Facility” issued by EBA in January 2010. A detailed design subject to additional confirmatory drilling in the vicinity of the proposed DSTF was completed by EBA in the summer of 2010.

Confirmatory drilling in August 2010 led to the discovery of massive ice not previously encountered and the requirement for EBA to revisit the detailed design of the DSTF. The details of the confirmatory drilling findings were summarized in a letter submitted on September 24, 2010 entitled “DSTF Detailed Drilling Findings and Revised DSTF Location”. To prevent disruption to production timelines, EBA issued “Quarter 1 Tailings Placement Provisions” on September 7, 2010 which detailed the construction of a tailings containment facility to accommodate three months worth of tailings production during the finalizing of the detailed design for the DSTF.

This report summarizes the findings of the confirmatory drill investigation conducted in August 2010 and presents the detailed design for the DSTF.

3.0 DRY-STACKED TAILINGS FACILITY DESIGN ASSUMPTIONS

The design of the DSTF at the Keno Hill District Mill Site is based on the following information, provided by Alexco:

- Tailings discharge rate of 7.75 dmt/h (dry-metric tonnes per hour) for Years 1 and 2 and 13.95 dmt/h for Years 3 and 4.
- Tailings specific gravity of 3.95.
- 60% of tailings stored on surface.
- The remaining 40% of tailings will be placed as backfill underground.
- An evapo-transpirative cover consisting of 0.5 m of vegetated soil will be used for closure of the DSTF.

The following assumptions were used by EBA in the design of the facility:

- 10% of the porewater in the DSTF will drain out of the pile in the long term.

- The design seismic event was selected to be 1:500 year return period, as recommended in “Mined Rock and Overburden Piles Investigation and Design Manual” (Piteau 1991).

The anticipated rate of tailings generation is 187 dmt (dry metric tonnes)/day for the first two years and 335 dmt/day for the next year and nine months. This information was provided to EBA by Alexco. The anticipated in place tailings volumes are summarized in Table 1.

Table 1 – Anticipated Yearly Tailings Volumes

Months of Operation	Tailings Produced (dmt)	Tailings Produced (m ³)	Tailings Stored Underground (m ³)	Tailings Stored on Surface (m ³)	Cumulative Tailings Stored on Surface (m ³)
0 – 12	67,890	39,940	15,970	23,970	23,970
12 – 24	67,890	39,940	15,970	23,970	47,940
24 – 36	122,200	71,890	28,750	43,140	91,080
36 – 45	91,070	53,570	21,430	32,140	123,220

4.0 GEOTECHNICAL INVESTIGATIONS

The preliminary geotechnical investigation was summarized in a letter “Geotechnical Evaluation – Proposed Mill (Option 3) and DSTF” dated August 7, 2009.

The detailed geotechnical investigation was summarized in a report “Preliminary Engineering Design and Management Plan, Dry-Stacked Tailings Facility” dated January 2010.

The confirmatory drilling geotechnical investigation was conducted between August 18 and September 11, 2010. EBA’s representative on site was Mr. Justin Pigage, EIT. Ten boreholes were drilled using a track mounted air-rotary drill rig provided by Geotech Drilling of Prince George, BC. Approximate UTM (NAD83 datum) coordinates, noted on the attached borehole logs, were determined using a hand-held GPS unit. Elevations shown on the logs were determined using the approximate coordinates and 1 m contour information generated from topographic survey information provided by Alexco.

4.1 Surface Conditions

The site in the vicinity of the DSTF slopes generally west at approximately 15% to 20%. There is disturbance in the area from previous surface earthwork and historic mining. A trail runs roughly north with a ditch that follows it to convey runoff around the former Flame and Moth Mine. Vegetation in the area consists of mosses and small spruce trees. A ridge crosses the site in a north-south direction. The ridge slopes approximately 5% to 10% towards the south.

4.2 Subsurface Conditions

The subsurface conditions encountered during the confirmatory drill investigation consist of four distinct zones. A brief summary of each zone is included below and the assumed extent of each zone is shown in Figure 2. The detailed borehole logs are included in Appendix B.

- **Shallow Bedrock** – Unfrozen sand and gravel (till) underlain by bedrock within the top 4.5 m was encountered in BH26 and BH27.

- **Ice Rich Silt** – Varying depths of ice rich silt till were encountered in BH32 through BH35.
- **Massive Ice** – Varying thicknesses of massive ice were encountered in BH28, BH30, BH31 and BH35.
- **Gravel** – Unfrozen gravel underlain by bedrock was encountered in BH29.

4.3 Groundwater

No groundwater was encountered during the confirmatory drill investigation.

4.4 Permafrost

Permafrost was encountered throughout the proposed DSTF. The permafrost encountered ranged from non-visible, non-excess ice to massive ice. Ice volumes estimated as a percentage of the total soil volume vary between less than 5% and nearly 100%. The type and amount of ice inclusions within the permafrost generally follows the soil stratigraphy.

The permafrost in the ice rich silt area contains a combination of horizontally stratified ice lenses, randomly oriented ice inclusions, and non-visible excess ice. The top 3.5 m of the permafrost here is considered to be ice-rich, containing 10% to 35% randomly orientated ice crystals and non-visible excess ice by volume. Below this, the permafrost is considered to be ice-poor (moisture contents in the soil are below the 100% saturation moisture content).

The permafrost in the overall massive ice area contains a combination of horizontally stratified ice lenses, massive ice, and non-visible excess ice. The ice lenses are typically about 5 mm thick. The thickness of massive ice varies in this region between roughly 10 and 15 m. Massive ice was identified within the footprint of the proposed DSTF footprint in one borehole (BH35); 4 m of massive ice was encountered in BH35 at a depth below 11.5 m within this region.

Ground temperature instrumentation was installed in two locations: BH31, and BH32. Data collected from these instruments shows that the permafrost on site is very warm, between -0.2°C and -0.4°C. Ground temperature information for all instrumentation in the vicinity of the DSTF is shown in Appendix C.

4.5 Bedrock

Bedrock was encountered in all holes advanced during the confirmatory drill investigation. The bedrock was classified as a competent quartzite. The drilling method (air rotary) provides fragments of rock sufficient for classification only -- no additional information can be provided on the bedrock.

4.6 Earthquake Parameters

The DSTF has been designed based on PGA from 2005 NBC for Keno Hill area: 0.138 g for 1/476 years.

5.0 LABORATORY TESTING

EBA conducted laboratory tests on recovered samples from the drill program and tailings samples provided by Alexco. The following tests were conducted and are explained in more detailed below:

- Moisture Content

- Particle Size Distribution
- Moisture-Density
- Direct Shear

5.1 Moisture Content

Moisture content determination was conducted on all samples returned to EBA's Whitehorse laboratory. Results of the tests are reported on the borehole logs. The moisture content reported is defined as mass of water divided by mass of dry solids.

5.2 Particle Size Distribution

Particle size distribution determination was conducted by sieve hydrometer method on tailings samples returned to EBA's Whitehorse laboratory. Results for the tailings samples tested are in Appendix D.

5.3 Moisture-Density Relationship

Moisture-density testing was conducted on the tailings samples provided by Alexco to establish density values for use in slope stability modelling. The results are provided in Appendix D.

5.4 Direct Shear

Direct shear testing was conducted on the tailings samples provided by Alexco. The resulting strength values were used in slope stability modelling. The strengths are summarized in Table 2 and included in Appendix D.

Table 2 – Tailings Strength Parameters

Description	Peak Strength		Residual Strength	
	Cohesion (kPa)	Friction (Φ)	Cohesion (kPa)	Friction (Φ)
Tailings	33.5	32.6	10.5	31.6

6.0 DRY-STACKED TAILINGS FACILITY DESIGN

Much of the design was summarized in the report "Preliminary Engineering Design and Management Plan, Dry-Stacked Tailings Facility" issued by EBA in January 2010. The following sections contain additional design work completed since January 2010, as part of the detailed design of the DSTF.

The design configuration of the dry stack facility has been modified since the preliminary design was developed. The revised configurations are shown in Figures 1, 2, 3, and 4. The modifications were put forth to avoid most of the identified massive ice areas, and to create a relatively flat pile profile over the ice rich areas.

6.1 Geothermal Analysis

A geothermal analysis was carried out to investigate the long-term impact of dry-stacked tailings placement on the thermal regime of the underlying original ground in the DSTF area under climatic

conditions including a climate change scenario (global warming). The analysis is presented in Appendix E. The following summarizes the analysis and results.

Analyses were carried out using EBA's proprietary two-dimensional finite element computer model, GEOTHERM. The model simulates transient, two-dimensional heat conduction with change of phase for a variety of boundary conditions. The heat exchange at the ground surface is modelled with an energy balance equation considering air temperatures, wind velocity, snow depth, and solar radiation.

Climate data for the analysis was synthesized from long term climate data from the Mayo station and the Galena Hill weather station near the site. Estimates of climate change magnitudes were obtained from a recent report prepared for CSA and The Adaptation and Impacts Research Section (AIRS) of Environment Canada (CSA 2010). The estimated mean annual temperature 100 years from present is 3.1°C.

The geothermal model was calibrated to the measured ground temperatures at the site. Good agreement was obtained between the measured and modelled temperatures.

The soil profile from BH35 was used in the DSTF thermal analysis. The model simulated dry stack tailings placed over the drainage blanket over the original ground. The initial ground temperature was assumed to be -0.35°C.

The analysis predicted that the frozen overburden and ice thawed in approximately 50 years. The rate of thaw varied slightly for different sensitivity parameters as presented in Table 8 in Appendix E.

6.2 Thaw Consolidation

Construction of the DSTF will involve placing and compacting relatively warm tailings on relatively cold ground. This will change the thermal equilibrium that exists on the site and eventually thaw the existing permafrost in the area.

EBA conducted thaw-consolidation testing on samples of undisturbed ice-rich permafrost recovered from BH23. An average C_v value of 0.0014 cm²/s was determined using standard consolidation theory. The C_v value is low and accounts for volume changes due to melting ice within the soil profile. An assumption in thaw-consolidation theory is that drainage is not impeded from the top of the consolidating layer. EBA has assumed that a 0.5 m thick gravel drainage blanket sufficiently fulfills this. The potential for differential settlement under the DSTF exists. This may create localized pockets of elevated porewater pressure. EBA's opinion is that this will not affect overall stability of the pile. Furthermore, the entire site slopes to free draining gravel at the toe of the pile.

Using a C_v of 0.0014 cm²/s and a rate of thaw of 1.2 m, in four months, the anticipated excess porewater pressure generated is $R_u=0.35$. This value was used in slope stability calculations, where appropriate.

6.3 Slope Inclinator Data

Slope inclinometers (SI) were installed in August 2010 in two boreholes adjacent to the proposed DSTF, BH28 and BH30. Both boreholes are located in an area with ice rich soil on a slope.

The measured SI data is presented in Appendix F. Data is available for BH30 up to February 2011. Limited data is available for BH28 as the SI has been covered with snow and debris over the winter.

BH30 SI has no significant differential movement from the bedrock at the base of the SI to the overburden at the top of SI. This indicates that the slope is not currently creeping.

The data indicates some perpendicular and parallel movement in the pipe. The movement reverses direction within the ice rich zone. The pipe movement is not believed to be slope movement, as the top of the slope is not moving. It is speculated that the grout used to install the SI liberated heat of hydration during curing and melted ice around the SI pipe creating a void. The SI pipe is likely moving within this void.

6.4 Liquefaction Assessment

A liquefaction assessment was carried out to determine if the DSTF is susceptible to liquefaction under earthquake loading. The dry stack tailings themselves are not considered to be highly liquefiable since they are expected to be drained and unsaturated. The assessment was carried out on the foundation soils. The assessment was carried out using the NCEER SPT-based method (Youd et al. 2001).

Foundation soils beneath the proposed DSTF area are silty sand, gravel and sand, silt (ice-rich) or silt (till). The liquefaction assessment is a function the soil density as measured by the Standard Penetration Test (SPT) N-value of the soils. The SPTs conducted at the mine site in the area in or close to the proposed DSTF area in the unfrozen overburden soils are summarized in Table 3. SPTs in the frozen (permafrost) soil zones are not included in the table. SPTs ranged from 12 to 36 with an average of 21. The lowest SPT measured was 12; this was carried through the liquefaction assessment.

The ice-rich silt or silt till soils in the existing permafrost would thaw gradually during the mine operation and after closure based on the thermal analysis results. It is expected that the silt or silt till soils will consolidate with time after thawed. A summary of the assessment is presented in Table 4.

Table 3 Standard Penetration and Soil Property Summary

Borehole No.	Depth from the Ground Surface (m)	Soil Description in Borehole Logs	SPT N Value
BH17	3.3	Silt (till), gravelly, some sand, trace clay, firm, non-plastic, damp	19
BH24	3.2	Silt (till), gravelly, some/sandy, trace clay, very stiff, low to non-plastic, damp to moist, gravel particles, subangular	36
BH25	3.2	Sand and gravel, glaciofluvial, trace silt, compact, medium grained, well graded, damp, rounded to sub-rounded	21
BH26	1.7	Sand, silty, some gravel, damp, loose	12
BH27	1.8	Silt, sandy, trace gravel, moist, firm, non-plastic	18

Table 4 Liquefaction Assessment

Soil Profile and Properties Assumed	SPT N Value Assumed	Moment Magnitude of Earthquake, M_w	Peak Horizontal Acceleration at the Ground Surface, a_{max} , (g)	Calculated Factor of Safety against Cyclic Liquefaction
9 m dry-stacked tailings, 0.5 m gravel drainage layer; water table at 0.5 m below the original ground;	12	7.0	0.138	1.45
	12	7.5	0.138	1.22
	12	8.1	0.138	1.00
0.5 m gravel drainage layer; ground water table at 0.5 m below the original ground surface;	12	7.0	0.138	1.54
	12	7.5	0.138	1.29
	12	8.3	0.138	1.00

Under the design Peak Horizontal Acceleration of 0.138 g, the calculated factor of safety against cyclic liquefaction is ranges from 1.2 to 1.5 for high earthquake magnitudes (7.0 and 7.5). The FS is greater than or equal to 1.0 when the magnitude of earthquake is below 8.0 for the silty sand foundation soils. This is considered an extreme event with a low risk of occurring nearby to the mine. The consequence of liquefaction is expected to be limited movement and cracking of the dry stack facility as opposed to a catastrophic collapse. Given the extreme event and consequence of failure it judged that there is low risk of a significant failure event due to liquefaction.

6.5 Stability of the DSTF

The stability of the DSTF was determined using Geostudio 2007 – Slope/W module, which is a computer program that uses limit equilibrium theory to compute the factor of safety (FS) of slopes. The DSTF slopes were analyzed in several different conditions, including during construction (Years 1 through 4) and after closure activities in both static and pseudo-static scenarios.

Minimum FSs are suggested by the BC Mine Waste Rock Pile Research Committee (Piteau 1991). The suggested FS are provided for two cases: Case A and Case B. Case A is typically used when less rigorous analyses are conducted or when material properties and actual failure mechanisms are not well understood. Case B is typically used when more rigorous analyses are conducted or when material properties and failure mechanisms are well understood. EBA has chosen to compare the calculated FS against Case A except when the long-term strength of ice-rich frozen silt is considered in the analysis. The method used to determine the long-term strength of ice-rich silt is considered to be very conservative, and thus these scenarios should be compared against Case B.

The stability of the DSTF was analyzed along two sections in three scenarios:

- Permafrost
- Permafrost thawed to 1.0 m depth
- Permafrost fully thawed

Analyses were run for static and pseudo static conditions. The parameters used for and the results of each analysis are summarized in the subsequent sections.

6.5.1 Soil Strength Parameters

Six material types were used in the slope stability model:

- Bedrock
- Frozen ice-rich silt
- Thawed silt
- Tailings
- Gravel
- Loose Gravel

The material parameters are summarized in Table 5.

Table 5 – Slope Stability Model - Material Properties

Material Description	Unit Weight (kN/m ³)	Frictional Strength		Non-Frictional Strength
		Cohesion (kPa)	Friction (Φ)	c _u (kPa)
Bedrock	Bedrock is considered impenetrable in this model			
Frozen ice-rich silt	11.8	0	30°	50
Thawed silt	19.1	0	30°	N/A
Tailings	22.5	0	32°	N/A
Gravel	24.0	0	35°	N/A
Loose gravel	21.1	0	30°	N/A

All soils are expected to behave as frictional materials for any short-term loading conditions; these are modelled in the drained state. Short-term loading is considered to be during construction of the pile or during any pseudo-static analysis.

All soils, except for the frozen ice-rich silt, are also expected to behave as frictional materials during long-term loading conditions.

The properties of each soil type are discussed in more detail below.

6.5.1.1 Bedrock

The bedrock in the area is a competent quartzite. The strength of the bedrock is much greater than that of the overburden and therefore the bedrock will not control the stability. For modelling purposes, the Bedrock was assumed to be impenetrable.

6.5.1.2 Frozen Ice-Rich Silt

A conservative approach to determining the strength of a frozen soil is to assume that the internal angle of friction (Φ) of the soil is equal to 0, thus relying solely on the cohesive properties of the frozen soil. A relationship between shear strength and temperature is (Johnston 1981):

$$C_u = 35 + 28T$$

Where: T is in degrees °C below freezing (with a positive sign) and

C_u is lower limit of undrained shear strength.

Assuming that the temperature of the frozen ice-rich silt is -0.4°C, the long term shear strength would be 46 kPa. This value is considered to be the lower limit. Based on experience and engineering judgement a value of 50 kPa has been assumed in the stability analysis. The bulk density of the ice-rich silt was estimated assuming a moisture content of 90%. In short-term loading, it is expected that the ice-rich silt will behave as a frictional material with properties similar to those determined for the thawed state.

6.5.1.3 Thawed Silt

The thawed silt will behave as a frictional material in both short-term and long-term loading conditions. The strength was determined using direct shear test results.

6.5.1.4 Tailings

Tailings will behave as a frictional material in both short-term and long-term loading conditions. The strength of the tailings was determined using direct shear test results. The bulk density was determined by first determining the maximum dry density of the tailings (2080 kg/m³) and then adding the mass of water (assuming moisture content of 15%).

6.5.1.5 Gravels

Gravel will behave as a frictional material in both short-term and long-term loading conditions. The friction angle of the gravel was conservatively assumed as 35° based on EBA's experience with gravels in the Keno City area. This was reduced to 30° for gravel placed in a loose state. The bulk density was based on a maximum dry density of 2,385 kg/m³. It is assumed that the gravel would be placed at 95% density and 8% moisture for the drain area and 87% density and 4% moisture for the cover material.

6.5.2 Analysis Results

6.5.2.1 Permafrost Condition

This scenario is intended to model the condition where the tailings have been placed and the underlying soils have remained frozen. The factor of safety against long-term slope instability was determined using the long-term strength of ice-rich silt. This is considered a conservative lower bound strength assumption. A summary of the factors of safety for several conditions within this scenario are provided in Table 6. Slope stability analyses results are presented in Appendix G.

Table 6 – DSTF Slope Stability Factor of Safety – Fully Frozen Case

Stability Conditions	Factor of Safety - Suggested Minimum (Piteau 1991)		Calculated FS for DSTF	
	Case A	Case B	Alignment A	Alignment B
Stability of Surface				
Short-term (during construction – static)	1.0	<i>1.0</i>	1.8	2.0
Long-term (after closure – static)	<i>1.2</i>	1.1	1.9	2.0
Deep Seated Stability				
Short-term (during construction – static)	1.3-1.5	<i>1.1-1.3</i>	2.0	1.8
Short-term (during construction – pseudo-static)	1.1-1.3	<i>1.0</i>	1.3	1.2
Long-term (after closure – static)	<i>1.5</i>	1.3	1.4	1.3
Long-term (after closure – pseudo-static)	1.1-1.3	<i>1.0</i>	1.3	1.2

Bold values are recommended minimum for each condition.

Italic values are provided for information only.

6.5.2.2 Permafrost Thawed to 1.0 m Depth

This scenario is intended to model the condition where the tailings are placed and the underlying soils have thawed 1.0 m in four months. This rate of thaw is relatively quick. It was determined assuming that the tailings would remain at +20°C for four consecutive months. The porewater pressures developed due to this rate of thaw is $R_u=0.35$. This is considered an upper bound for thawing of the ice-rich silt. Any thaw beyond this initial 1.0 m will occur at a much slower rate. The slower rate of thaw will allow porewater to dissipate prior to developing excess porewater pressures. A summary of the factors of safety for several conditions within this scenario are provided in Table 7. Slope stability plots are found in Appendix H.

Table 7 – DSTF Slope Stability Factor of Safety – 1.0 m Thawed Case

Stability Conditions	Factor of Safety - Suggested Minimum (Piteau 1991)		Calculated FS for DSTF	
	Case A	Case B	Alignment A	Alignment B
Stability of Surface				
Short-term (during construction – static)	1.0	<i>1.0</i>	1.6	2.0
Long-term (after closure – static)	<i>1.2</i>	1.1	1.6	1.7
Deep Seated Stability				
Short-term (during construction – static)	1.3-1.5	<i>1.1-1.3</i>	1.9	1.6

Table 7 – DSTF Slope Stability Factor of Safety – 1.0 m Thawed Case Cont'd

Stability Conditions	Factor of Safety - Suggested Minimum (Piteau 1991)		Calculated FS for DSTF	
	Case A	Case B	Alignment A	Alignment B
Stability of Surface				
Short-term (during construction – pseudo-static)	1.1-1.3	<i>1.0</i>	1.3	1.1
Long-term (after closure – static)	<i>1.5</i>	1.3	1.4	1.3
Long-term (after closure – pseudo-static)	1.1-1.3	<i>1.0</i>	1.2	1.2

Bold values are recommended minimum for each condition.

Italic values are provided for information only.

6.5.2.3 Permafrost Fully Thawed

This scenario is intended to model the anticipated long-term condition where the tailings are placed and the underlying soils have fully thawed and consolidated. Due to the rate of thaw and the lack of excess ice below the ice-rich silt layer, no excess porewater pressure is anticipated. This should be considered a reasonable approximation of the DSTF's long-term state. A summary of the factors of safety for several conditions within this scenario are provided in Table 8. Slope stability plots are found in Appendix I.

Table 8 – DSTF Slope Stability Factor of Safety – Fully Thawed Case

Stability Conditions	Factor of Safety Suggested - Minimum (Piteau 1991)		Calculated FS for DSTF	
	Case A	Case B	Alignment A	Alignment B
Stability of Surface				
Short-term (during construction – static)	1.0	<i>1.0</i>	N/A ¹	
Long-term (after closure – static)	<i>1.2</i>	1.1	1.6	2.0
Deep Seated Stability				
Short-term (during construction – static)	1.3-1.5	<i>1.1-1.3</i>	N/A ¹	
Short-term (during construction – pseudo-static)	1.1-1.3	<i>1.0</i>	N/A ¹	
Long-term (after closure – static)	<i>1.5</i>	1.3	2.0	1.9
Long-term (after closure – pseudo-static)	1.1-1.3	<i>1.0</i>	1.4	1.4

Bold values are recommended minimum for each condition.

Italic values are provided for information only.

¹Foundation will not be fully thawed during construction of the pile.

6.5.3 Creep

Ice and ice rich soils can creep over time. The magnitude of creep movement is a function of the shear stresses in the slopes.

Slope inclinometers installed at site indicate that there is no significant movement in ice rich soils in existing slopes. The DSTF is configured such that there are flat areas over the ice rich areas; therefore the shear stresses in the foundation soils should be similar or less than they are presently. This is expected to limit the creep deformation in the DSTF foundation soils.

Continued monitoring of the pile is recommended to confirm that movements are limited.

6.6 DSTF Foundation

The foundation for the DSTF consists of the drainage blanket, geosynthetic clay liner (GCL), and geocomposite drain. Proper construction and material specifications for the DSTF foundation are described in detail in the "Runoff Diversion Structure Specs" issued by EBA in September 2010. A summary of each component of the DSTF foundation is included in the following sections.

6.6.1 Drainage Blanket

The drainage blanket is a 0.6 m layer of gravel constructed over the existing organic cover without disturbing the surface, to limit the degradation of permafrost. The drainage blanket is designed to allow any water generated from thawing permafrost to drain from the DSTF. It also provides an acceptable surface for the placement of the GCL.

6.6.2 Geosynthetic Clay Liner

A properly bedded geosynthetic clay liner is to be placed above the drainage blanket to collect any seepage leaving the tailings stack. The liner will help prevent tailings and tailings porewater from infiltrating the coarser gravel material of the drainage blanket below. The GCL consists of a layer of bentonite clay sandwiched between a layer of woven geotextile and a layer of nonwoven geotextile. The nonwoven layer of geotextile shall be oriented upward to maximize friction between the GCL and the geocomposite drain.

6.6.3 Geocomposite Drain

A geocomposite drain is required above the GCL to help alleviate any potential porewater pressure buildup in the tailings stack. The geocomposite drain is a sheet of geo-net placed directly on the GCL and a layer of nonwoven geotextile above the geo-net. The tailings are to be placed and compacted directly over the nonwoven geotextile.

6.6.4 Stability of the DSTF Foundation

The stability of the DSTF foundation was determined using Geostudio 2007 – Slope/W module. The DSTF foundation was analyzed in both static and pseudo-static scenarios.

The minimum factors of safety suggested by the BC Mine Waste Rock Pile Research Committee used in the stability analysis of the DSTF were also used in the DSTF foundation analysis.

6.6.4.1 Material Strength Parameters

Soil and tailings strength parameters assumed in the DSTF foundation stability analysis were equal to the DSTF stability analysis (Section 6.5.1).

The strength of the geocomposite liner and drain was modeled as an interface frictional material. The interface friction value was based on review of relevant literature (State of California, 2006), (Lydic and Zagorski, 1991), and (Koerner, 2005). The properties of the manufactured materials are summarized in Table 9.

Table 9 – DSTF Foundation Stability Model – Material Properties

Material Description	Unit Weight (kN/m ³)	Frictional Strength		Non-Frictional Strength
		Cohesion (kPa)	Friction (Φ)	C _u (kPa)
Geocomposite liner and drain	24.0	0	16°	N/A

6.6.4.2 Analysis Results

The factor of safety along the geocomposite liner and drain was determined by forcing the failure plane through the material. A summary of the factors of safety for the DSTF foundation is provided in Table 10. The stability plots are presented in Appendix J.

Table 10 – DSTF Foundation Stability Factor of Safety

Stability Conditions	Factor of Safety – Suggested Minimum (Piteau 1991)		Calculated Factor of Safety for DSTF Foundation	
	Case A	Case B	Alignment A	Alignment B
Short-term (during construction – static)	1.3-1.5	<i>1.1-1.3</i>	1.4	1.4
Short-term (during construction – pseudo-static)	1.1-1.3	<i>1.0</i>	1.1	1.1
Long-term (after closure – static)	<i>1.5</i>	1.3	1.4	1.4
Long-term (after closure – pseudo-static)	1.1-1.3	<i>1.0</i>	1.1	1.2

Bold values are recommended minimum for each condition.

Italic values are provided for information only.

7.0 OPERATION, MAINTENANCE, AND SURVEILLANCE MANUAL

Construction and operation of the DSTF will be carried out in accordance with the Operation, Maintenance, and Surveillance (OMS Manual) submitted to Alexco by EBA in September 2010.

8.0 DSTF CLOSURE PLAN

Since the DSTF will be constructed as a sidehill fill, progressive reclamation is feasible and will be conducted. Once tailings placement for a portion of the DSTF is complete, an evapo-transpirative cover (0.5 m of loosely placed gravel soil) will be placed over the surface of the compacted tailings to temporarily store runoff and allow it evaporate or to be used by plants. The surface water collection pond and diversion berms and ditches will be left in place. The water collection pond will be able to act as a bio-reactor if necessary, and the berms will continue to divert runoff water away from the DSTF area. The entire affected footprint will be re-vegetated with plants that promote soil evapo-transpiration, similar to those used at Brewery Creek Mine. This procedure has been successfully used at the Brewery Creek Mine, which was reclaimed by Alexco (Tremblay et al. 2001).

The DSTF will require an annual geotechnical inspection for at least five years after closure. This requirement should be reviewed after five years.

9.0 CLOSURE

We trust this report meets your present requirements. Should you have any questions or comments, please contact the undersigned.

EBA, A Tetra Tech Company



Justin Pigage, EIT
Project Engineer
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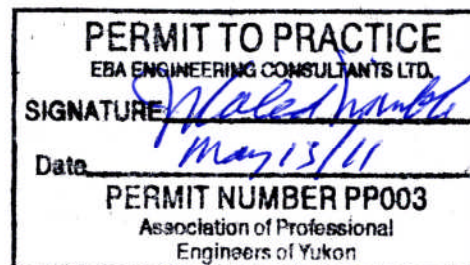


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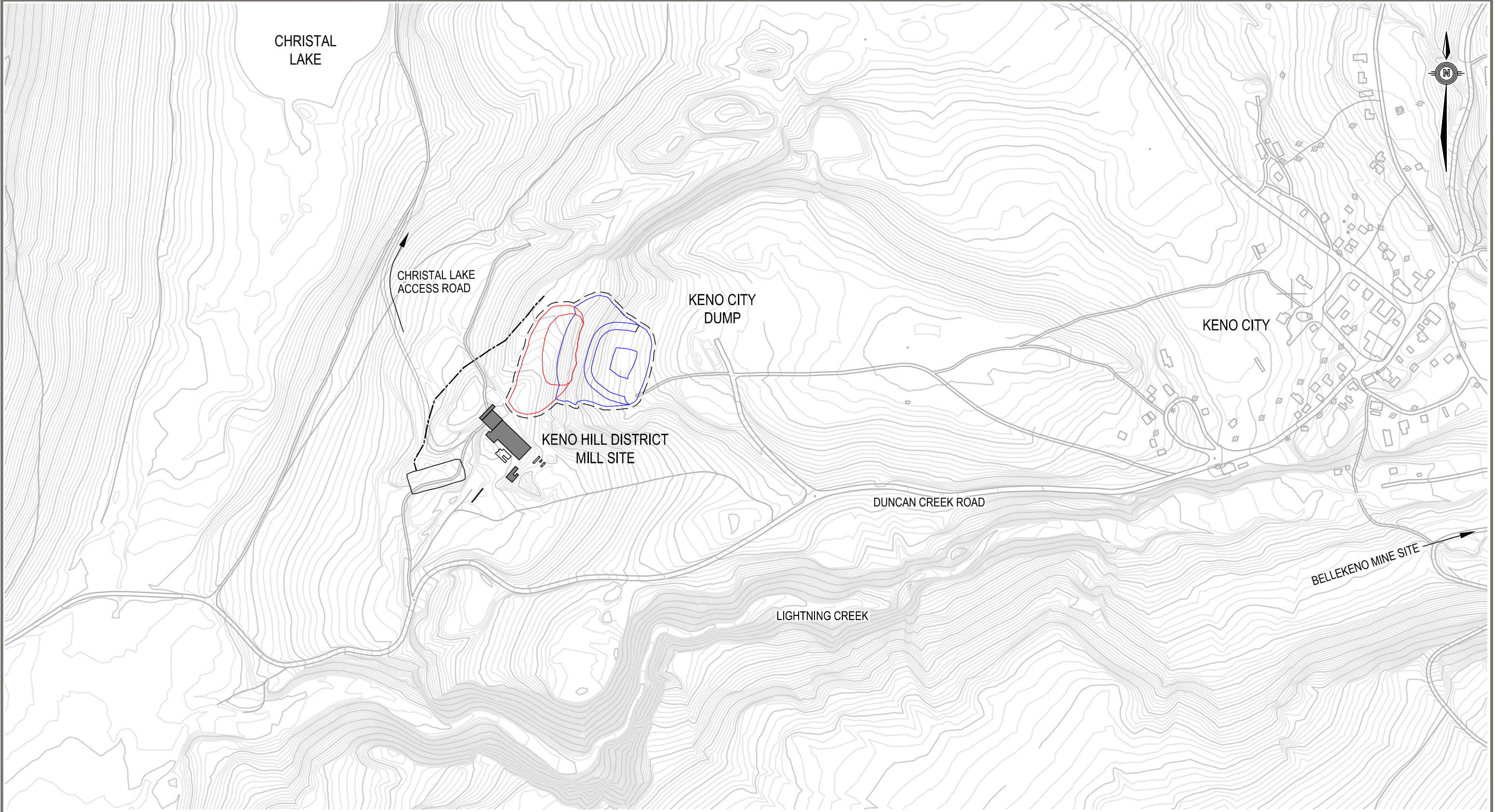


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FIGURES

Figure 1	Site Location Plan
Figure 2	Site Plan Showing Borehole Locations and Assumed Subsurface Conditions
Figure 3	DSTF Plan View
Figure 4	DSTF Sections



LEGEND

Scale: 1: 5 000 (metres)

STATUS

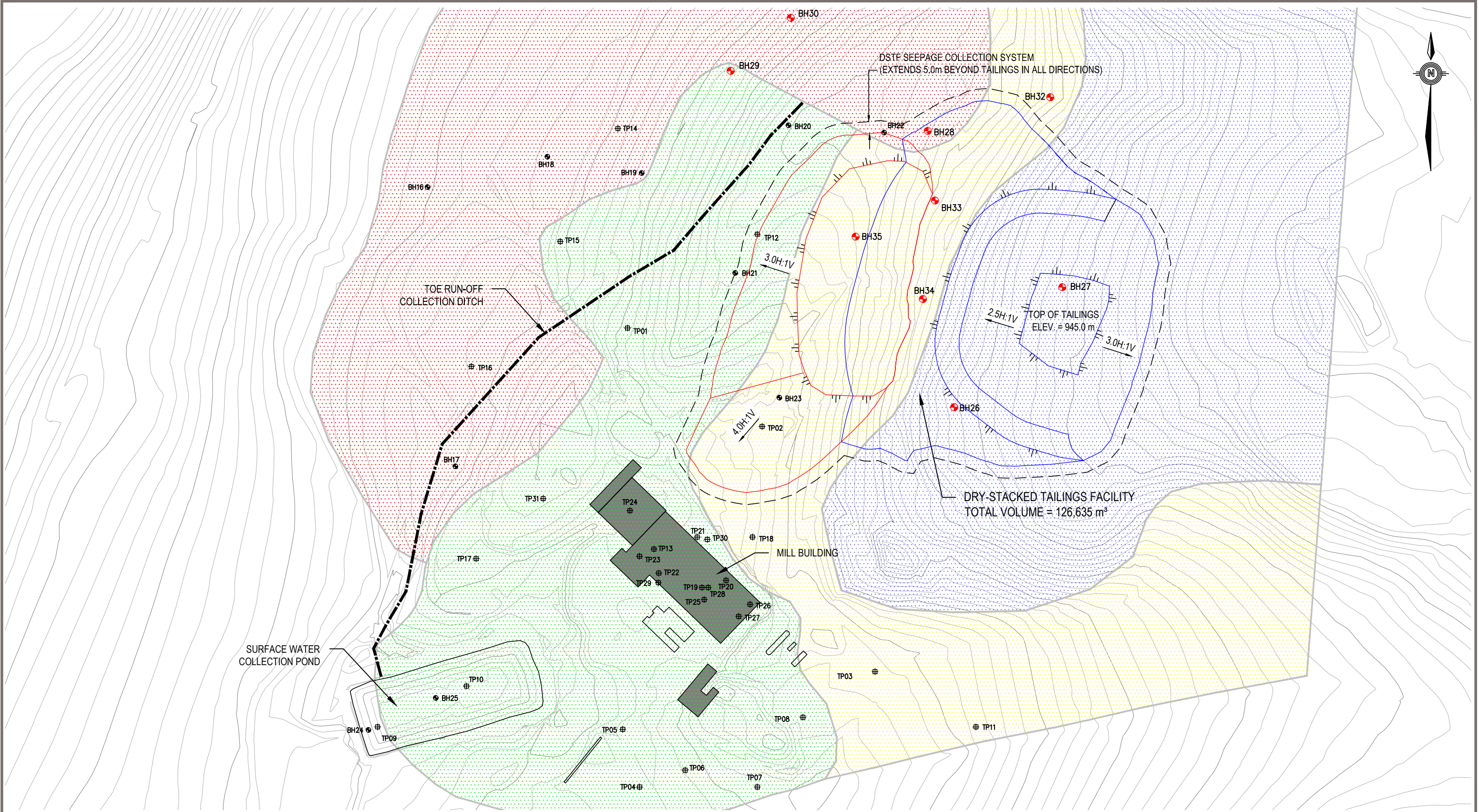
ISSUED FOR USE

CLIENT

DRY STACKED TAILINGS FACILITY
KENO HILL DISTRICT MILL SITE, YUKON

SITE LOCATION PLAN

PROJECT NO. W14101178.011	DWN CB	CKD JTP	REV 0	Figure 1
OFFICE EBA-WHSE	DATE May 13, 2011			



LEGEND

- - BOREHOLE LOCATION (CONFIRMATORY DRILLING)
- - BOREHOLE LOCATION (PREVIOUSLY ADVANCED)
- ⊕ - TESTPIT LOCATION

- GRAVEL
- MASSIVE ICE
- ICE RICH SILT TILL
- SHALLOW BEDROCK

STATUS
ISSUED FOR USE

CLIENT



DRY STACKED TAILINGS FACILITY
KENO HILL DISTRICT MILL SITE, YUKON

SITE PLAN SHOWING BOREHOLE LOCATIONS
AND ASSUMED SUBSURFACE CONDITIONS

PROJECT NO.
W14101178.011

DWN
CB

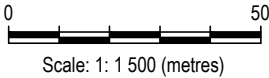
CKD
JTP

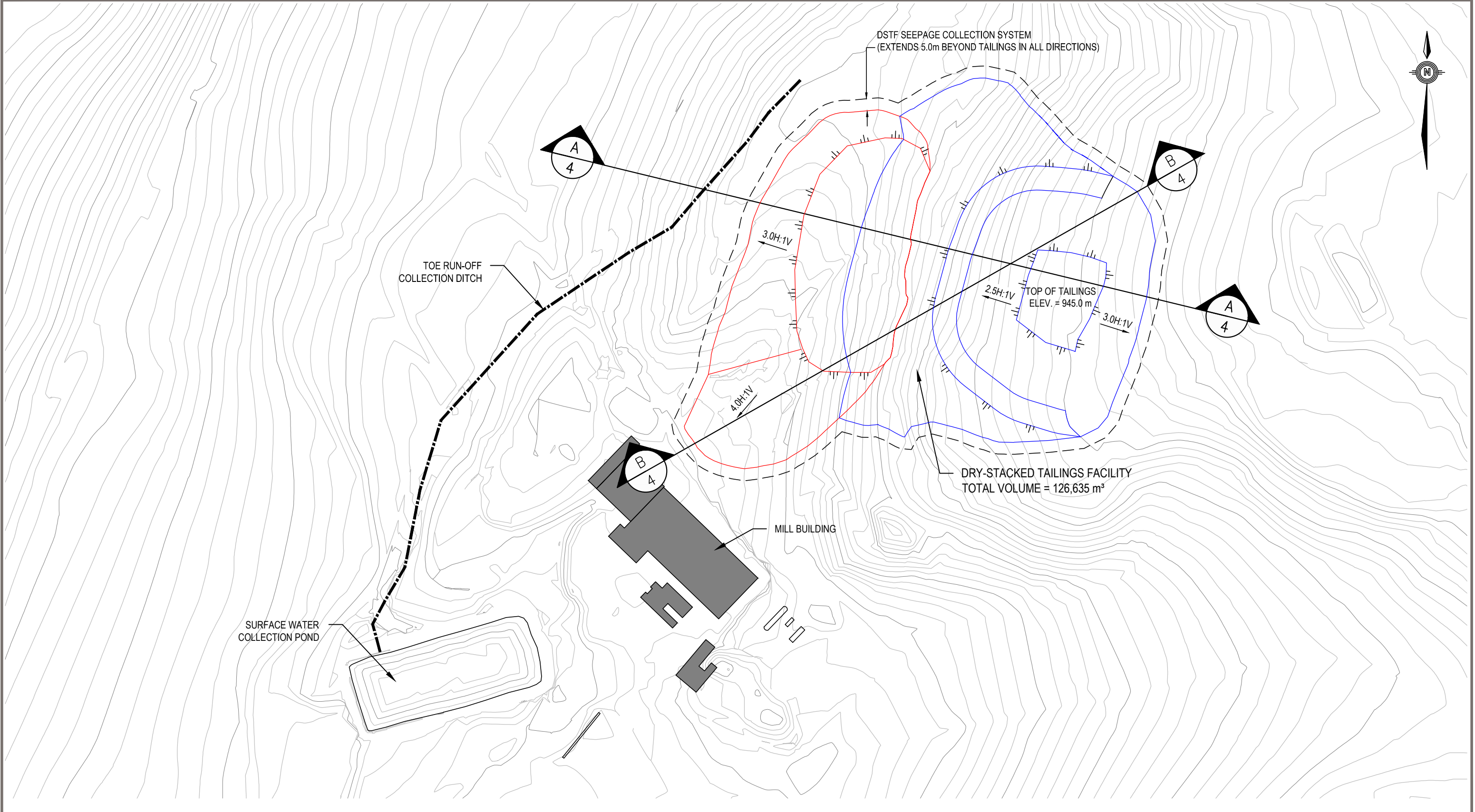
REV
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OFFICE
EBA-WHSE

DATE
May 13, 2011

Figure 2





LEGEND

STATUS
ISSUED FOR USE

CLIENT

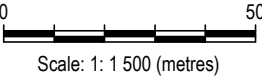


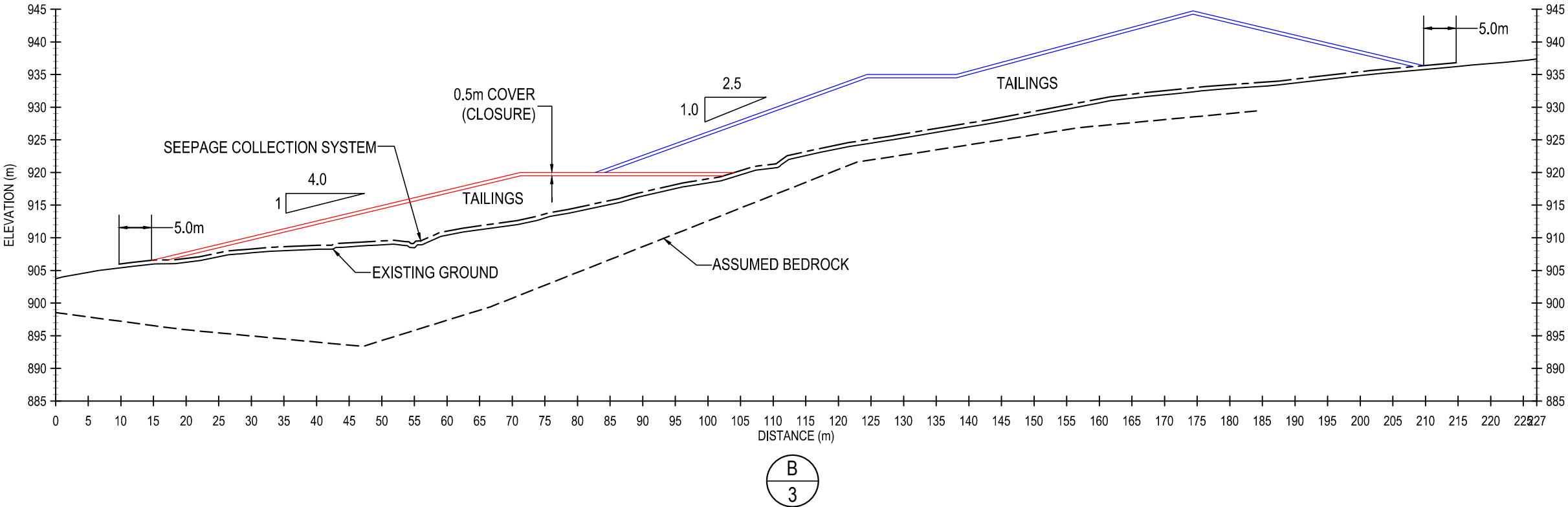
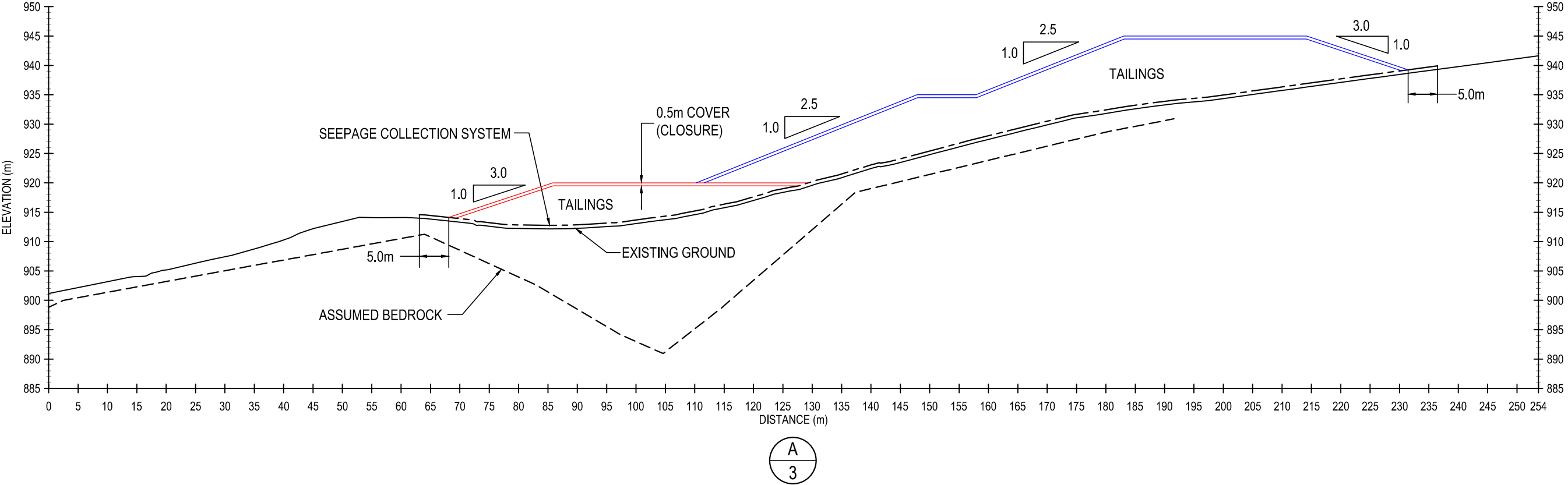
DRY STACKED TAILINGS FACILITY
KENO HILL DISTRICT MILL SITE, YUKON

DSTF PLAN VIEW

PROJECT NO. W14101178.011	DWN CB	CKD JTP	REV 0
OFFICE EBA-WHSE	DATE May 13, 2011		

Figure 3





LEGEND

STATUS
ISSUED FOR USE

CLIENT

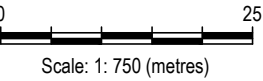


DRY STACKED TAILINGS FACILITY
KENO HILL DISTRICT MILL SITE, YUKON

DSTF SECTIONS

PROJECT NO. W14101178.011	DWN CB	CKD JTP	REV 0
OFFICE EBA-WHSE	DATE May 13, 2011		

Figure 4



APPENDIX A

APPENDIX A EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's Client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's Client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. EBA's instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TEST HOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B

APPENDIX B BOREHOLE LOGS

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.	
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH26	
Keno City, YT		7086870N; 484037E; Zone 8		ELEVATION: 928.5m	
SAMPLE TYPE		☒ DISTURBED	☐ NO RECOVERY	☒ SPT	☐ A-CASING
BACKFILL TYPE		☒ BENTONITE	☐ PEA GRAVEL	☐ SLOUGH	☐ GROUT
		☐ DRILL CUTTINGS	☐ SAND	☐ CORE	

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	STANDARD PENETRATION (N)				Elevation (m)
						UNCONFINED (kPa)				
						20	40	60	80	
0	SAND - silty, some gravel, damp, loose, dark grey, organics near surface									928.0
1		☒	SA01		7.6					
2		☒	SA02	12	9.7					
	GRAVEL and SAND (TILL) - some silt, damp, compact, grey									
3		☒	SA03		2.8					926.0
4		☒	SA04		4.6					
	BEDROCK - weathered, grey with quartz and staining - soft rock seems 0.2 m thick, easy drilling									
5		☒	SA05		2.4					924.0
	BEDROCK - hard drilling									
6		☒	SA06		0.1					923.0
	END OF BOREHOLE @ 6.0 m (Target Depth)									
	NOTE: Hole grouted to surface; Bentonite plug installed on surface.									922.0
7										921.0
8										920.0
9										919.0
10										



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REVIEWED BY: JRT
DRAWING NO:

COMPLETION DEPTH: 6m
COMPLETE: 8/18/2010
Page 1 of 1

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH27				
Keno City, YT		7086920N; 484082E; Zone 8		ELEVATION: 933.75m				
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	PLASTIC M.C. LIQUID 20 40 60 80	STANDARD PENETRATION (N)	Elevation (m)
							20 40 60 80	
0	SILT - sandy, trace gravel, moist, firm, non-plastic, olive brown, organics near surface							933.0
1		☒	SA07		13.3			
2	- becomes sandier	☒	SA08	18	12.6			932.0
	SAND and GRAVEL - some silt, dry, light grey							
	BEDROCK - grey, hard drilling	☒	SA09		2.1			931.0
3	END OF BOREHOLE @ 3.0 m (Target Depth)							930.0
	NOTE: hole filled with bentonite chips							929.0
4								928.0
5								927.0
6								926.0
7								925.0
8								924.0
9								
10								



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DRAWING NO:

COMPLETION DEPTH: 3m
COMPLETE: 8/18/2010
Page 1 of 1

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.						
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH28						
Keno City, YT		7086985N; 484026E; Zone 8		ELEVATION: 917.8m						
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND										
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	STANDARD PENETRATION (N)		Elevation (m)		
						20 40 60 80	50 100 150 200			
						PLASTIC	M.C.	LIQUID	POCKET PEN. (kPa)	
						20 40 60 80			100 200 300 400	
0	ORGANIC MOSS COVER SILT - some sand, uniform, moist, soft, dark brown, some organics	☒	SA10		59					917.0
1										
2	SILT (TILL) - gravelly, trace sand, frozen (Vx), firm, grey	☒	SA11	42	45.3					916.0
		☒	SA12		43.2					
3	- ICE and SILT	☒	SA13	57	25.7					915.0
4										914.0
5	- attempted SPT - spoon refusal	☒	SA14		13.5					913.0
	SAND and GRAVEL (TILL) - gravelly, moist, firm, grey									912.0
6										
7	MASSIVE ICE									911.0
8	- attempted SPT - spoon refusal	☒	SA15		22.6					910.0
	SILT (TILL) - gravelly, moist, firm, grey									909.0
9										908.0
10										907.0
11	MASSIVE ICE									906.0
12										905.0
13										904.0
14	GRAVEL (TILL) - some silt, frozen (Vx), compact, grey with other minerals									903.0
15	MASSIVE ICE - occasional gravel									



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COMPLETION DEPTH: 27.5m

COMPLETE: 8/20/2010

Page 1 of 2

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH28				
Keno City, YT		7086985N; 484026E; Zone 8		ELEVATION: 917.8m				
SAMPLE TYPE ☐ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☐ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☒ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	STANDARD PENETRATION (N)		Elevation (m)
						20 40 60 80	50 100 150 200	
					PLASTIC M.C. LIQUID 20 40 60 80	◆ UNCONFINED (kPa) ◆ 50 100 150 200 ▲ POCKET PEN. (kPa) ▲ 100 200 300 400		
15								902.0
16								901.0
17								900.0
18								899.0
19								898.0
20								897.0
21	GRAVEL (TILL) - silty, some sand, dry, dense, grey SILT (TILL) - gravelly, dry, stiff, grey with staining							896.0
22								895.0
23								894.0
24	SAND and GRAVEL (TILL) - trace silt, dry, dense, grey - grey rock seem 0.3 m thick - sand seem 0.2 m thick, tan - sand seem 0.2 m thick, tan							893.0
25	- becomes damp - becomes some silt							892.0
26								891.0
27	BEDROCK - hard drilling, light grey							890.0
28	END OF BOREHOLE @ 27.5 m (Target Depth) NOTES: Installed SI casing to 89' (27.13 m). Grouted hole to surface with tremie line (approx. 60 gal.)							889.0
29								888.0
30								

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GEOTECHNICAL W14101178.011.GPJ EBA.GDT 3/24/11

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DRAWING NO:	Page 2 of 2

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.					
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH29					
Keno City, YT		7087010N; 483944E; Zone 8		ELEVATION: 906.5m					
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND									
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	MOISTURE CONTENT	PLASTIC M.C. LIQUID		STANDARD PENETRATION (N)		Elevation (m)
					20 40 60 80	50 100 150 200	20 40 60 80	100 200 300 400	
0	MOSS COVER								
	SAND and GRAVEL - some silt, medium grained, well graded, sub-rounded, moist, compact (est.), dark brown, trace organics	☒	SA16	12.6	●				906.0
1	ROCK - fractured angular cuttings returned, various colours, some staining								
	SILT - some sand, trace gravel, damp, firm (est.), non-plastic, olive grey hint of green	☒	SA17	16.5	●				905.0
2	BEDROCK - hard drilling								
		☒	SA18	1.7	●				904.0
3	END OF BOREHOLE @ 3.0 m (Target Depth)								903.0
4									902.0
5									901.0
6									900.0
7									899.0
8									898.0
9									897.0
10									

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH30				
Keno City, YT		7087032N; 483969E; Zone 8		ELEVATION: 907.25m				
SAMPLE TYPE ☒ DISTURBED ☒ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	PLASTIC M.C. LIQUID 20 40 60 80	STANDARD PENETRATION (N) 20 40 60 80	Elevation (m)
0	SAND and GRAVEL (FILL) - trace silt, well graded, damp, brown PEAT and ORGANICS - frozen, dark brown	☒	SA19		73.4			907.0
1	SILT (TILL) - some gravel, frozen (Nbn), brown - becomes Vx - attempted SPT - spoon refusal	☒	SA20		36.8			906.0
2	SAND and GRAVEL - trace silt, well graded, medium grained, sub-angular, frozen (Vx), grey	☒	SA21		36.3			905.0
3		☒	SA22		16.3			904.0
4	- less silt, sub-rounded							903.0
5	ROCK - fractured, angular, multi coloured	☒	SA23		6.9			902.0
	SILT (TILL) - some gravel, frozen (Vx)	☒	SA24					901.0
6	ICE - massive ice with little or no soil	☒	SA25	43	313.5		314	901.0
7								900.0
8								899.0
9		☒	SA26	48	2421.1		2421	898.0
10								897.0
11								896.0
12								895.0
13								894.0
14	- contains some gravel for 0.3 m							893.0
15								



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DRAWING NO:

COMPLETION DEPTH: 26m
COMPLETE: 9/8/2010
Page 1 of 2

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH30				
Keno City, YT		7087032N; 483969E; Zone 8		ELEVATION: 907.25m				
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE								
BACKFILL TYPE ☒ BENTONITE ☐ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	PLASTIC M.C. LIQUID 20 40 60 80	STANDARD PENETRATION (N)	Elevation (m)
							20 40 60 80	
15								892.0
16								891.0
17								890.0
18	- contains some silt for 0.3 m							889.0
19								888.0
20								887.0
21								886.0
22	GRAVEL - some sand, some silt, frozen (Nbn), grey							885.0
23	- becomes Vx		SA27		10.4			884.0
24	- becomes damp		SA28		6.9			883.0
25	- sand seem 0.2 m thick							882.0
26	ROCK - easy drilling, dry, shiny black/grey							881.0
27	BEDROCK - hard drilling, grey							880.0
28								879.0
29								878.0
30	END OF BOREHOLE @ 26.0 m (Target Depth)							

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.						
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH31						
Keno City, YT		7078058N; 484016E; Zone 8		ELEVATION: 907.8m						
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND										
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	PLASTIC M.C. LIQUID 20 40 60 80	STANDARD PENETRATION (N) 20 40 60 80	UNCONFINED (kPa) 50 100 150 200	POCKET PEN. (kPa) 100 200 300 400	Elevation (m)
0	PEAT - frozen, black/dark brown									907.0
1		☒	SA29		666.2					
2	SILT - trace gravel, frozen (Vx), brown	☒	SA30	50	130.1					906.0
3	- organics (wood) for 1.5 m	☒	SA31	45	177.6					905.0
4										904.0
5	SILT (TILL) - gravelly, trace sand, frozen (Vx), grey	☒	SA32		10.4					903.0
		☒	SA33		15.8					
6		☒	SA34	72	14.5					902.0
7	- becomes some gravel									901.0
8	SAND and GRAVEL - trace silt, well graded, medium grained, sub-angular, frozen (Vx), multi-coloured	☒	SA35		8.8					900.0
	SILT (TILL) - some gravel, frozen, grey									899.0
9										898.0
10										897.0
11	MASSIVE ICE - trace silt									896.0
12										895.0
13										894.0
14	SAND and GRAVEL - some silt, frozen (Vx), grey									893.0
15										



Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH31				
Keno City, YT		7078058N; 484016E; Zone 8		ELEVATION: 907.8m				
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	STANDARD PENETRATION (N)		Elevation (m)
						20 40 60 80	50 100 150 200	
					PLASTIC M.C. LIQUID 20 40 60 80		▲ POCKET PEN. (kPa) ▲ 100 200 300 400	
15	MASSIVE ICE - trace silt							
16								892.0
17								891.0
18			SA36		977.9		978	890.0
19								889.0
20								888.0
21	SILT (TILL) - some gravel, frozen (Vx), grey		SA37		10.3			887.0
22								886.0
23	ROCK - fractured, angular, damp, multi-coloured							885.0
24	BEDROCK - hard drilling, grey							884.0
25	END OF BOREHOLE @ 24.4 m (Target Depth)							883.0
26								882.0
27								881.0
28								880.0
29								879.0
30								878.0



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COMPLETION DEPTH: 24.4m
COMPLETE: 9/10/2010
Page 2 of 2

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.	
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH32	
Keno City, YT		7086999N; 484077E; Zone 8		ELEVATION: 923.75m	
SAMPLE TYPE		☒ DISTURBED	☐ NO RECOVERY	☒ SPT	☐ A-CASING
BACKFILL TYPE		☐ BENTONITE	☐ PEA GRAVEL	☐ SLOUGH	☐ GROUT
		☐ DRILL CUTTINGS	☐ SAND	☐ CORE	

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	MOISTURE CONTENT	STANDARD PENETRATION (N)		Elevation (m)
					UNCONFINED (kPa)	POCKET PEN. (kPa)	
					20 40 60 80	50 100 150 200	
0	SAND and GRAVEL (FILL) - some silt, medium grained, well graded, sub-round, damp, loose, brown						923.0
1	PEAT - frozen, black/dark brown						922.0
2	SILT - some sand, frozen (Vx), grey						921.0
3		SA38	109		109		920.0
4							919.0
5	- hard drilling for 0.3 m - attempted SPT - spoon refusal	SA39 SA40	12.8				918.0
6	- gravel content increases	SA41	8.6				917.0
7	BEDROCK - hard drilling, grey	SA42	7.8				916.0
8							915.0
9		SA43	1.2				914.0
10	END OF BOREHOLE @ 9.0 m (Target Depth)						



EBA Engineering Consultants Ltd.

LOGGED BY: JTP
REVIEWED BY: JRT
DRAWING NO:

COMPLETION DEPTH: 9m
COMPLETE: 9/10/2010
Page 1 of 1

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.					
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH33					
Keno City, YT		7086956N; 484029E; Zone 8		ELEVATION: 920.5m					
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND									
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT			Elevation (m)		
								STANDARD PENETRATION (N)	
					PLASTIC	M.C.		LIQUID	UNCONFINED (kPa)
					20 40 60 80	50 100 150 200	100 200 300 400		
0	SAND and GRAVEL (FILL) - some silt, medium grained, well graded, sub-round, damp, loose, brown PEAT - frozen, dark brown								
1									
2	SILT (TILL) - gravelly, frozen (Vx), grey - becomes trace gravel	SA44	73	18.5					
3		SA45	71	41.3					
4									
5	- becomes some gravel with visible staining - becomes damp	SA46		13.8					
6	SAND and GRAVEL - silty, fine grained, dense, dry, tan	SA47		12.2					
7	BEDROCK - hard drilling, grey	SA48 SA49		1.9					
8	END OF BOREHOLE @ 7.5 m (Target Depth)								
9									
10									



EBA Engineering Consultants Ltd.

LOGGED BY: JTP
REVIEWED BY: JRT
DRAWING NO:

COMPLETION DEPTH: 7.5m
COMPLETE: 9/10/2010
Page 1 of 1

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.			
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH34			
Keno City, YT		7086915N; 484024E; Zone 8		ELEVATION: 922m			
SAMPLE TYPE ☒ DISTURBED ☒ NO RECOVERY ☒ SPT ☒ A-CASING ☒ SHELBY TUBE ☒ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☒ SLOUGH ☒ GROUT ☒ DRILL CUTTINGS ☒ SAND							
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	MOISTURE CONTENT	STANDARD PENETRATION (N)		Elevation (m)
					UNCONFINED (kPa)	POCKET PEN. (kPa)	
					PLASTIC M.C. LIQUID		
					20 40 60 80	20 40 60 80	
0	SAND and GRAVEL (FILL) - trace silt, medium grained, well graded, sub-rounded, damp, loose, brown PEAT - frozen, dark brown						922.0
1	SILT (TILL) - gravelly, frozen (Vx), grey - attempted SPT - spoon refusal	☒	SA50	16.4			921.0
2	BEDROCK - hard drilling, light grey	☒	SA51	4.1			920.0
3	END OF BOREHOLE @ 3.0 m (Target Depth)						919.0
4							918.0
5							917.0
6							916.0
7							915.0
8							914.0
9							913.0
10							912.0



EBA Engineering Consultants Ltd.

LOGGED BY: JTP
REVIEWED BY: JRT
DRAWING NO:

COMPLETION DEPTH: 3m
COMPLETE: 9/11/2010
Page 1 of 1

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH35				
Keno City, YT		7086941N; 483996E; Zone 8		ELEVATION: 914.25m				
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE BACKFILL TYPE ☒ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☐ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	PLASTIC M.C. LIQUID 20 40 60 80	STANDARD PENETRATION (N) 20 40 60 80 ◆ UNCONFINED (kPa) ◆ 50 100 150 200 ▲ POCKET PEN. (kPa) ▲ 100 200 300 400	Elevation (m)
0	SAND and GRAVEL (FILL) - trace silt, medium grained, well graded, sub-rounded, damp, loose, brown							914.0
1	PEAT - frozen, dark brown							913.0
2		☒	SA52	30	199.6		200	912.0
2	SILT (TILL) - some gravel, frozen (Vx), grey							912.0
3		☒	SA53		37.5			911.0
4								910.0
5		☒	SA54	78	52.4			909.0
6	- becomes gravelly	☒	SA55					908.0
7		☒	SA56		13.4			907.0
7	- becomes some gravel							907.0
8								906.0
9	- becomes trace							905.0
10								904.0
11	- becomes SILT and GRAVEL							903.0
12	MASSIVE ICE - trace silt							902.0
13	SILT and GRAVEL (TILL) - frozen (Vx), grey	☒	SA57		9.3			901.0
14								900.0
15	MASSIVE ICE - some gravel							900.0



EBA Engineering Consultants Ltd.

LOGGED BY: JTP
REVIEWED BY: JRT
DRAWING NO:

COMPLETION DEPTH: 26m
COMPLETE: 9/11/2010
Page 1 of 2

Detailed DSTF Drilling		CLIENT: Alexco Resource Corporation		PROJECT NO. - BOREHOLE NO.				
Keno Hill District Mill Site		DRILL: M5 Air Rotary		W14101178.011-BH35				
Keno City, YT		7086941N; 483996E; Zone 8		ELEVATION: 914.25m				
SAMPLE TYPE ☒ DISTURBED ☐ NO RECOVERY ☒ SPT ☐ A-CASING ☐ SHELBY TUBE ☐ CORE								
BACKFILL TYPE ☐ BENTONITE ☒ PEA GRAVEL ☐ SLOUGH ☐ GROUT ☐ DRILL CUTTINGS ☒ SAND								
Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	SPT (N)	MOISTURE CONTENT	STANDARD PENETRATION (N)		Elevation (m)
						20 40 60 80	100 150 200	
						PLASTIC M.C. LIQUID	50 100 150 200	
						20 40 60 80	100 200 300 400	
15	- becomes trace silt							899.0
16								898.0
17	GRAVEL seem - frozen (Vx), hard drilling							897.0
18								896.0
19								895.0
20	SILT and GRAVEL (TILL) - frozen (Vx), grey		SA58		15.2			894.0
21	- hard drilling for 1.0 m, possible rock							893.0
22								892.0
23	SAND - some silt, trace gravel, fine grained, compact (est.), dry, dark tan							891.0
24	BEDROCK - hard drilling - soft black rock seem, 0.3 m		SA59		4.5			890.0
25								889.0
26	END OF BOREHOLE @ 26.0 m (Target Depth)							888.0
27								887.0
28								886.0
29								885.0
30								



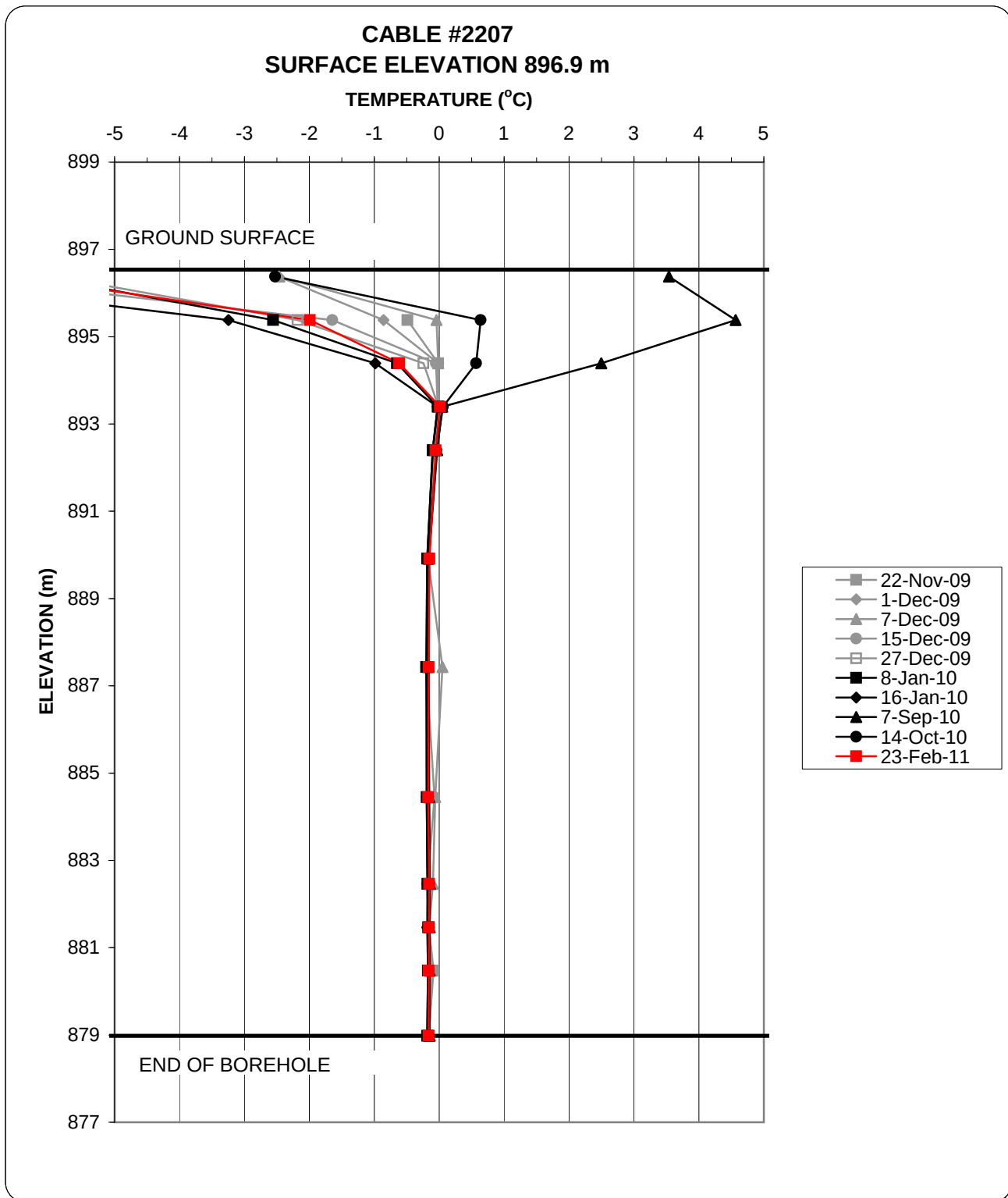
EBA Engineering Consultants Ltd.

LOGGED BY: JTP
 REVIEWED BY: JRT
 DRAWING NO:

COMPLETION DEPTH: 26m
 COMPLETE: 9/11/2010
 Page 2 of 2

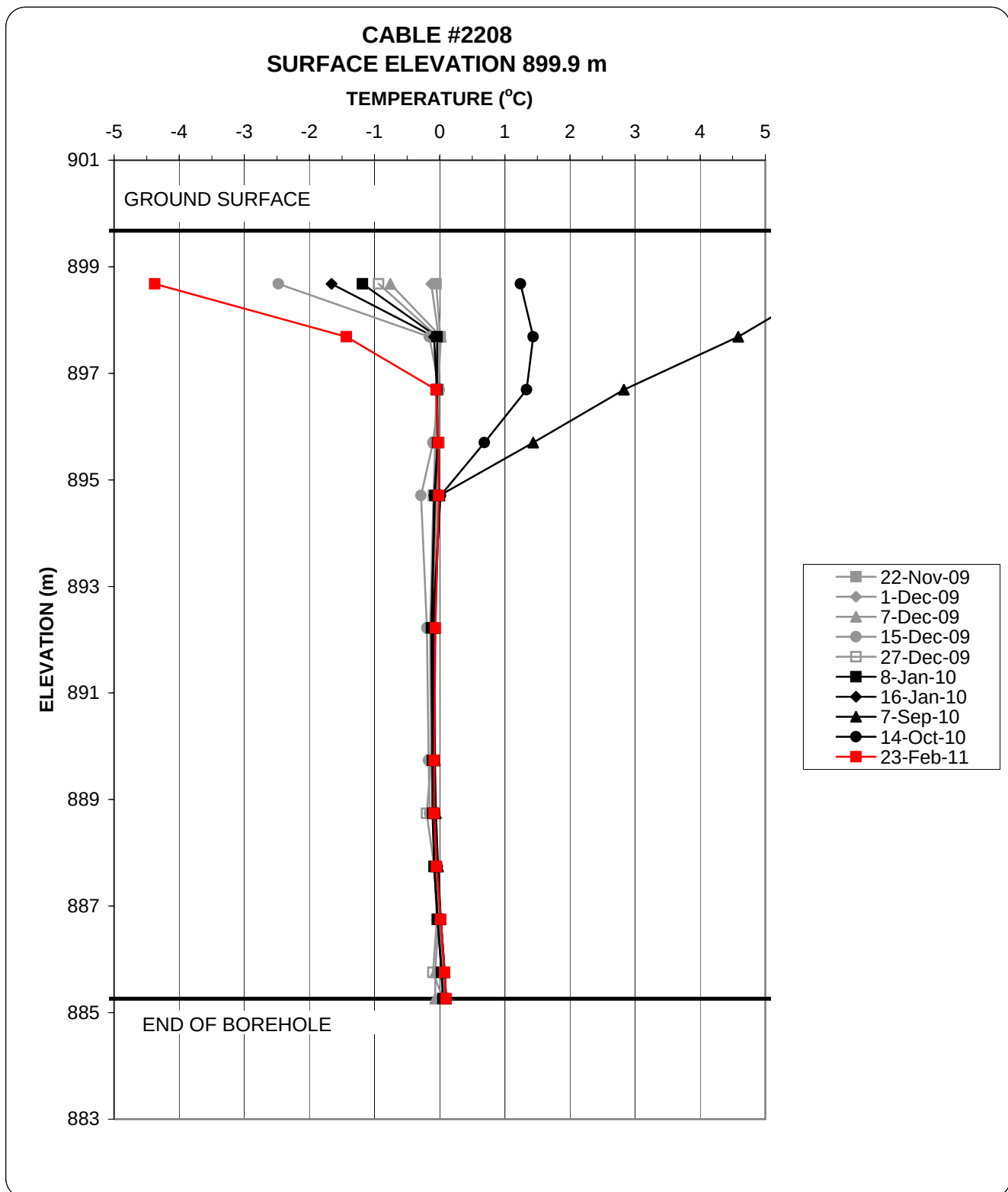
APPENDIX C

APPENDIX C GROUND TEMPERATURE PROFILES



Drilled August 30, 2009

Ground Temperature Profile
Mill Site
Borehole #15 - Flame and Moth

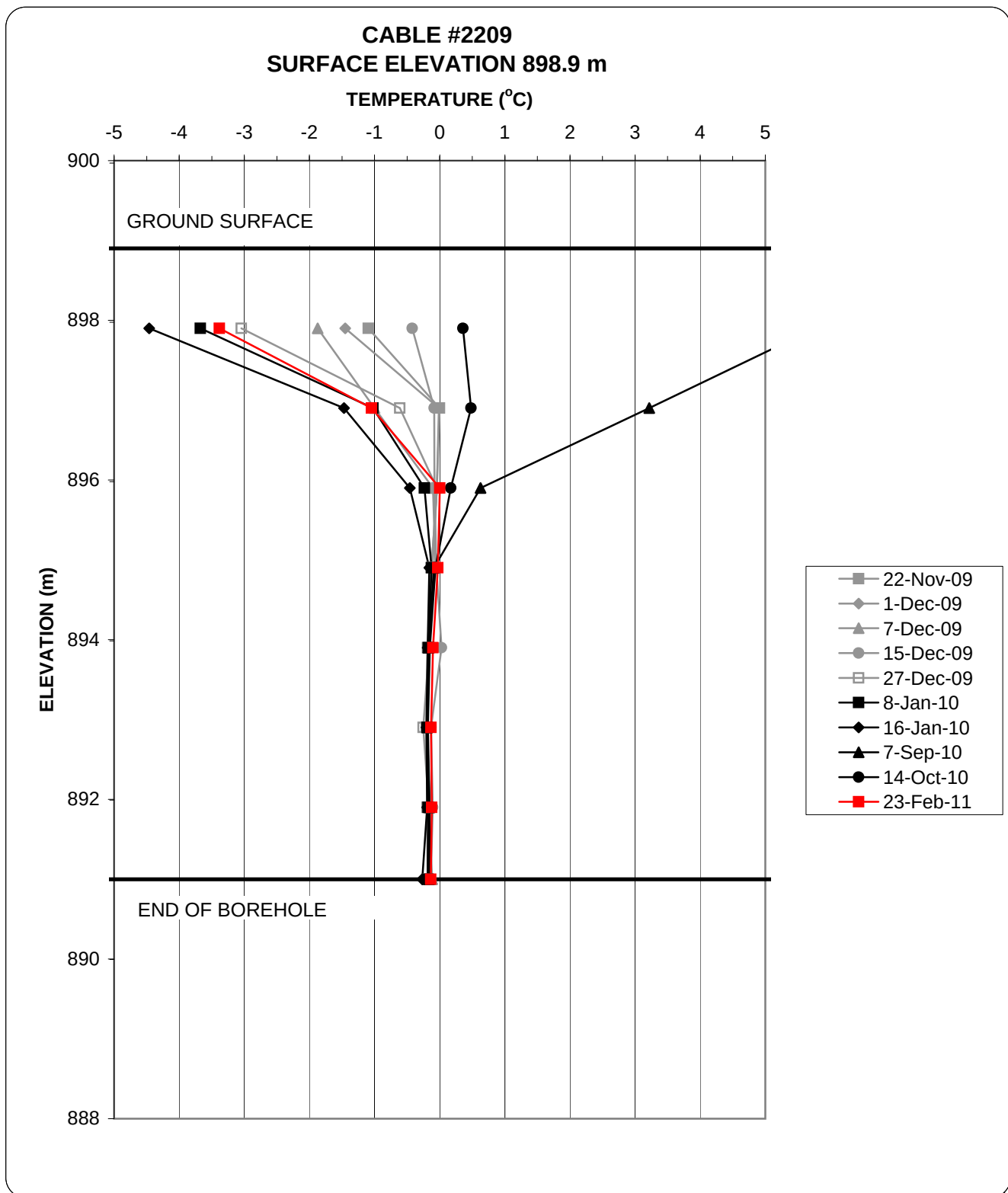


Drilled August 30, 2009

Ground Temperature Profile

Mill Site

Borehole #17 - Flame and Moth

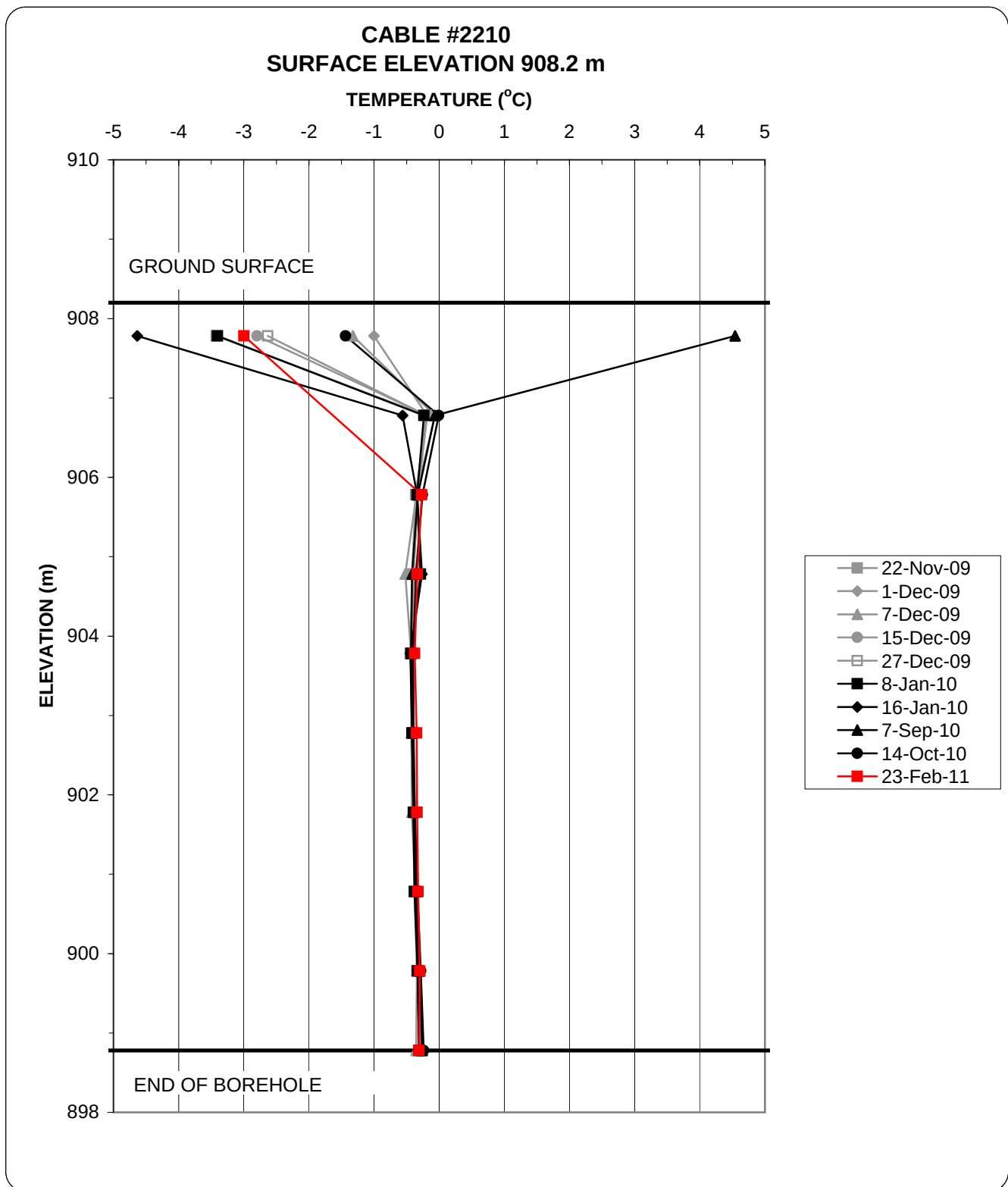


Drilled September 2, 2009

Ground Temperature Profile

Mill Site

Borehole #18 - Flame and Moth

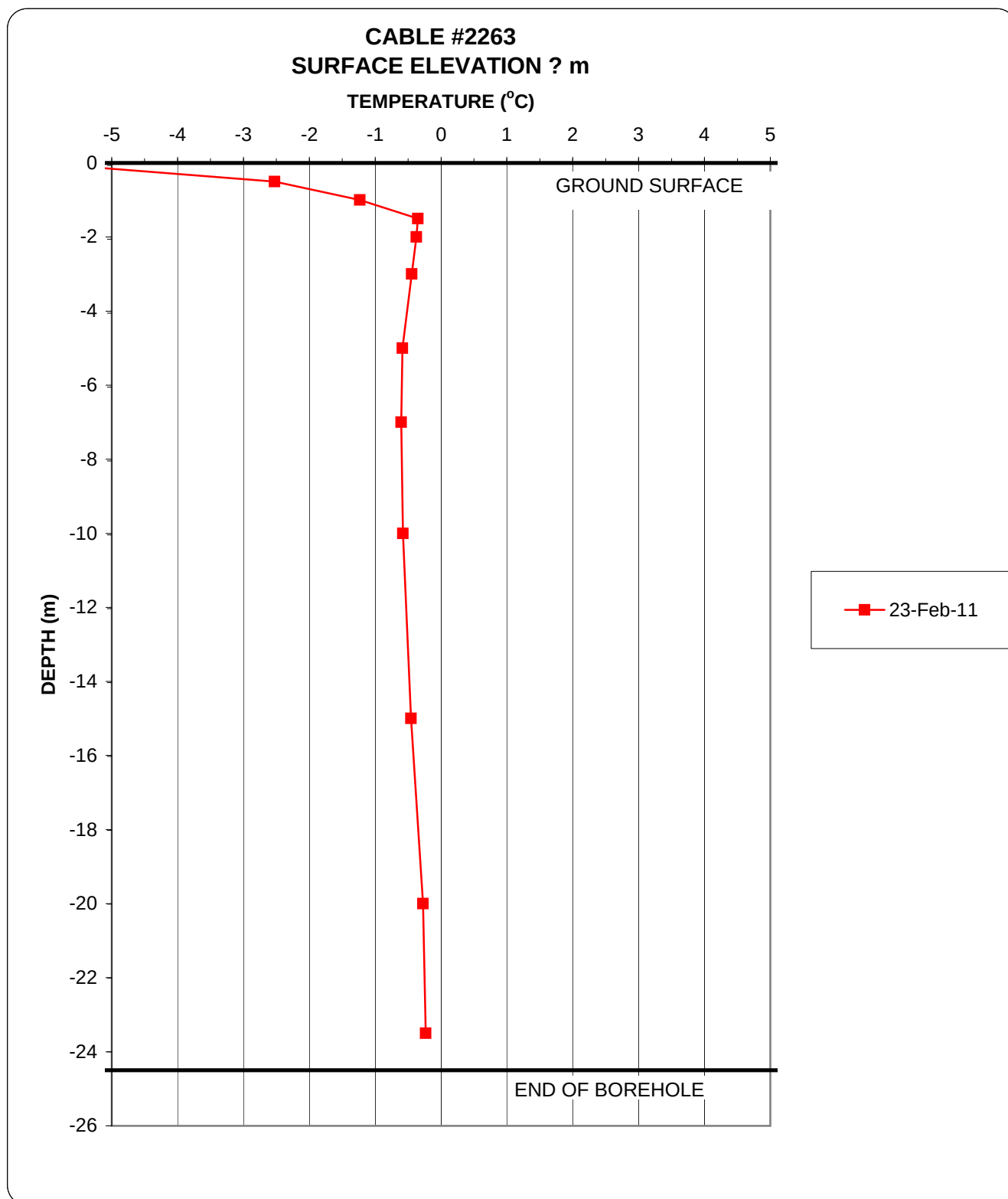


Drilled August 29, 2009

Ground Temperature Profile

Mill Site

Borehole #23 - Flame and Moth

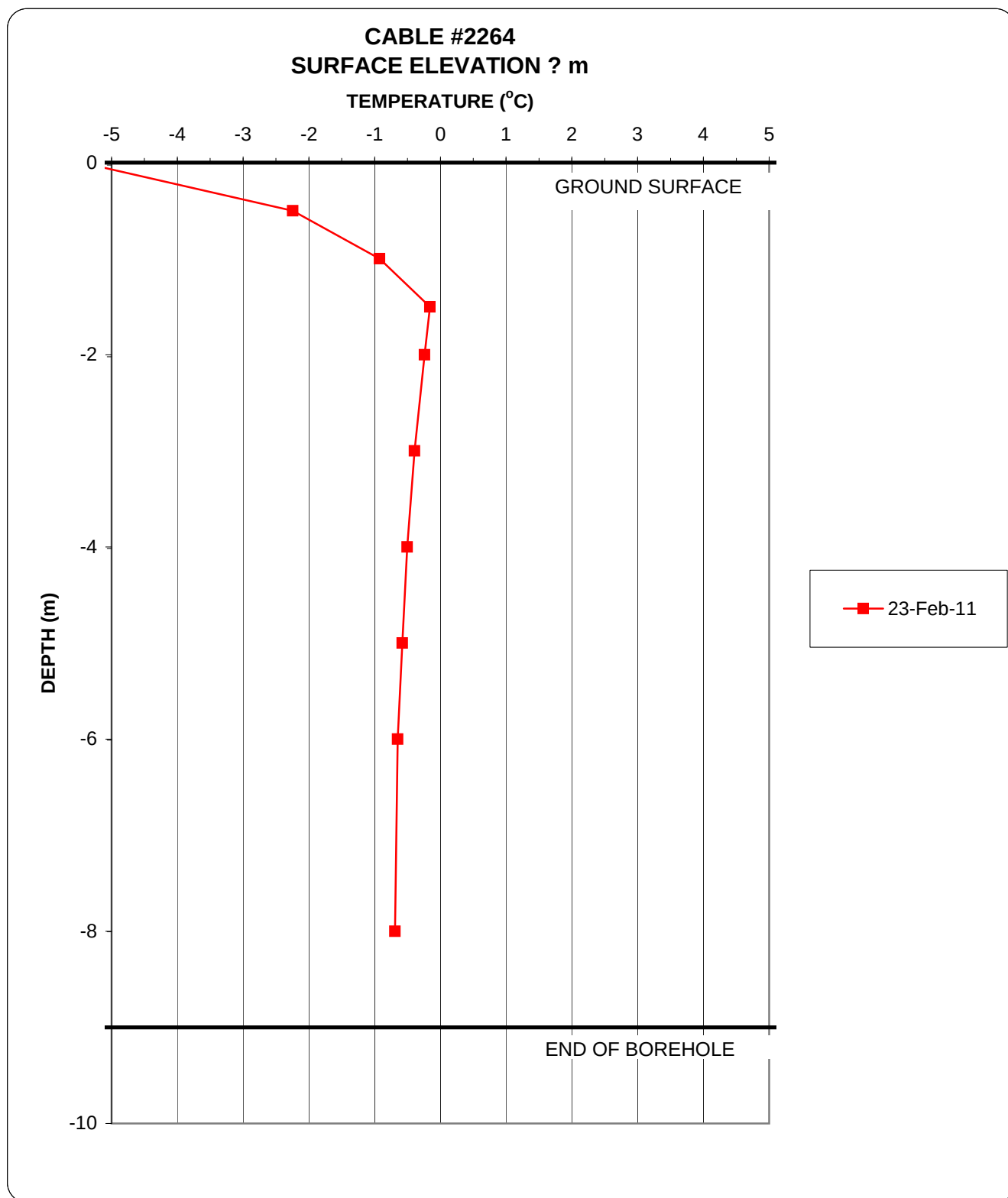


Drilled September 10, 2010

Ground Temperature Profile

DSTF

Borehole #31 - DSTF



Drilled September 10, 2010

Ground Temperature Profile

DSTF

Borehole #32 - DSTF

APPENDIX D

APPENDIX D LABORATORY TEST RESULTS - TAILINGS

MOISTURE-DENSITY RELATIONSHIP (Proctor) REPORT

ASTM D698 (Standard Proctor)

Project: Keno Hill District Mill - DSTF

Sample No.: combined tailings

Project No.: W14101178.011

Sampled By: Alexco

Client: Alexco Resource Corp.

Date Received: 3-Feb-11

Attention: Scott Davidson

Test Date: 4-Feb-11

E-mail:

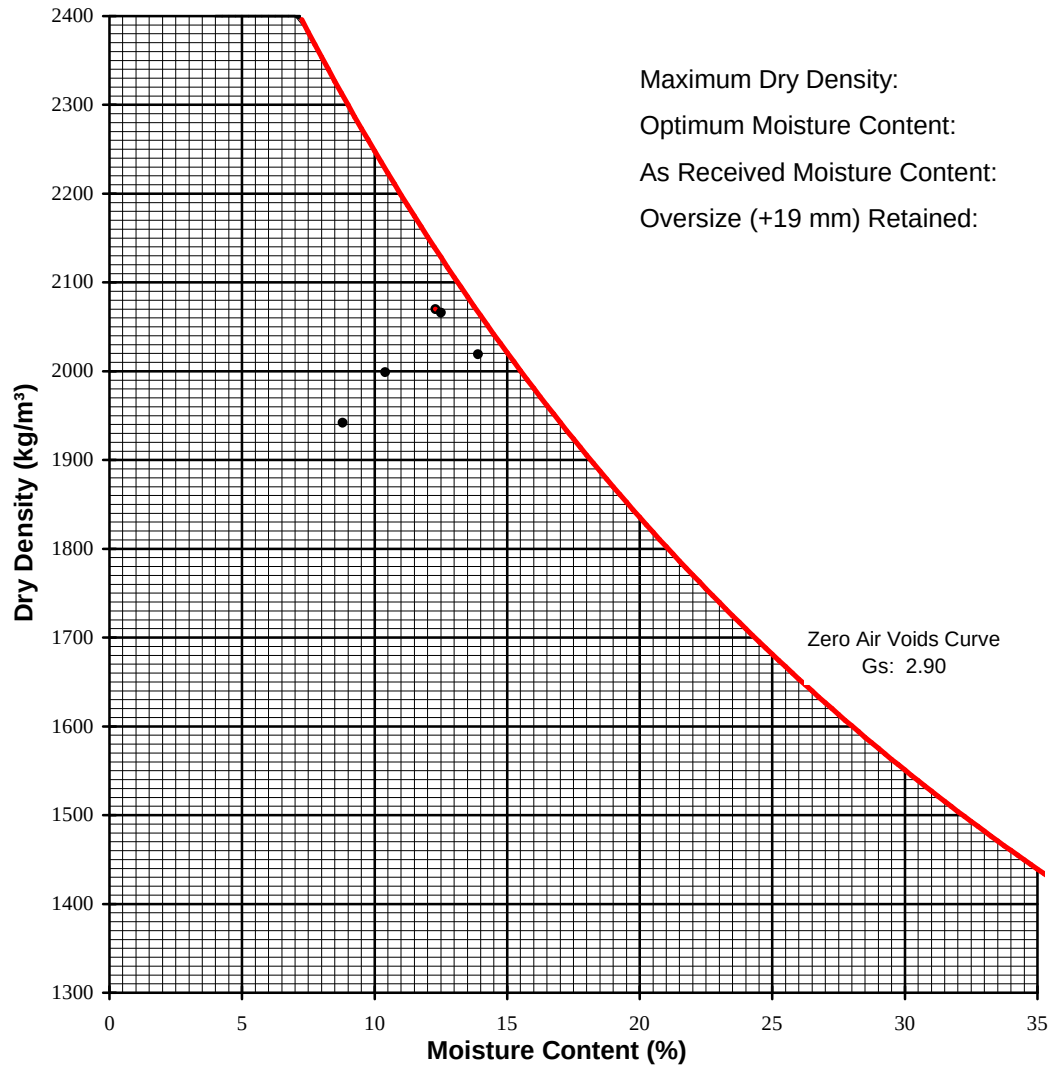
Test Method: Method A

Source: Combined Tailings

Compaction: Manual

Sample Location: Tailings Stockpile

Sample Description: SAND, silty, trace clay - grey



Maximum Dry Density: **2070** kg/m³

Optimum Moisture Content: **12.3** %

As Received Moisture Content: 3.0 %

Oversize (+19 mm) Retained: 0.0 %

Remarks: _____

Reviewed By: _____

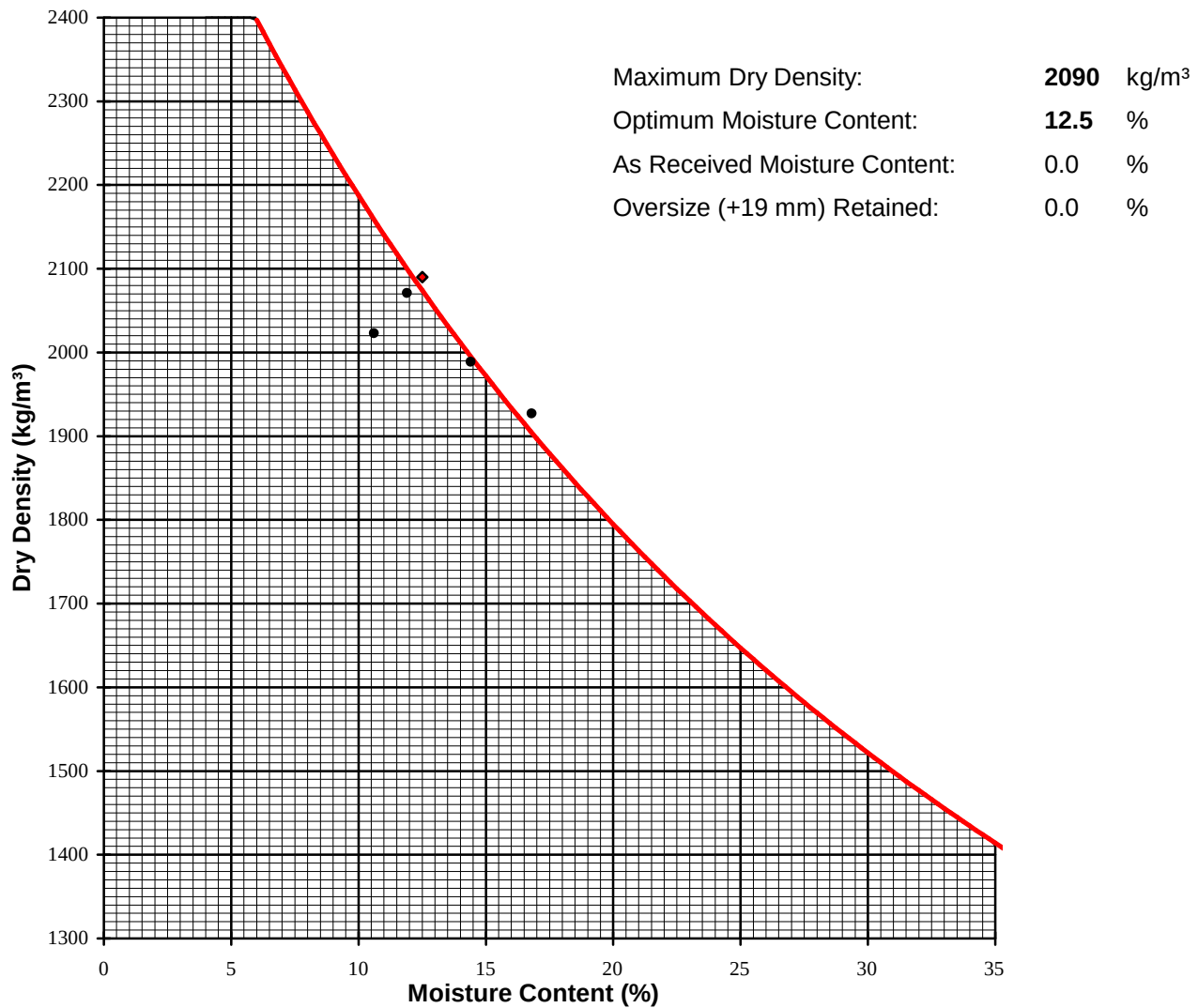
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MOISTURE-DENSITY RELATIONSHIP (Proctor) REPORT

ASTM D698 (Standard Proctor)

Project: Keno Hill District Mill - DSTF
Project No.: W14101178.011
Client: Alexco Resource Corp
Attention:
E-mail:
Source: Tailings
Sample Location: Tailings Stockpile
Sample Description: SILT and SAND - trace clay

Sample No.: composite
Sampled By: Alexco
Date Received: 21-Jan-11
Test Date: 25-Jan-11
Test Method: Method A
Compaction: Manual



Remarks: _____

Reviewed By: _____

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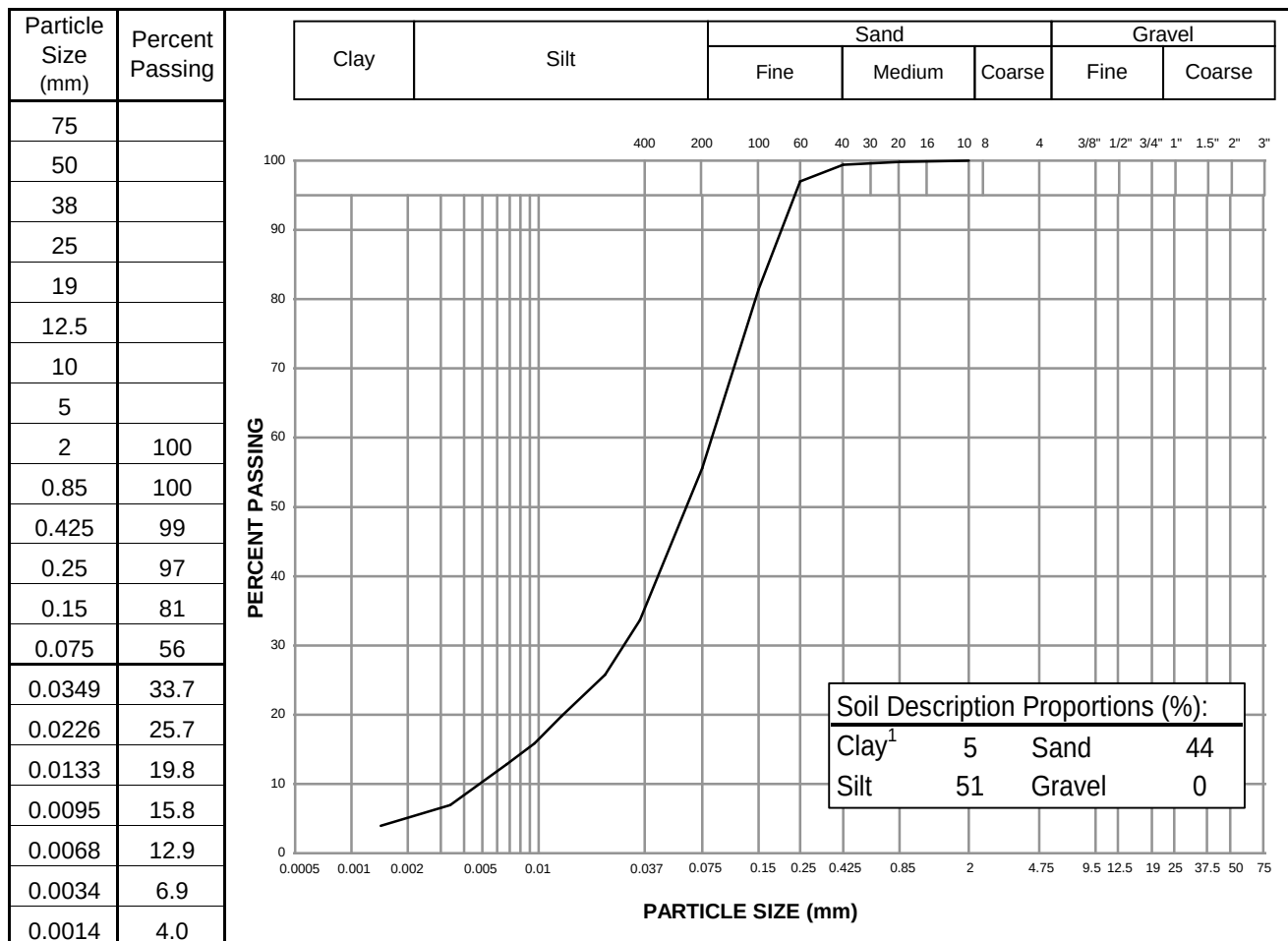
PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422, C136 & C117

Project: Keno Hill District Mill - DSTF
 Project No.: W14101178.011
 Site: Keno City, YT
 Client: Alexco Resource Corp
 Client Rep.:
 Date Tested: January 24, 2011 By: SMS
 Soil Description²: SILT and SAND - trace clay

Sample No.: SA01
 Material Type: Tailings
 Sample Loc.:
 Sample Depth:
 Sampling Method: Grab
 Date sampled: January, 2011
 Sampled By: Alexco
 USC Classification: Cu: 17.1
 Cc: 1.9

Moisture Content: 18.7%



Notes: ¹ The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

² The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____

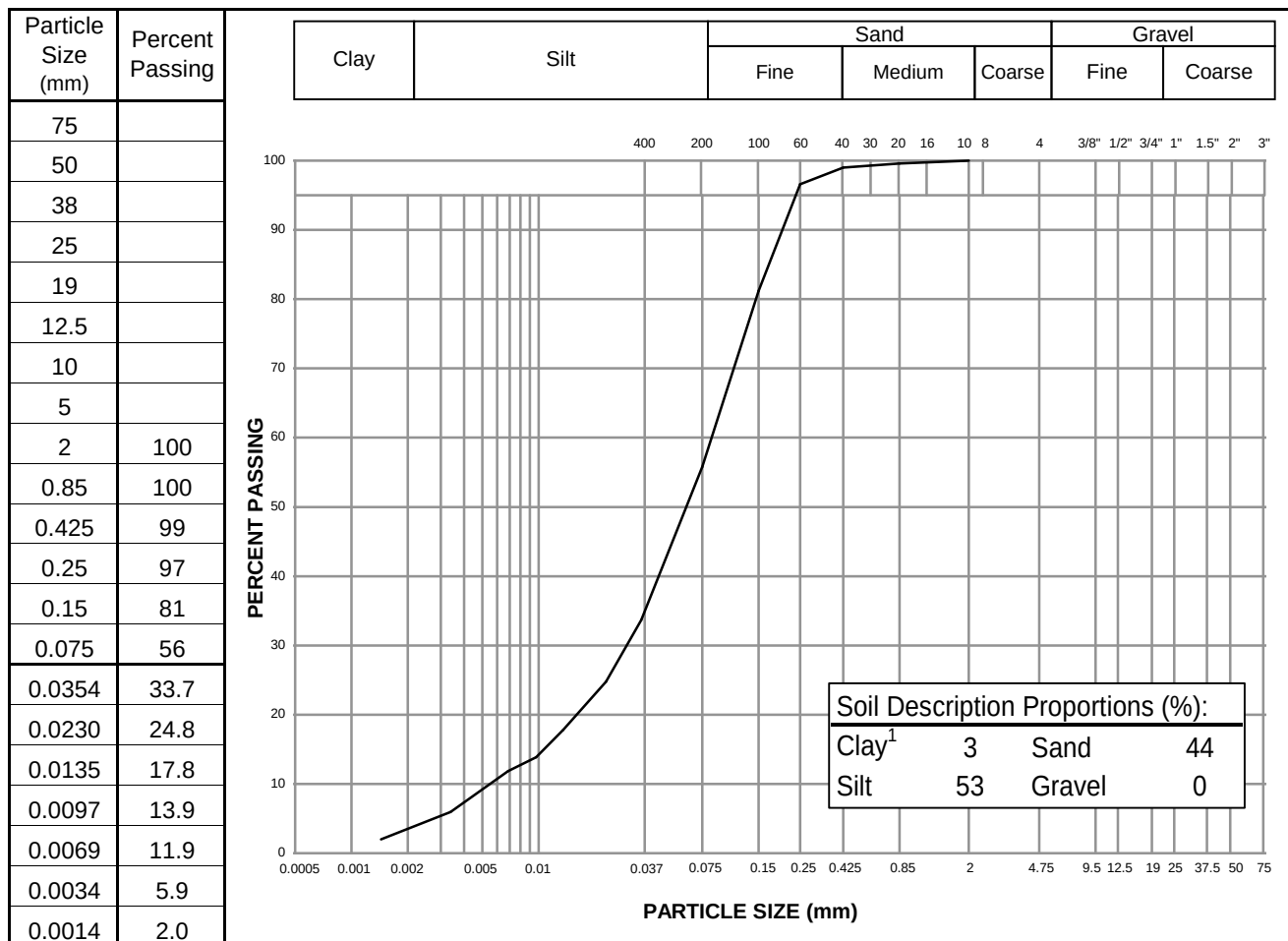
PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422, C136 & C117

Project: Keno Hill District Mill - DSTF
 Project No.: W14101178.011
 Site: Keno City, YT
 Client: Alexco Resource Corp
 Client Rep.:
 Date Tested: January 24, 2011 By: SMS
 Soil Description²: SILT and SAND - trace clay

Sample No.: SA02
 Material Type: Tailings
 Sample Loc.:
 Sample Depth:
 Sampling Method: Grab
 Date sampled: January, 2011
 Sampled By: Alexco
 USC Classification: Cu: 15.2
 Cc: 1.8

Moisture Content: 21.3%



Notes: ¹ The upper clay size of 2 μ m, per the Canadian Foundation Engineering Manual

² The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____

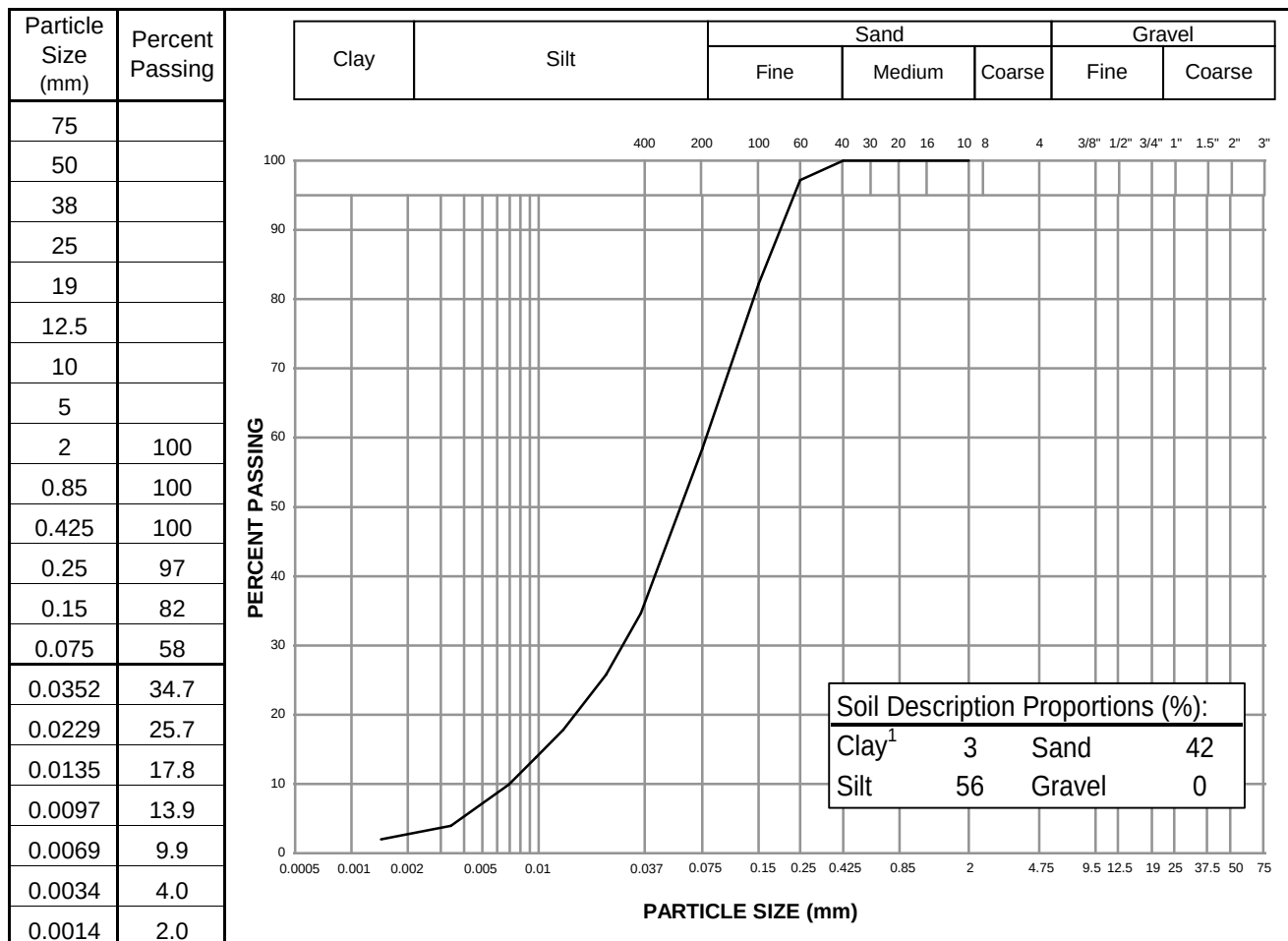
PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422, C136 & C117

Project: Keno Hill District Mill - DSTF
 Project No.: W14101178.011
 Site: Keno City, YT
 Client: Alexco Resource Corp
 Client Rep.:
 Date Tested: January 24, 2011 By: SMS
 Soil Description²: SILT and SAND - trace clay

Sample No.: SA03
 Material Type: Tailings
 Sample Loc.:
 Sample Depth:
 Sampling Method: Grab
 Date sampled: January, 2011
 Sampled By: Alexco
 USC Classification: Cu: 11.5
 Cc: 1.5

Moisture Content: 11.0%



Notes: ¹ The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

² The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____

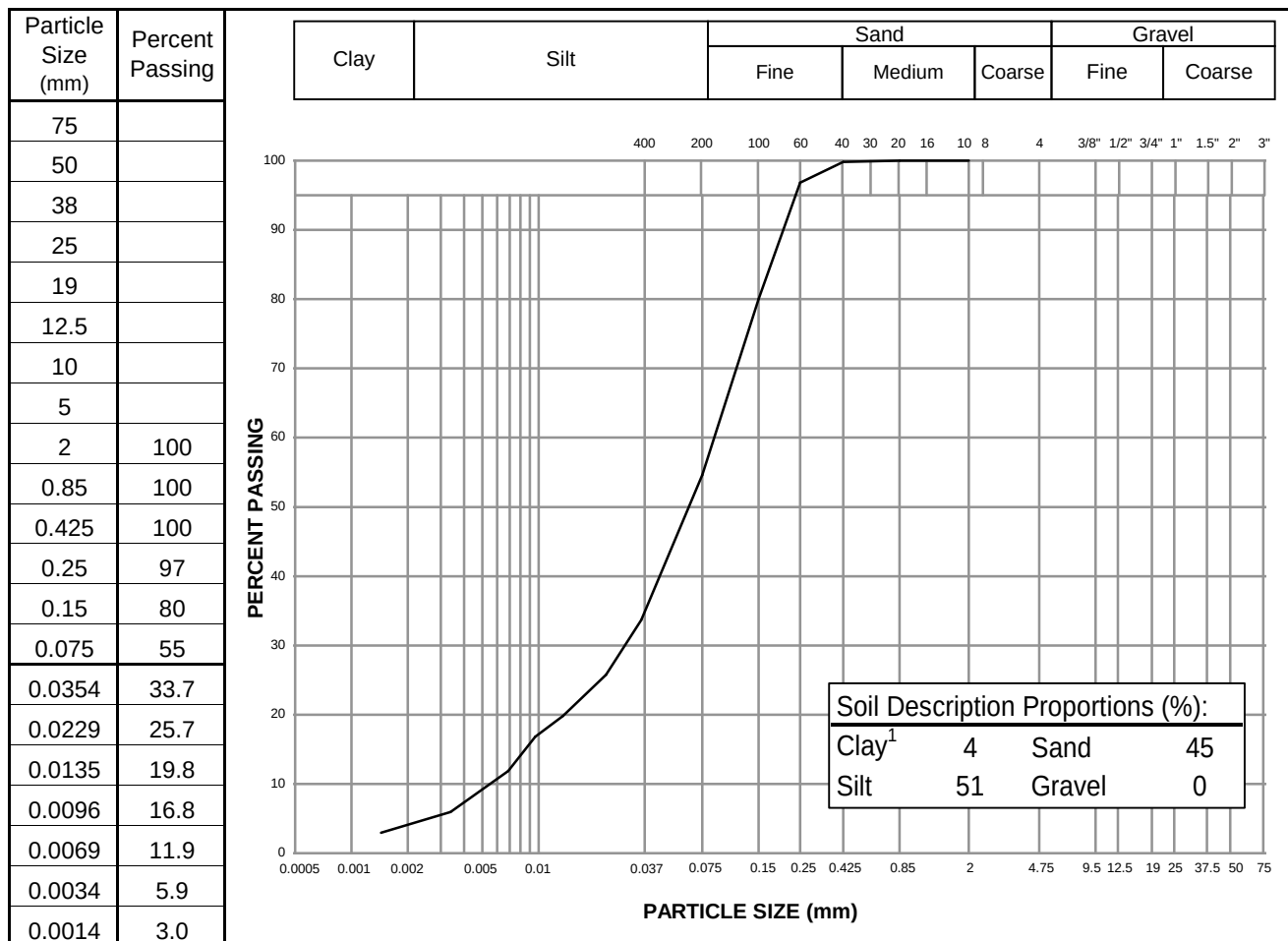
PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422, C136 & C117

Project: Keno Hill District Mill - DSTF
 Project No.: W14101178.011
 Site: Keno City, YT
 Client: Alexco Resource Corp
 Client Rep.:
 Date Tested: January 24, 2011 By: SMS
 Soil Description²: SILT and SAND - trace clay

Sample No.: SA04
 Material Type: Tailings
 Sample Loc.:
 Sample Depth:
 Sampling Method: Grab
 Date sampled: January, 2011
 Sampled By: Alexco
 USC Classification: Cu: 15.8
 Cc: 1.7

Moisture Content: 12.9%



Notes: ¹ The upper clay size of 2 μ m, per the Canadian Foundation Engineering Manual

² The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____

PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422, C136 & C117

Project: Keno Hill District Mill - DSTF

Sample No.: SA05

Project No.: W14101178.011

Material Type: Tailings

Site: Keno City, YT

Sample Loc.:

Client: Alexco Resource Corp

Sample Depth:

Client Rep.:

Sampling Method: Grab

Date Tested: January 24, 2011 By: SMS

Date sampled: January, 2011

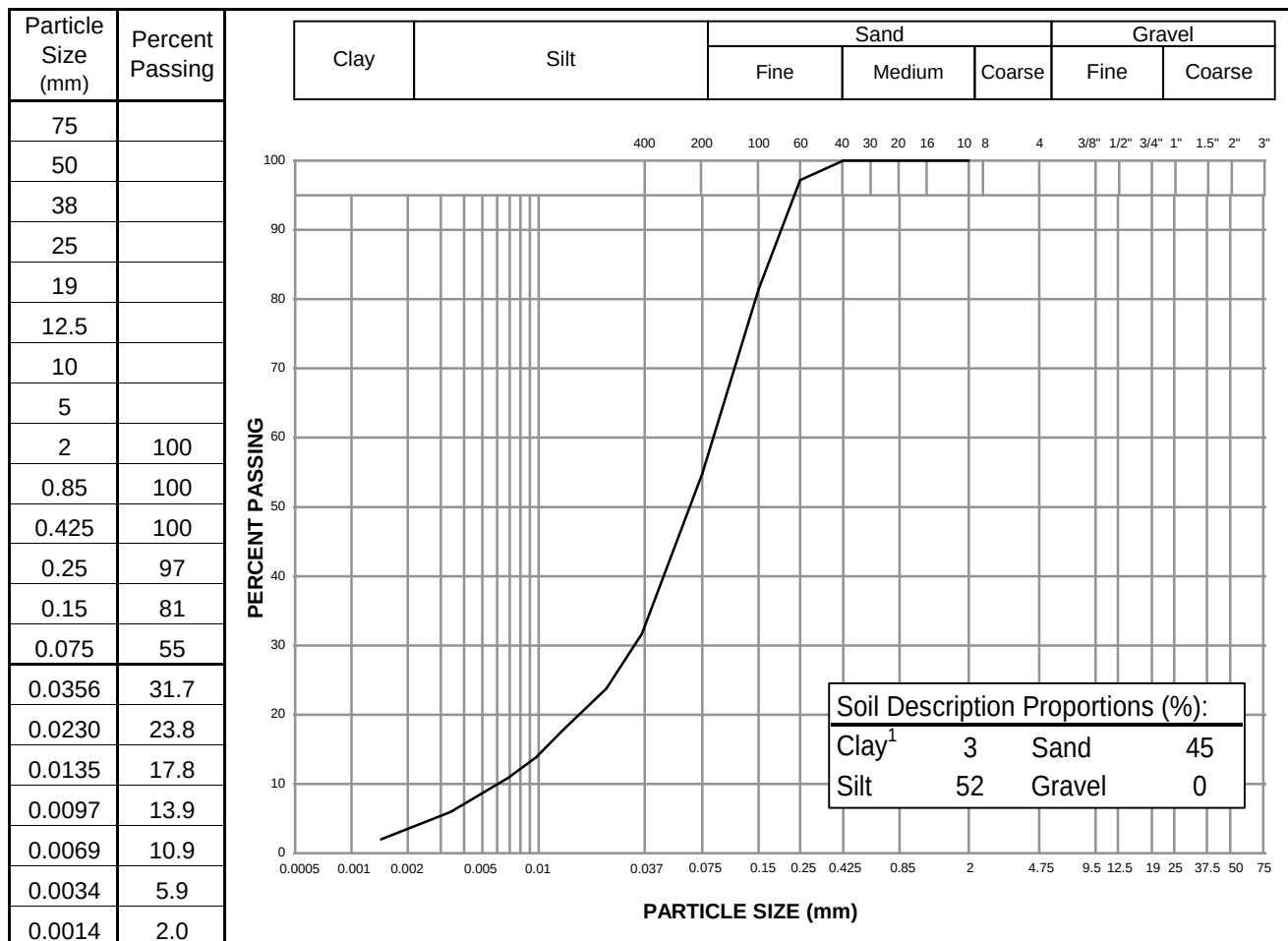
Soil Description²: SILT and SAND - trace clay

Sampled By: Alexco

USC Classification: Cu: 14.3

Moisture Content: 9.4%

Cc: 1.9



Notes: ¹ The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

² The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____

PARTICLE SIZE ANALYSIS TEST REPORT

ASTM D422, C136 & C117

Project: Keno Hill District Mill - DSTF

Sample No.: SA06

Project No.: W14101178.011

Material Type: Tailings

Site: Keno City, YT

Sample Loc.:

Client: Alexco Resource Corp

Sample Depth:

Client Rep.:

Sampling Method: Grab

Date Tested: January 24, 2011 By: SMS

Date sampled: January, 2011

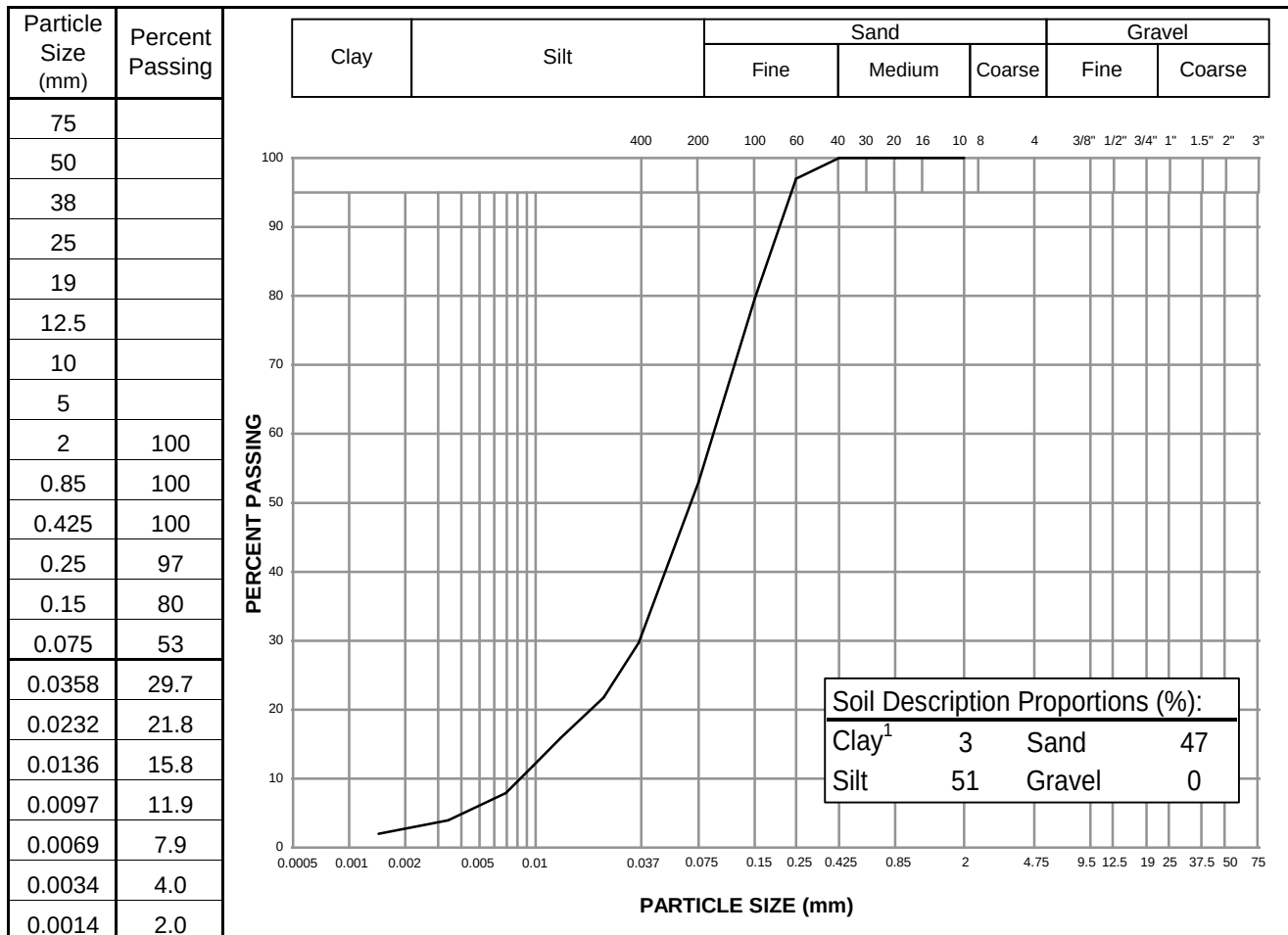
Soil Description²: SILT and SAND - trace clay

Sampled By: Alexco

USC Classification: Cu: 11.3

Cc: 1.7

Moisture Content: 8.6%



Notes: ¹ The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

² The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____

SUMMARY of DIRECT SHEAR TEST RESULTS

ASTM D3080

Project : Keno Hill District Mill - DSTF

Test Hole : Combined Tailings

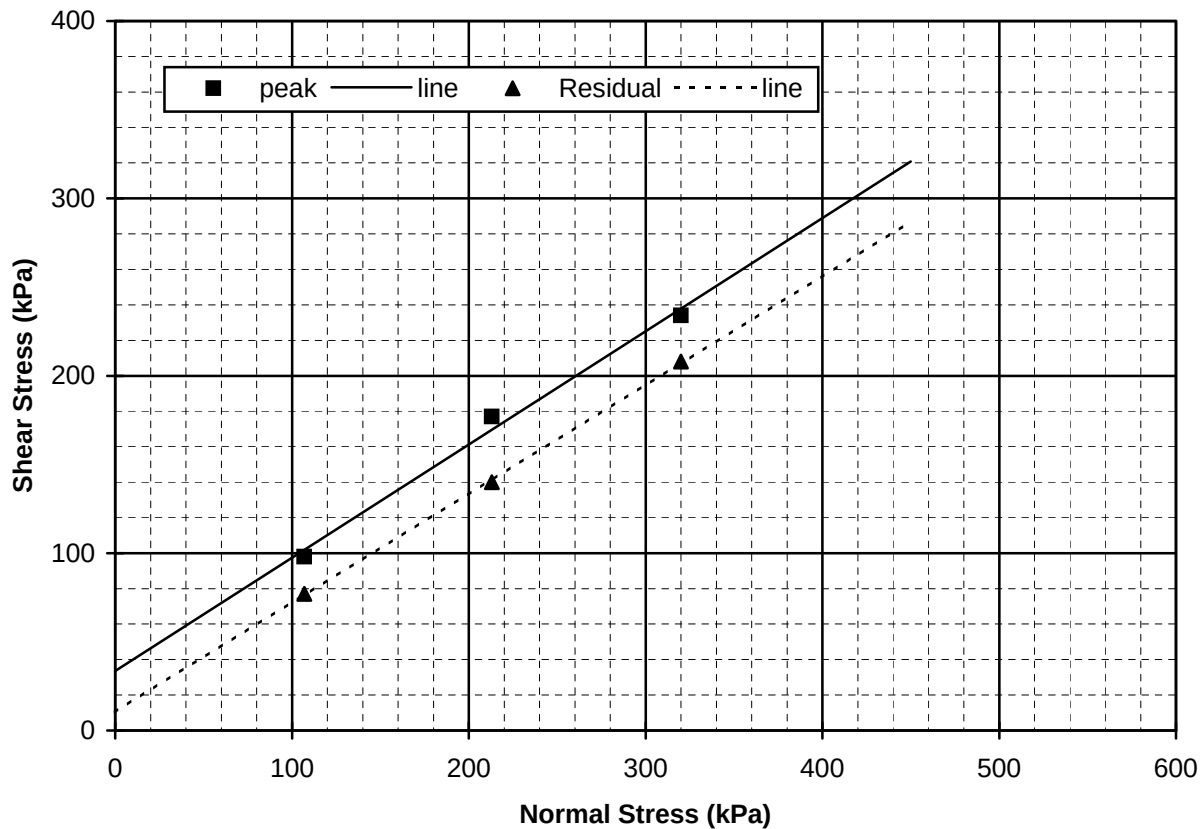
Project No. : W14101178.011

Depth: _____

Client: Alexco Resource Corp

Date : 11-02-10

Tested By: SK



Inferred Shear Strength Parameters :-

	Cohesion Intercept (kPa)	Inferred Angle of Shearing Resistance (Degrees)
Peak Strength:	33.5	32.6
Residual Strength:	10.5	31.6

Reviewed By: _____ P.Eng.

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DIRECT SHEAR TEST

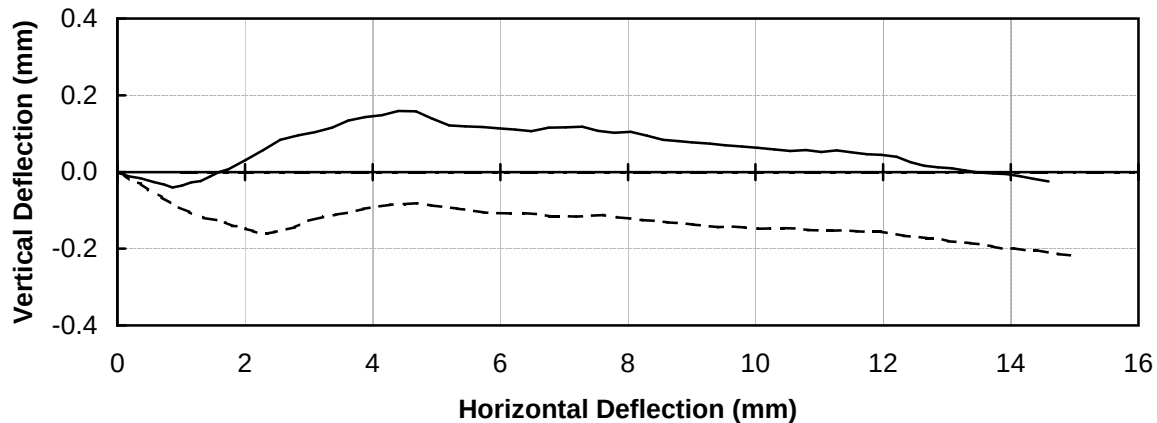
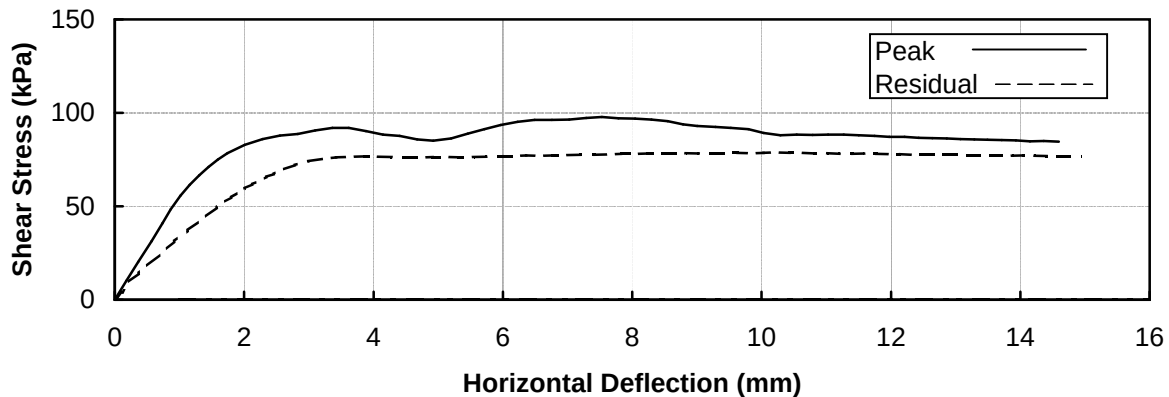
ASTM D3080

Project: Keno Hill District Mill - DSTF
Project No.: W14101178.011
Client: Alexco Resource Corp
Date Tested: 11-02-07
Description: SAND, silty, trace clay

Test Hole No.: Combined Tailings
Depth: _____
Test No.: DS-1
Machine: 1
Preparation: Remolded

Peak Stress (kPa) = 98
Residual Stress (kPa) = 77
Shear Displacement (mm) = 14.6

Normal Stress (kPa) = 107
Displacement Rate (mm/min.) = 0.012



Remarks: _____

Reviewed By: _____ P.Eng.

DIRECT SHEAR TEST

ASTM D3080

Project: Keno Hill District Mill - DSTF

Test Hole No.: Combined Tailings

Project No.: W14101178.011

Depth (m):

Client: Alexco Resource Corp

Test No.: DS-1

Date Tested: 11-02-07

	Initial	Final
Moisture Content (%)	12.8	16.3
Wet Density (Mg/m ³)	2.231	2.301
Dry Density (Mg/m ³)	1.978	1.978

Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.53	0.107	97.7
0.18	-0.011	10.1	7.79	0.102	97.0
0.36	-0.016	20.2	8.04	0.105	97.0
0.57	-0.026	31.4	8.30	0.094	96.4
0.74	-0.033	40.9	8.55	0.084	95.5
0.86	-0.040	48.4	8.79	0.081	93.8
1.01	-0.036	55.6	9.00	0.077	92.9
1.16	-0.027	61.5	9.29	0.073	92.5
1.30	-0.024	66.7	9.52	0.070	91.9
1.45	-0.012	71.0	9.79	0.066	91.2
1.59	0.000	75.1	10.03	0.063	89.2
1.74	0.007	78.3	10.29	0.059	88.0
2.01	0.032	82.9	10.54	0.054	88.3
2.29	0.057	85.9	10.79	0.057	88.2
2.55	0.084	87.9	11.03	0.052	88.4
2.83	0.096	88.8	11.27	0.056	88.3
3.10	0.104	90.6	11.50	0.051	88.0
3.37	0.115	92.0	11.74	0.046	87.7
3.61	0.134	92.0	11.97	0.045	87.1
3.88	0.143	90.3	12.21	0.040	87.2
4.15	0.148	88.4	12.43	0.025	86.7
4.40	0.159	87.7	12.64	0.016	86.5
4.68	0.158	85.8	12.86	0.012	86.2
4.92	0.140	85.1	13.08	0.010	86.0
5.20	0.122	86.2	13.29	0.003	85.9
5.46	0.119	88.8	13.49	-0.002	85.7
5.71	0.117	91.3	13.72	-0.004	85.5
5.97	0.114	93.4	13.93	-0.005	85.3
6.23	0.110	95.2	14.15	-0.011	84.8
6.49	0.106	96.3	14.36	-0.018	84.9
6.76	0.116	96.3	14.59	-0.025	84.6
7.02	0.116	96.5			
7.29	0.118	97.2			

RESIDUAL STRENGTH TEST

ASTM D3080

Project: Keno Hill District Mill - DSTF

Sample No.: Combined Tailings

Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.62	-0.113	77.7
0.11	-0.008	3.9	7.83	-0.118	78.0
0.22	-0.024	9.6	8.04	-0.121	78.1
0.37	-0.030	14.3	8.23	-0.125	78.2
0.48	-0.046	17.6	8.43	-0.127	78.3
0.70	-0.066	24.3	8.62	-0.131	78.3
0.92	-0.089	31.3	8.83	-0.133	78.4
1.13	-0.105	37.1	9.03	-0.137	78.3
1.35	-0.119	43.3	9.22	-0.141	78.4
1.58	-0.127	49.4	9.42	-0.144	78.4
1.69	-0.131	52.3	9.63	-0.142	78.5
1.80	-0.140	54.9	9.83	-0.145	78.4
1.91	-0.141	57.3	10.03	-0.148	78.6
2.01	-0.148	59.6	10.23	-0.148	78.7
2.13	-0.154	61.8	10.43	-0.146	78.7
2.24	-0.161	63.8	10.64	-0.147	78.5
2.35	-0.161	65.8	10.83	-0.152	78.3
2.46	-0.157	67.4	11.02	-0.152	78.3
2.56	-0.153	69.2	11.20	-0.153	78.1
2.78	-0.144	72.1	11.41	-0.152	78.1
2.99	-0.127	74.2	11.59	-0.154	78.2
3.22	-0.118	75.6	11.78	-0.156	78.1
3.43	-0.111	76.2	11.96	-0.155	77.9
3.63	-0.105	76.5	12.14	-0.161	77.9
3.85	-0.096	76.7	12.33	-0.166	77.6
4.07	-0.091	76.6	12.50	-0.169	77.6
4.28	-0.086	76.4	12.68	-0.172	77.5
4.49	-0.084	76.2	12.85	-0.172	77.5
4.71	-0.081	76.2	13.02	-0.180	77.6
4.92	-0.087	76.3	13.19	-0.183	77.4
5.13	-0.091	76.3	13.37	-0.185	77.5
5.32	-0.095	76.2	13.54	-0.189	77.3
5.54	-0.100	76.4	13.71	-0.194	77.3
5.74	-0.105	76.6	13.87	-0.200	77.1
5.95	-0.107	76.9	14.05	-0.199	77.1
6.16	-0.108	76.9	14.22	-0.204	77.0
6.36	-0.107	77.1	14.40	-0.204	76.8
6.57	-0.110	77.1	14.57	-0.210	76.7
6.77	-0.116	77.2	14.75	-0.214	76.7
6.98	-0.116	77.4	14.92	-0.218	76.5
7.19	-0.117	77.5			
7.42	-0.114	77.5			

DIRECT SHEAR TEST

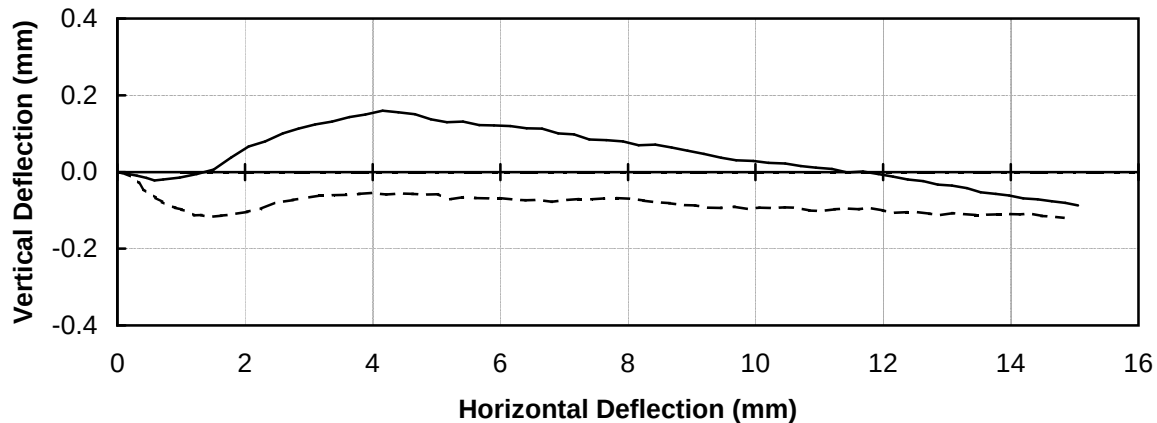
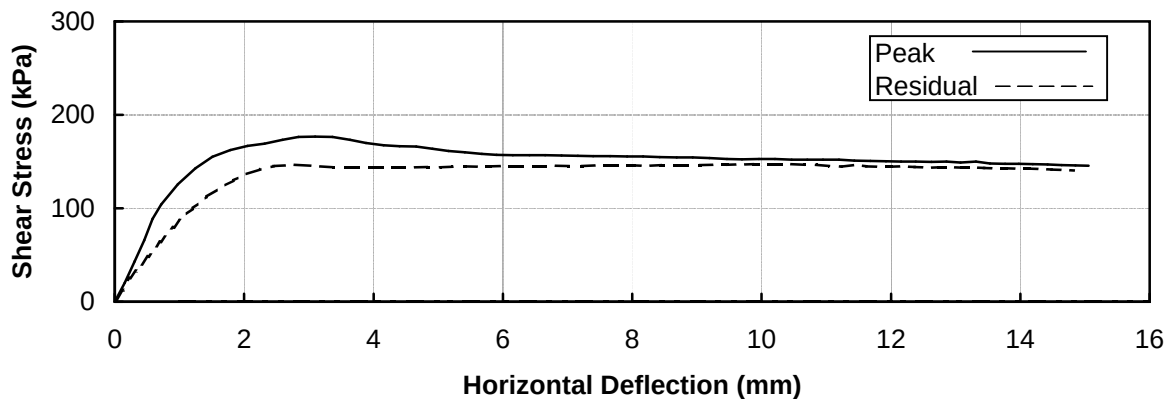
ASTM D3080

Project: Keno Hill District Mill - DSTF
Project No.: W14101178.011
Client: Alexco Resource Corp
Date Tested: 11-02-07
Description: SAND, silty, trace clay

Test Hole No.: Combined Tailings
Depth: _____
Test No.: DS-2
Machine: 2
Preparation: Remolded

Peak Stress (kPa) = 177
Residual Stress (kPa) = 140
Shear Displacement (mm) = 15.1

Normal Stress (kPa) = 213
Displacement Rate (mm/min.) = 0.012



Remarks: _____

Reviewed By: _____ P.Eng.

DIRECT SHEAR TEST

ASTM D3080

Project: Keno Hill District Mill - DSTF

Test Hole No.: Combined Tailings

Project No.: W14101178.011

Depth (m):

Client: Alexco Resource Corp

Test No.: DS-2

Date Tested: 11-02-07

	Initial	Final
Moisture Content (%)	12.7	16.1
Wet Density (Mg/m ³)	2.242	2.309
Dry Density (Mg/m ³)	1.989	1.989

Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.92	0.079	155.6
0.15	-0.005	20.1	8.17	0.069	155.3
0.30	-0.009	43.1	8.43	0.071	154.8
0.46	-0.016	65.8	8.69	0.064	154.6
0.58	-0.022	88.7	8.94	0.055	154.3
0.72	-0.020	104.1	9.19	0.047	153.7
0.98	-0.015	125.6	9.46	0.037	152.9
1.24	-0.005	142.9	9.70	0.031	152.5
1.51	0.007	155.2	9.96	0.029	152.6
1.78	0.038	162.4	10.21	0.024	152.6
2.05	0.067	166.7	10.47	0.022	152.2
2.32	0.079	169.3	10.71	0.015	152.0
2.59	0.101	173.1	10.95	0.011	152.2
2.84	0.113	176.4	11.20	0.008	151.9
3.10	0.124	176.8	11.44	-0.001	151.1
3.36	0.131	176.4	11.68	0.001	150.8
3.63	0.143	173.2	11.92	-0.005	150.2
3.88	0.150	170.0	12.16	-0.012	150.0
4.16	0.160	167.5	12.39	-0.020	150.0
4.40	0.156	166.4	12.63	-0.024	149.8
4.66	0.151	166.0	12.86	-0.033	149.9
4.91	0.137	163.8	13.07	-0.036	149.0
5.16	0.130	161.4	13.31	-0.043	149.8
5.41	0.131	159.8	13.53	-0.053	147.9
5.67	0.122	158.3	13.77	-0.057	147.5
5.90	0.121	157.2	13.97	-0.062	147.5
6.15	0.120	156.7	14.20	-0.069	147.3
6.41	0.114	157.0	14.42	-0.071	146.9
6.65	0.113	156.9	14.64	-0.077	146.4
6.91	0.100	156.6	14.85	-0.081	145.8
7.16	0.098	156.3	15.05	-0.087	145.4
7.40	0.085	155.8			
7.66	0.083	155.7			

RESIDUAL STRENGTH TEST

ASTM D3080

Project: Keno Hill District Mill - DSTF

Sample No.: Combined Tailings

Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.43	-0.072	145.8
0.13	-0.004	12.2	7.63	-0.069	145.8
0.23	-0.014	25.3	7.83	-0.068	146.0
0.33	-0.028	32.7	8.04	-0.070	146.0
0.41	-0.045	40.0	8.25	-0.075	145.7
0.51	-0.057	48.1	8.45	-0.079	146.2
0.60	-0.067	55.8	8.65	-0.081	146.2
0.70	-0.078	64.1	8.85	-0.086	146.2
0.80	-0.088	72.1	9.05	-0.087	146.4
0.91	-0.093	79.6	9.26	-0.093	146.5
1.01	-0.098	87.0	9.47	-0.094	146.6
1.11	-0.104	93.7	9.67	-0.091	146.9
1.20	-0.113	100.1	9.87	-0.096	147.2
1.32	-0.112	106.8	10.07	-0.093	147.4
1.42	-0.118	112.3	10.26	-0.094	147.4
1.63	-0.114	122.0	10.46	-0.092	147.3
1.83	-0.109	129.7	10.66	-0.093	146.6
2.04	-0.104	136.6	10.84	-0.100	146.7
2.25	-0.096	141.8	11.04	-0.102	145.2
2.46	-0.080	145.2	11.24	-0.097	144.6
2.75	-0.073	146.5	11.43	-0.096	146.2
3.17	-0.062	144.7	11.62	-0.097	144.8
3.38	-0.061	143.9	11.81	-0.094	144.6
3.59	-0.060	143.4	12.00	-0.101	144.4
3.80	-0.057	143.4	12.18	-0.106	144.8
4.01	-0.054	143.7	12.37	-0.105	144.2
4.22	-0.058	143.9	12.55	-0.105	143.5
4.42	-0.056	143.8	12.72	-0.109	143.7
4.63	-0.057	144.0	12.90	-0.112	143.7
4.83	-0.059	144.1	13.09	-0.108	143.6
5.03	-0.058	144.0	13.26	-0.110	143.5
5.22	-0.071	144.4	13.44	-0.112	143.3
5.42	-0.066	144.8	13.62	-0.111	142.9
5.61	-0.068	144.6	13.79	-0.111	142.8
5.81	-0.069	144.8	13.97	-0.109	142.6
6.00	-0.068	145.0	14.14	-0.111	142.3
6.20	-0.071	145.3	14.32	-0.109	142.0
6.40	-0.074	145.1	14.49	-0.115	141.4
6.60	-0.073	145.3	14.66	-0.116	141.1
6.81	-0.078	145.5	14.83	-0.119	140.3
7.02	-0.074	145.3			
7.23	-0.071	145.3			

DIRECT SHEAR TEST

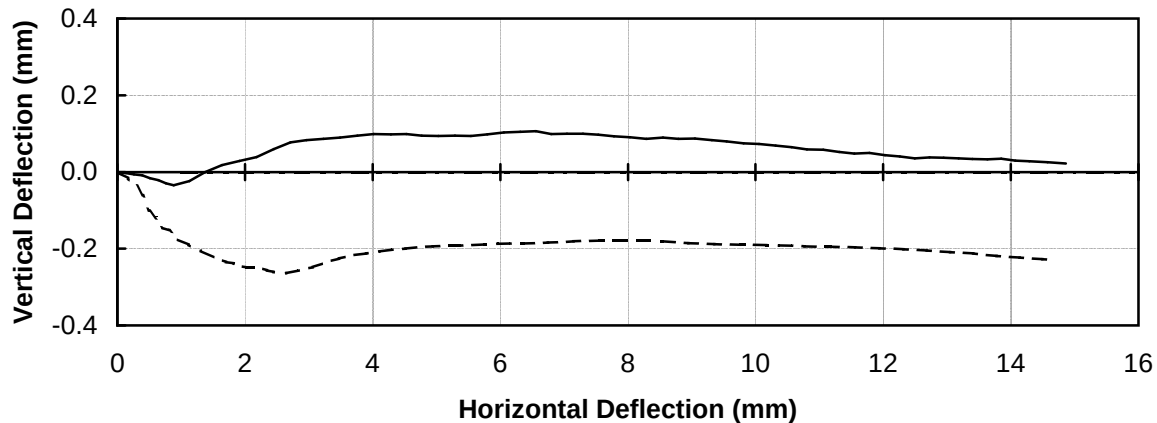
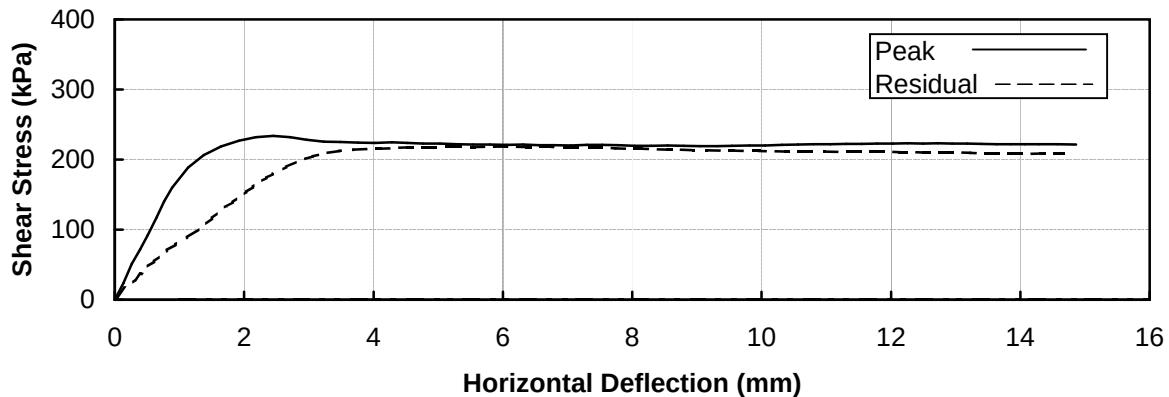
ASTM D3080

Project: Keno Hill District Mill - DSTF
Project No.: W14101178.011
Client: Alexco Resource Corp
Date Tested: 11-02-07
Description: SAND, silty, trace clay

Test Hole No.: Combined Tailings
Depth: _____
Test No.: DS-3
Machine: 3
Preparation: Remolded

Peak Stress (kPa) = 234
Residual Stress (kPa) = 208
Shear Displacement (mm) = 14.9

Normal Stress (kPa) = 320
Displacement Rate (mm/min.) = 0.012



Remarks: _____

Reviewed By: _____ P.Eng.

DIRECT SHEAR TEST

ASTM D3080

Project: Keno Hill District Mill - DSTF

Test Hole No.: Combined Tailings

Project No.: W14101178.011

Depth (m):

Client: Alexco Resource Corp

Test No.: DS-3

Date Tested: 11-02-07

	Initial	Final
Moisture Content (%)	12.7	15.9
Wet Density (Mg/m ³)	2.236	2.300
Dry Density (Mg/m ³)	1.985	1.985

Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.53	0.097	220.9
0.13	-0.003	23.9	7.78	0.093	220.4
0.26	-0.006	51.3	8.03	0.090	219.7
0.39	-0.009	71.9	8.29	0.086	219.8
0.51	-0.016	92.3	8.55	0.089	220.0
0.64	-0.021	117.0	8.79	0.087	219.5
0.76	-0.030	140.0	9.05	0.087	219.0
0.88	-0.035	160.0	9.32	0.083	219.3
1.13	-0.024	188.5	9.55	0.079	219.7
1.37	0.000	206.5	9.81	0.075	220.1
1.64	0.018	218.8	10.05	0.073	220.2
1.92	0.029	227.1	10.31	0.069	220.8
2.18	0.038	231.9	10.56	0.064	221.7
2.45	0.059	233.6	10.81	0.058	221.8
2.71	0.077	232.2	11.06	0.058	222.1
2.96	0.083	228.5	11.31	0.052	222.2
3.23	0.086	225.7	11.55	0.048	222.4
3.49	0.090	225.2	11.79	0.049	222.8
3.76	0.095	224.2	12.03	0.044	223.1
4.02	0.098	223.9	12.26	0.040	223.2
4.29	0.098	224.5	12.50	0.036	223.1
4.53	0.099	223.8	12.72	0.038	223.2
4.77	0.095	223.1	12.95	0.037	223.1
5.03	0.094	222.6	13.18	0.036	222.8
5.29	0.095	221.9	13.40	0.034	222.5
5.54	0.094	221.7	13.63	0.033	222.1
5.80	0.098	221.4	13.85	0.035	221.9
6.06	0.103	221.2	14.07	0.030	221.9
6.31	0.104	221.4	14.29	0.028	221.8
6.56	0.106	220.5	14.58	0.026	221.8
6.80	0.099	220.5	14.86	0.022	221.7
7.05	0.099	220.2			
7.30	0.099	221.1			

RESIDUAL STRENGTH TEST

ASTM D3080

Project: Keno Hill District Mill - DSTF

Sample No.: Combined Tailings

Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)	Horizontal Displacement (mm)	Vertical Displacement (mm)	Shear Stress (kPa)
0.00	0.000	0.0	7.15	-0.181	217.4
0.17	-0.016	18.0	7.35	-0.180	216.9
0.31	-0.035	28.1	7.54	-0.179	216.7
0.40	-0.061	36.8	7.74	-0.179	216.2
0.49	-0.102	46.5	7.94	-0.179	215.8
0.61	-0.121	54.9	8.15	-0.179	215.3
0.71	-0.146	63.1	8.33	-0.179	214.9
0.81	-0.152	70.9	8.55	-0.181	214.2
0.94	-0.175	78.8	8.75	-0.183	214.3
1.12	-0.190	89.2	8.95	-0.185	213.4
1.31	-0.206	101.3	9.16	-0.187	213.1
1.50	-0.222	116.3	9.36	-0.188	212.7
1.71	-0.235	132.2	9.56	-0.189	212.9
1.82	-0.238	139.5	9.76	-0.190	212.4
1.93	-0.245	146.9	9.96	-0.190	212.2
2.03	-0.249	154.1	10.17	-0.191	212.0
2.14	-0.249	161.1	10.37	-0.191	211.4
2.24	-0.251	167.9	10.58	-0.193	211.4
2.34	-0.256	173.9	10.77	-0.194	211.4
2.45	-0.261	179.4	10.98	-0.195	211.3
2.65	-0.264	189.6	11.17	-0.195	211.1
2.84	-0.256	198.2	11.37	-0.196	211.3
3.06	-0.248	204.5	11.56	-0.197	211.4
3.26	-0.235	209.0	11.74	-0.197	210.8
3.47	-0.226	212.2	11.94	-0.199	210.8
3.69	-0.217	214.1	12.13	-0.200	210.3
3.90	-0.212	214.9	12.32	-0.202	210.3
4.11	-0.207	215.6	12.50	-0.203	210.1
4.31	-0.202	216.5	12.68	-0.204	210.1
4.52	-0.200	217.6	12.87	-0.207	210.1
4.73	-0.196	217.9	13.05	-0.209	210.1
4.94	-0.194	218.0	13.23	-0.211	209.7
5.13	-0.193	218.3	13.41	-0.213	209.2
5.35	-0.192	218.1	13.60	-0.216	209.0
5.55	-0.190	217.9	13.78	-0.219	208.4
5.75	-0.189	218.1	13.96	-0.221	208.4
5.96	-0.188	218.6	14.14	-0.223	208.3
6.16	-0.187	218.1	14.32	-0.225	208.4
6.36	-0.186	218.0	14.50	-0.227	208.3
6.56	-0.186	218.3	14.67	-0.229	208.3
6.75	-0.184	218.1			
6.95	-0.183	217.6			

APPENDIX E

APPENDIX E THERMAL ANALYSIS

TECHNICAL MEMO

EBA, A Tetra Tech Company
14940 - 123 Avenue
Edmonton, AB T5V 1B4 CANADA
p. 780.451.2121 f. 780.454.5688

TO: Bill Horne
C: Gordon Zhang
FROM: Hongwei Xia
DATE: March 28 ,2011
EBA FILE: W14101178.011
SUBJECT: Thermal Analysis of Dry Stacked Tailings Facility Area, Keno Hill Silver District, YT

1.0 INTRODUCTION

EBA, a Tetra Tech Company (EBA) was retained by Alexco Resource Corp. (Alexco) to conduct thermal analyses for the proposed dry-stacked tailings facility (DSTF) area at the Bellekeno mine site in Keno Hill Silver District, Yukon. The purpose of the analysis was to investigate the long-term impact of dry-stacked tailings placement on the thermal regime of the underlying original ground in the DSTF area under climatic conditions including a climate change scenario (global warming). This memo summarizes the methodology, input data, and results of the thermal analyses. Conclusions drawn from the results are also presented in this memo.

2.0 PROJECT DESCRIPTION

2.1 General Site Condition

The proposed DSTF area generally slopes west at approximately 15% to 20%. The overburden thickness in the area varies with locations, typically increasing along the valley bed and decreasing on the valley slope. The overburden thickness in the area approximately ranged from 2 m to 25 m based on the available borehole information. The overburden soil generally consists of a peat or moss layer overlying ice-rich silt, sand, and glaciofluvial gravel underlain by predominately igneous rocks of quartzite (EBA 2010).

2.2 Permafrost Condition

A total of twenty boreholes were drilled at the mine site including ten boreholes drilled in and near the proposed DSTF area. Permafrost was encountered throughout the proposed DSTF area during the site investigation. The permafrost encountered ranged from non-visible, non-excess ice to massive ice lenses. Ice volumes estimated as a percentage of the total soil volume vary between less than 5% and nearly 100%. In eight of the boreholes drilled at the mine site, massive ice was encountered and the thickness of massive ice ranged from 1.0 m to 15 m (EBA 2010). The DSTF was located to avoid most of the ice rich permafrost; however one borehole within the proposed DSTF had a total of 4 m of massive ice below 9.5 m.

2.3 Ground Temperature

Two ground temperature cables (GTCs) were installed at the proposed DSTF area. Ground temperature data measured from the GTCs indicated that the ground temperature near the proposed DSTF area approximately ranged from -0.2°C and -0.4°C (EBA 2010).

2.4 Porewater Salinity

Six salinity tests were performed on the selected samples. The salinity test results indicated that porewater salinity ranged from 1 ppt to 3 ppt. The porewater salinity was assumed to be 2 ppt in the thermal analysis to consider the freezing point depression due to the impact of porewater salinity.

3.0 THERMAL ANALYSES MODEL

3.1 General

Analyses were carried out using EBA's proprietary two-dimensional finite element computer model, GEOTHERM. The model simulates transient, two-dimensional heat conduction with change of phase for a variety of boundary conditions. The heat exchange at the ground surface is modelled with an energy balance equation considering air temperatures, wind velocity, snow depth, and solar radiation. The model facilitates the inclusion of temperature phase change relationships for soils, such that any freezing depression and unfrozen water content variations can be explicitly modelled. The model has been verified by comparing its results with closed-form analytical solutions and many different field observations. The model has successfully formed the basis for thermal evaluations and designs of tailings dykes, dams, foundations, pipelines, utilidor systems, landfills, and ground freezing systems in both arctic and sub-arctic regions.

3.2 Climatic Data Input for Thermal Model

Climatic data required for the thermal analyses includes monthly air temperature, wind speed, solar radiation, and snow cover. No long-term climatic data is available at the DSTF. A meteorological station on Galena Hill in Keno Hill Silver District has been operated since June 2007 at an elevation of approximately 1380 m above sea level to record wind speed, air temperature, relative humidity, barometric pressure, solar radiation, and rainfall. The weather station is close the DSTF; however the weather station is at an elevation approximately 400 m higher. The available climatic data at this station are from June 2007 to November 2010.

Mayo is the closest meteorological station that has a long-term climate record for the region. The station is located at 63° 37' N, 135° 52' W and an elevation of 504 m, which is approximately 40 km northwest of Keno Hill. The station has daily air temperature records from January 1971 to November 2010. Measured long-term air temperatures at the Mayo station were obtained from Environment Canada (<http://www.climate.weatheroffice.ec.gc.ca>).

Comparison of the measured air temperatures between the Mayo station and Galena Hill station for the past four years of the overlapped period indicates that mean air temperatures at the Galena Hill station (1380 m) are approximately 3°C to 5°C warmer than those at the Mayo station (504 m) during winter

periods, and approximately 5°C cooler than those at the Mayo station during summer periods. One possible reason for the temperature discrepancy in winter period is general winter temperature inversion in the Yukon where temperatures increase with height during winter (Wahl et al, 1987). Analysis of a 43-year period of data (1958-2000) from Whitehorse shows a long-term average lapse rate of approximately +8°C/km up to an elevation of 1500 m during the winter (Pinard, 2009). The positive sign indicates a warming with elevation, or an inversion. Long-term mean monthly air temperatures for this study were estimated based on the long-term monthly air temperatures at Mayo and then adjusted the air temperatures based on the measured monthly air temperature differences between the Mayo and Galena Hill stations during the overlapped period of 2007 to 2010.

Measured wind speed data from the Galena Hill station is available from June 2007 to September 2010. Long-term mean wind speed data is available from 1971-2000 at the Mayo station. Comparison between the measured wind speed data from the Mayo and Galena Hill stations indicated that the measured wind speed at the Mayo and Galena stations are very similar; therefore, the measured wind speed data at Galena Hill station were used in the thermal analysis.

No snow depth data is available from the Galena Hill station. The climate records from available climate stations near the Keno Hill Silver District shows a linear relationship can be established between mean annual precipitation and elevation at these available stations. The mean annual precipitation increases by an average 27 mm for every 100 m of elevation increasing (ACCESS 2009). Snow depth were predicted based on the snow depth data from Mayo station using the linear relationship.

Norman Wells and Whitehorse are the closet stations to the Keno Hill Silver District with long-term solar radiation data. The measured solar radiation data from the Galena Hill station is available between June 2007 and September 2010. Comparison of the available solar radiation data from the three stations indicated that the measured solar radiation data from the Galena Hill is close to these from Norma Wells and Whitehorse. Therefore, the average monthly solar radiation data from the three stations was used in this study.

The mean climatic data estimated for the DSTF for this study are summarized in Table 1.

Table 1: Mean Climatic Conditions at Keno Hill Used in Thermal Analyses

Month	Estimated Mean Monthly Air Temperatures at Keno Hill (1971 to 2007) ^(a) (°C)	Measured Monthly Air Temperature at Keno Hill (2007-2010) ^(b) (°C)	Measured Monthly Wind Speed at Keno Hill ^(c) (km/h)	Estimated Monthly Snow Cover at Keno Hill ^(d) (m)	Estimated Daily Solar Radiation at Keno Hill ^(e) (W/m ²)
January	-14.7	-16.7	7.7	0.57	9.1
February	-14.0	-14.3	5.4	0.57	38.3
March	-14.4	-12.2	12.4	0.53	101.4
April	-4.9	-3.8	11.8	0.41	181.8
May	3.4	4.1	8.8	0	233.5
June	9.6	9.0	7.5	0	242.9
July	10.8	10.7	8.2	0	218.4
August	8.0	8.1	8.7	0	162.0
September	1.9	2.3	8.5	0	96.4
October	-5.1	-6.2	8.0	0.34	41.5
November	-13.6	-10.5	8.9	0.48	13.2
December	-10.2	-15.2	5.5	0.56	4.5
Annual	-3.6	-3.7			

Notes:

- (a) Based on measured monthly air temperatures at Mayo for the periods of 1971 to 2010, measured air temperatures at Galena Hill station for the period of 2007 to 2010
- (b) Based on measured temperature data at Galena Hill station (2007-2010)
- (c) Based on measured data at Galena Hill station for the period of 2007 to 2010
- (d) Based on mean month-end snow data at Mayo (Climate Normals 1971-2000, Environment Canada website) and environmental conditions report (Access Consulting Group, 2009)
- (e) Based on measured data at Galena Hill station (2007-2010), Norman Wells and Whitehorse (1951-1980)

3.3 Climate Change Projection

The historical air temperature data at Mayo for the period of 1970 to 2010 indicated that the long-term climatic trend at Mayo is warming, and a similar conclusion can be made at Keno Hill DSTF. Based on the observed warming trend in the historical air temperatures and state-of-practice, the thermal evaluations for this project should consider the long-term effects of climate change (or global warming).

The Adaptation and Impacts Research Section (AIRS) of Environment Canada recently produced a report (Environment Canada 2009) summarizing findings from the most recent modelling assessment for the Arctic. AIRS adopted an ensemble approach (multi-model means/medians) to reduce the uncertainty associated with any individual model. Model validation over the historical period from 1971-2000 was first used to identify those models which best reproduced the mean annual temperature of this period against the National Centre for Environmental Prediction global gridded dataset. Subsequently, only the four best-agreement models were used to produce the final ensemble projections. The four best ranking models within each sector were then used as an ensemble to produce projections of temperature change in

the 2020s, 2050s, and 2080s for both the 'A1B' (middle of the road emission), and 'A2' (high emission) scenarios. CSA (2010) adopted the climate change projections in Environment Canada (2009).

The Keno Hill site (63° N 135° W) is located at the arctic zone W1 in Environment Canada (2009) and CSA (2010). The predicted mean temperature changes from 1970-2000 baseline under the moderate greenhouse gas emission scenario in zone W1 (CSA 2010) are presented in Table 2. These rates of the predicted temperature change were applied in the thermal evaluations. Table 3 summarizes the estimated monthly air temperatures at Keno Hill during the period of 1971 to 2000, 1981 to 2010, and in 2013 considering the rates of the projected climate changes in the period of 2011 to 2040. Comparing the estimated air temperatures in 2013 with the recent measured air temperatures at the Galena Hill station (2007 to 2010) indicates that the estimated mean annual air temperature is slightly colder than the measured at the Galena Hill station. This suggests that the projected air temperature changes for the period of 2011 to 2040 may not be conservative.

Table 2 Predicted Seasonal Air Temperature Changes in Zone W1 (CSA 2010)

Period	Predicted Seasonal Air Temperature Changes from 1971-2000 Baseline under Moderate Green-house Gas Emission Scenario (°C)			
	Winter	Spring	Summer	Autumn
2011–2040	0.9	0.9	0.6	0.6
2041–2070	2.3	2.0	1.6	2.2
2070-2100	4.3	2.8	2.5	2.9

Table 3: Estimated Monthly Air Temperatures at Keno Hill

Month	Estimated Mean Monthly Air Temperature at Keno Hill (1971-2000) (°C) ¹	Estimated Mean Monthly Air Temperature at Keno Hill (1981-2010) (°C) ²	Estimated Mean Monthly Air Temperature at Keno Hill in 2013 Based on Projected Climate Change and 1971-2000 Air Temperatures (°C) ³
January	-18.9	-15.1	-18.3
February	-15.4	-14.0	-14.8
March	-12.9	-13.7	-12.3
April	-4.7	-4.6	-4.1
May	3.1	3.6	3.7
June	8.6	9.5	9.1
July	10.8	10.7	11.2
August	7.7	7.9	8.2
September	1.7	2.0	2.1
October	-6.6	-5.3	-6.2
November	-14.4	-12.9	-14.0
December	-14.8	-11.3	-14.2
Annual	-4.6	-3.6	-4.1
- Based on Mayo 1971 to 2000, adjusted to Keno using Galena Hill Data - Based on Mayo 1981 to 2010, adjusted to Keno using Galena Hill Data - Based on Mayo 1971 to 2000, adjusted to Keno using Galena Hill Data plus climate change estimate			

4.0 CALIBRATION THERMAL ANALYSIS

A thermistor cable was installed on August 29, 2009 to a depth of 9.4 m in Borehole BH23 within the footprint of the proposed DSTF area. One-dimensional thermal analysis was used to calibrate the thermal model with measured ground temperatures at BH23.

The soil profile at BH23 for the calibration thermal analysis consisted of a 0.5 m peat layer overlying 2.4 m ice rich sand and silt, 2.4 m sand, 2.3 m sand and silt, 0.4 m gravel, 1.3 m silt, and 7.7 m gravel over bedrock.

The material properties used in the analysis are presented in Table 4. The index soil properties were estimated from borehole logs and past experience with similar soils. The soil thermal properties were determined indirectly from well-established correlations with soil index properties (Farouki, 1986; Johnston, 1981).

Table 4: Material Properties Used in Thermal Calibration Analysis for BH23

Material	Water Content (%)	Bulk Density (Mg/m ³)	Thermal Conductivity (W/m-°C)		Specific Heat (kJ/kg°C)		Latent Heat (MJ/m ³)
			Frozen	Unfrozen	Frozen	Unfrozen	
Peat	130	0.8	0.57	0.31	1.92	3.10	152
Silt and Sand No. 1	60	1.65	2.35	0.96	1.24	2.03	206
Sand	17	2.16	2.48	1.57	0.93	1.23	105
Silt and Sand No. 2	17.1	2.17	2.48	1.57	0.93	1.24	106
Gravel No. 1	10	2.31	2.67	2.01	0.86	1.05	70
Silt	10	2.20	2.23	1.74	0.86	1.05	67
Gravel No. 2	8	2.32	2.46	2.02	0.83	0.99	57
Bedrock	1	2.63	4.00	4.00	0.75	0.77	9

Table 5 compares the predicted and measured ground temperatures on December 27, 2009 and February 23, 2011 at BH23.

Table 5: Measured and Predicted Ground Temperatures at BH23

Depth below Ground Surface (m)	Measured on Dec. 27, 2009 (°C)	Predicted on Dec. 27, 2009 (°C)	Measured on Feb. 23, 2011 (°C)	Predicted on Feb. 23, 2011 (°C)
-0.4	-2.63	-2.43	-3.0	-2.94
-1.4	-0.20	-0.30	N/A	-0.35
-2.4	-0.33	-0.33	-0.27	-0.32
-3.4	-0.39	-0.35	-0.33	-0.32
-4.4	-0.42	-0.35	-0.37	-0.33
-5.4	-0.41	-0.35	-0.35	-0.33
-6.4	-0.40	-0.35	-0.34	-0.33
-7.4	-0.37	-0.35	-0.32	-0.33
-8.4	-0.32	-0.33	-0.30	-0.32
-9.4	-0.30	-0.33	-0.31	-0.32

Good agreement was obtained between the measured and predicted ground, which suggests that the thermal model is reasonable and can be used in the thermal evaluations for other locations at the mine site.

5.0 THERMAL ANALYSIS FOR DRY-STACKED TAILINGS FACILITY AREA

5.1 General

The purposes of the thermal evaluation are to investigate the impact of tailing placement on the thermal regime of the original ground and to predict the permafrost thaw rate under climatic conditions including the climate change scenario.

The following schedules and assumptions for the dry-stacked tailings facility area were adopted in the thermal analyses:

- Removing trees in the tailings placement area;
- Placing 0.5 m sand and gravel fill as drainage blanket over the area in February 2011;
- Placing tailings overlying the sand and gravel blanket beginning in June 2011;
- The total height of placed tailings was assumed to be 10 m by 2013;
- The initial temperature for sand and gravel drainage blanket was assumed to be -5°C; and
- The initial temperature for dry stacked tailings was assumed to be +20 °C.

Several cases were run in the thermal analyses to investigate the impact of tailings placement under different climate conditions as summarized in Table 6.

Table 6: Cases Simulated in Thermal Modelling

Case	Mean Monthly Air Temperatures Used	Vegetation Layer Cover	Running Time
1	1971-2000	Yes	Long-Term (100 years)
2	1971-2000	No	Long-Term (100 years)
3	Climate Change	Yes	Long-Term (100 years)
4	Climate Change	No	Long-Term (100 years)
5	1981-2010	Yes	Long-Term (100 years)
6	1981-2010	No	Long-Term (100 years)

5.2 Thermal Analysis

One-dimensional analyses were carried out for a representative soil profile based on BH35 drilled in the proposed DSTF area. The soil profile at BH35 consisted of a 1.0 m peat layer overlying 9.5 m ice rich silt, 1.0 m massive ice, 1.8 m silt and gravel, 2.7 m massive ice, 3.0 m gravel, 2.2 m silt and gravel, and 1.0 m sand over bedrock.

The index properties for the sand and gravel drainage blanket and dry-stacked tailings have been estimated from limited available information (Jim, 2005) and past experience. Thermal properties of the

material were determined indirectly from well-established correlations with their index properties. Table 7 summarizes the material properties used in the thermal analyses.

Table 7: Material Properties Used in Thermal Analyses

Material	Water Content (%)	Bulk Density (Mg/m ³)	Thermal Conductivity (W/m-°C)		Specific Heat (kJ/kg°C)		Latent Heat (MJ/m ³)
			Frozen	Unfrozen	Frozen	Unfrozen	
Dry-stack Tailings	17	1.98	3.20	1.90	0.93	1.23	96
Sand and Gravel (Fill)	5	2.10	1.33	1.50	0.80	0.90	33
Peat before thaw consolidation	150	0.75	0.49	0.30	1.92	2.19	150
Peat after thaw consolidation	60	1.60	2.36	1.02	1.24	2.03	200
Silt (Till)	40	1.81	2.36	1.12	1.12	1.72	172
Ice		0.91	2.20	10.0	2.10	4.20	334
Silt and Gravel No 1	10	2.25	2.21	1.71	0.86	1.05	68
Gravel	10	2.31	2.67	2.00	0.86	1.05	70
Silt and Gravel No 2	15.5	2.19	2.59	1.70	0.92	1.20	98
Sand	10	2.25	2.27	1.73	0.86	1.05	68
Bedrock	1	2.63	4.00	4.00	0.75	0.77	9

5.3 Results and Discussions

One-dimensional thermal analyses were conducted for all six cases listed in Table 6. The predicted thaw rate and permafrost condition for each case are summarized in Table 8.

Table 8: Predicted Thaw Rate and Permafrost Condition in DSTF Area

Case	Mean Monthly Air Temperature Used	Vegetation Layer Cover	Thaw Rate in Soils (m/year)	Predicted Permafrost Condition
1	1971-2000	Yes	0.0 m/year (2013-2025) 0.15 m/year (2025-2038) 1.8 m/year (2038-2042)	Permafrost in soils would disappear in 29 years; the ice layer would disappear in 53 years
2	1971-2000	No	0.0 m/year (2013-2018) 0.17 m/year (2018-2036) 1.5 m/year (2036-2040)	Permafrost in soils would disappear in 27 years; the ice layer would disappear in 50 years
3	Climate Change	Yes	0.0 m/year (2013-2015) 0.13 m/year (2018-2034) 1.4 m/year (2034-2039)	Permafrost in soils would disappear in 26 years; the ice layer would disappear in 50 years
4	Climate Change	No	0.0 m/year (2013-2016) 0.17 m/year (2016-2036) 1.4 m/year (2036-2040)	Permafrost in soils would disappear in 27 years; the ice layer would disappear in 48 years
5	1981-2010	Yes	0.0 m/year (2013-2022) 0.16 m/year (2022-2039) 2.1 m/year (2037-2040)	Permafrost in soils would disappear in 27 years; the ice layer would disappear in 50 years
6	1981-2010	No	0.0 m/year (2013-2016) 0.17 m/year (2016-2032) 2.1 m/year (2032-2035)	Permafrost in soils would disappear in 22 years; the ice layer would disappear in 46 years

The following conclusions can be drawn from the thermal analysis results:

- 1) The predicted thaw depth below the original ground surface is 1.5 m by 2013 when the tailings placement in the study area is assumed to be completed.
- 2) The predicted rate of thaw into the permafrost soils is negligible during first several years after completion of the tailings placement and then starts to increase with time after that period.
- 3) The predicted rate of thaw into the permafrost interval from 1.5 m to 4.5 m below the original ground surface ranges from 0.13 m/year to 0.17 m/year, with an average of 0.15 m/year.

- 4) The predicted thaw rate dramatically increases after the top 4.5 m permafrost soils are completely thawed. The predicted rate of thaw into the depth interval from 4.5 m to 10.5 m below the original ground surface ranges from 1.4 m/year to 2.1 m/year, with an average of 1.7 m/year.
- 5) The permafrost in the soil layers is predicted thaw within 30 years but the ice layer is predicted to be thawed within 55 years under the climatic conditions evaluated.
- 6) Evapo-transpirative cover layer would slightly delay the permafrost degradation for several years.

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- Farouki, O.T., 1986. Thermal Properties of Soils. TransTech Publications, Germany, 136 p.
- Jim, G., Peri, M., and Mecheal, P., 2005. Thermal Conductivity of Sulphidic Tailings. BGC Engineering Inc. published Paper
- Johnston, G.H. (Editor), 1981. Permafrost, Engineering Design and Construction. Wiley & Sons Toronto, 540 p.

APPENDIX F

APPENDIX F SLOPE INCLINOMETER DATA

RST Instruments Ltd.

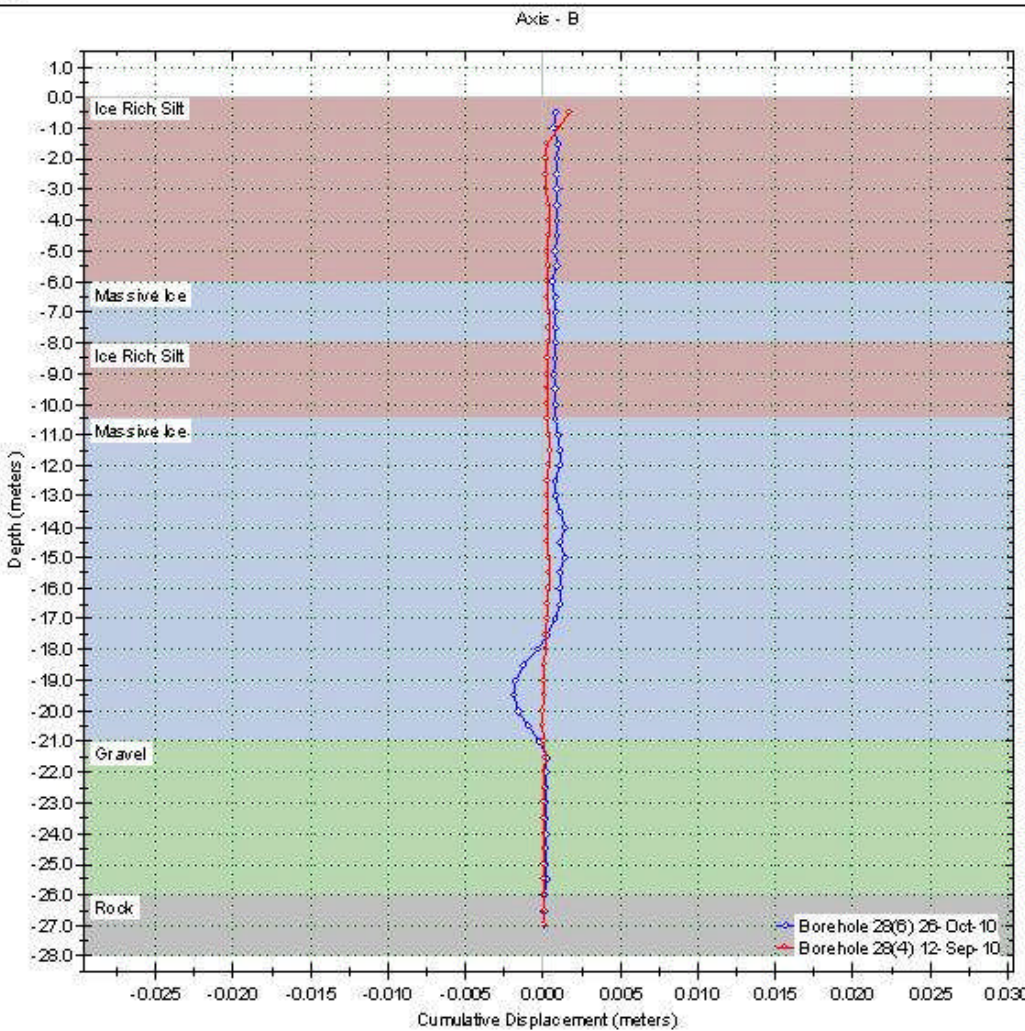
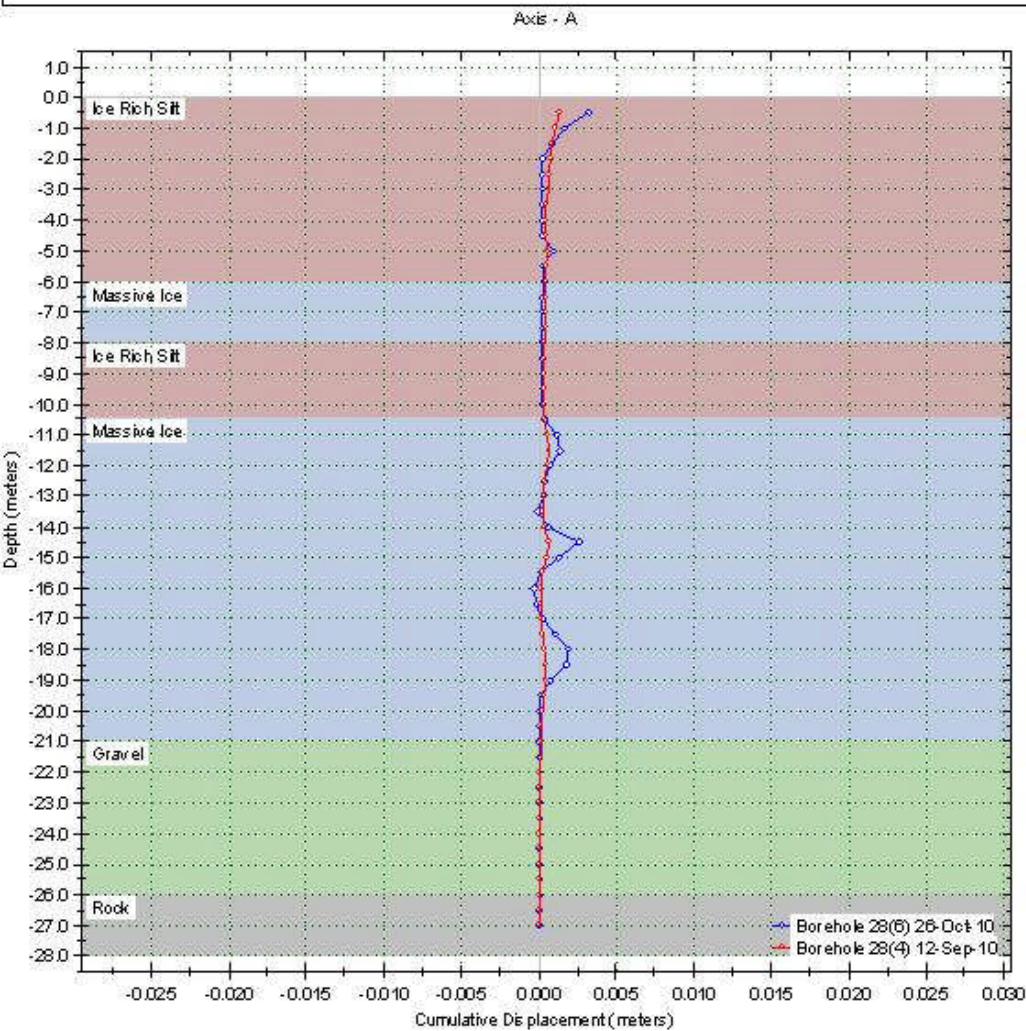
CUMULATIVE DISPLACEMENT

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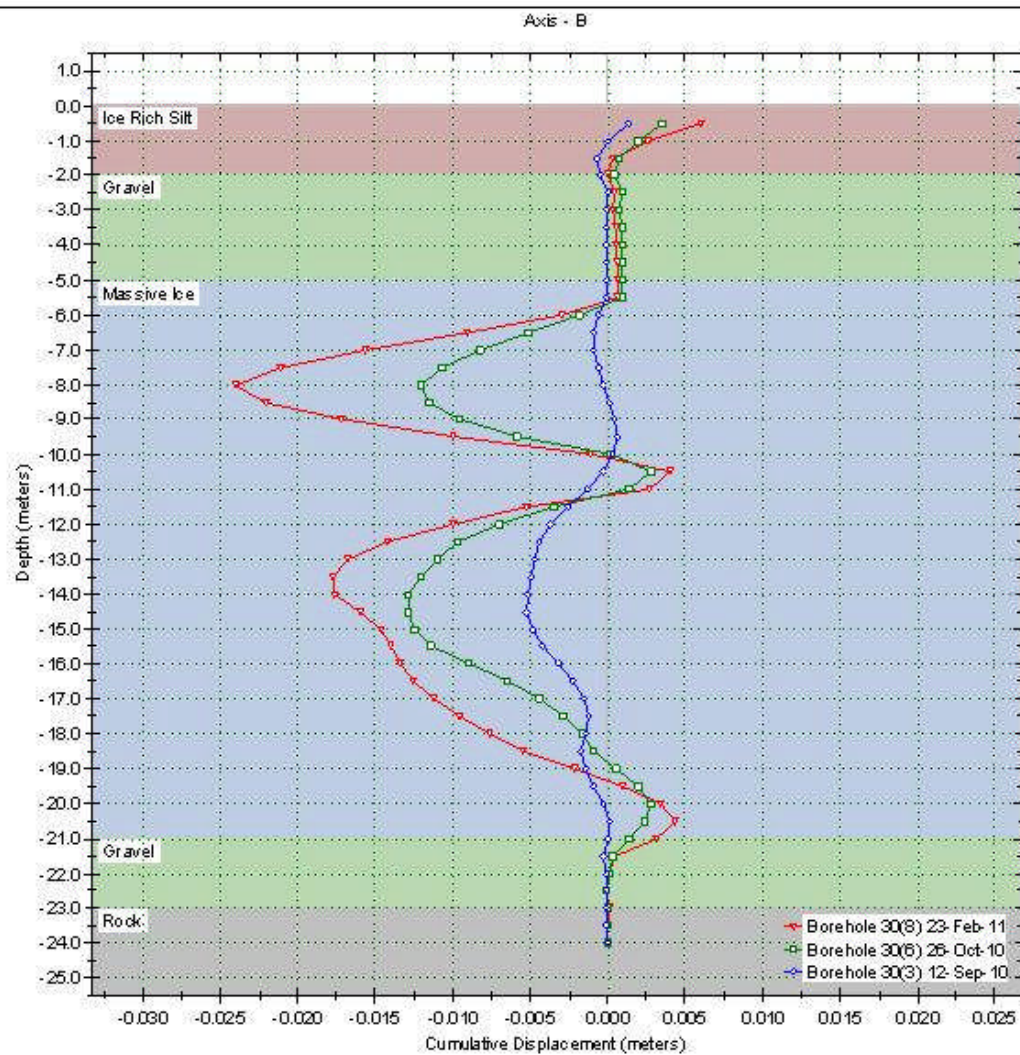
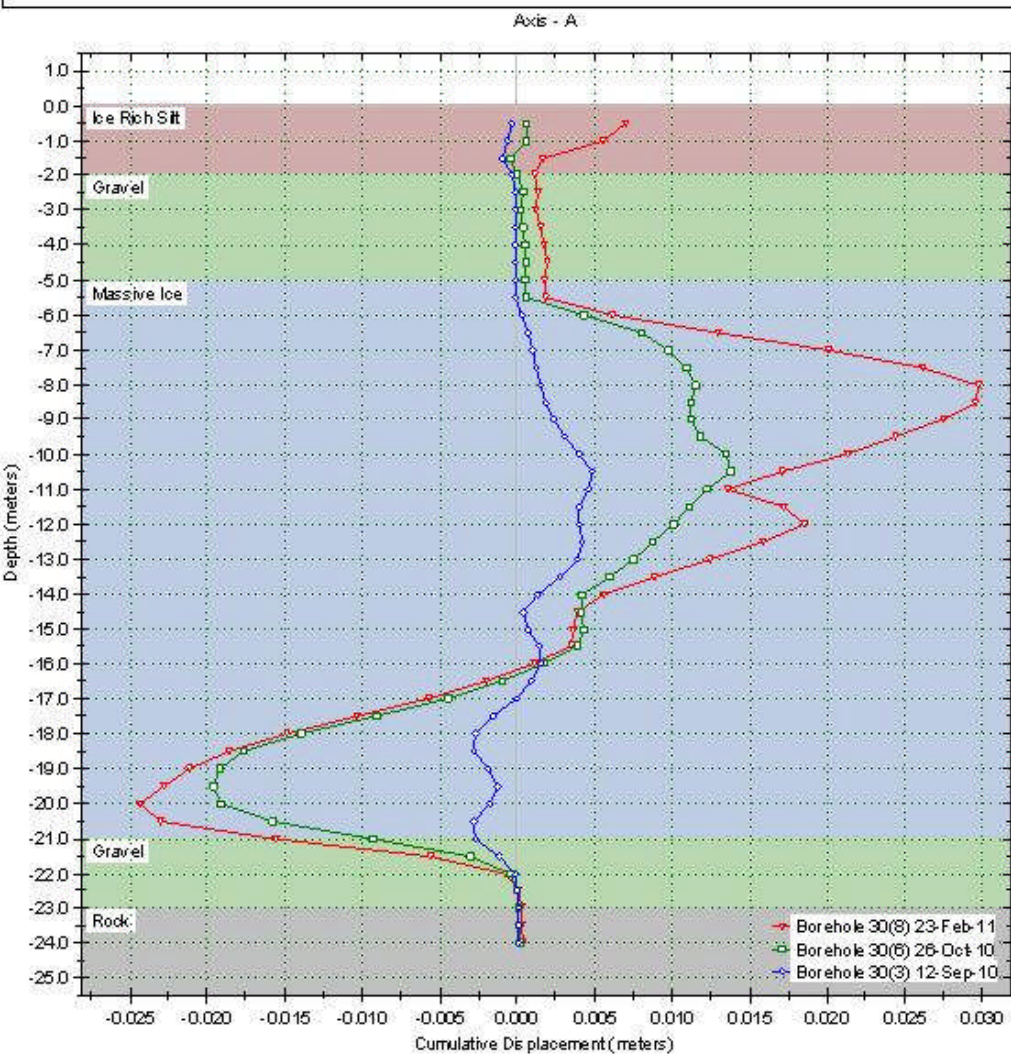
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North Groove Azimuth :
Base Reading : 2010 Sep 07 10:08
Axis A Azimuth : 0.0 degrees

SI Installed August 22



Borehole : Borehole 30
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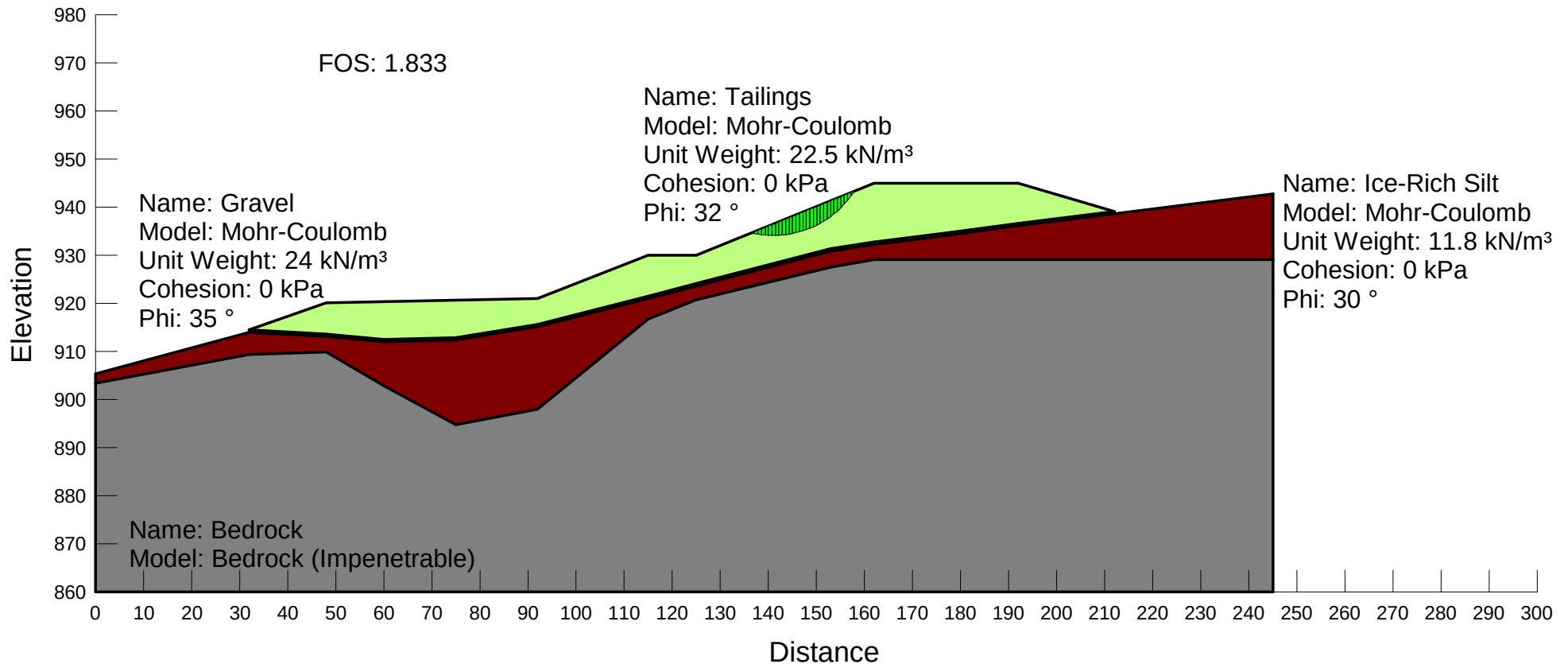
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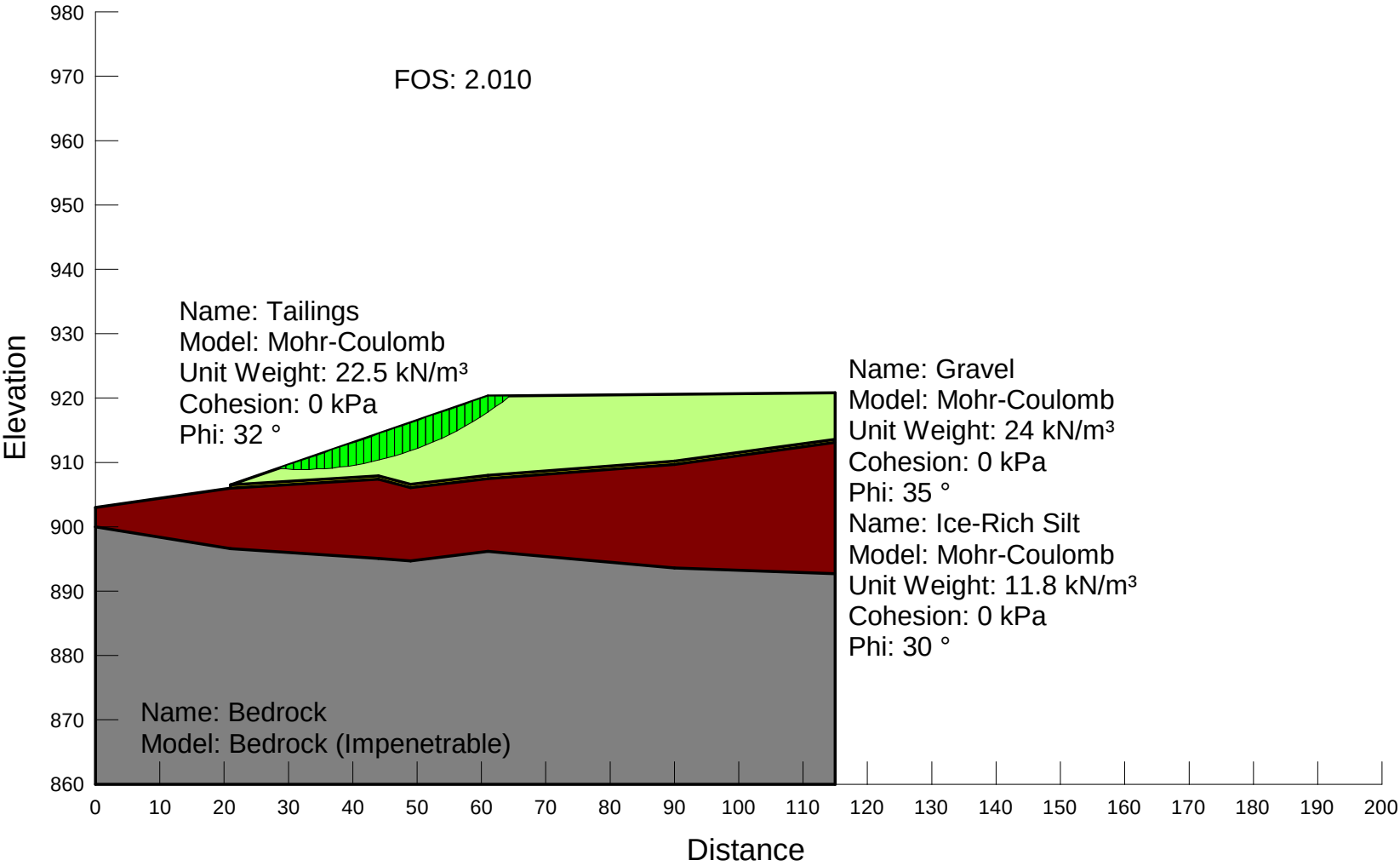
APPENDIX G

APPENDIX G SLOPE STABILITY RESULTS – PERMAFROST CONDITION

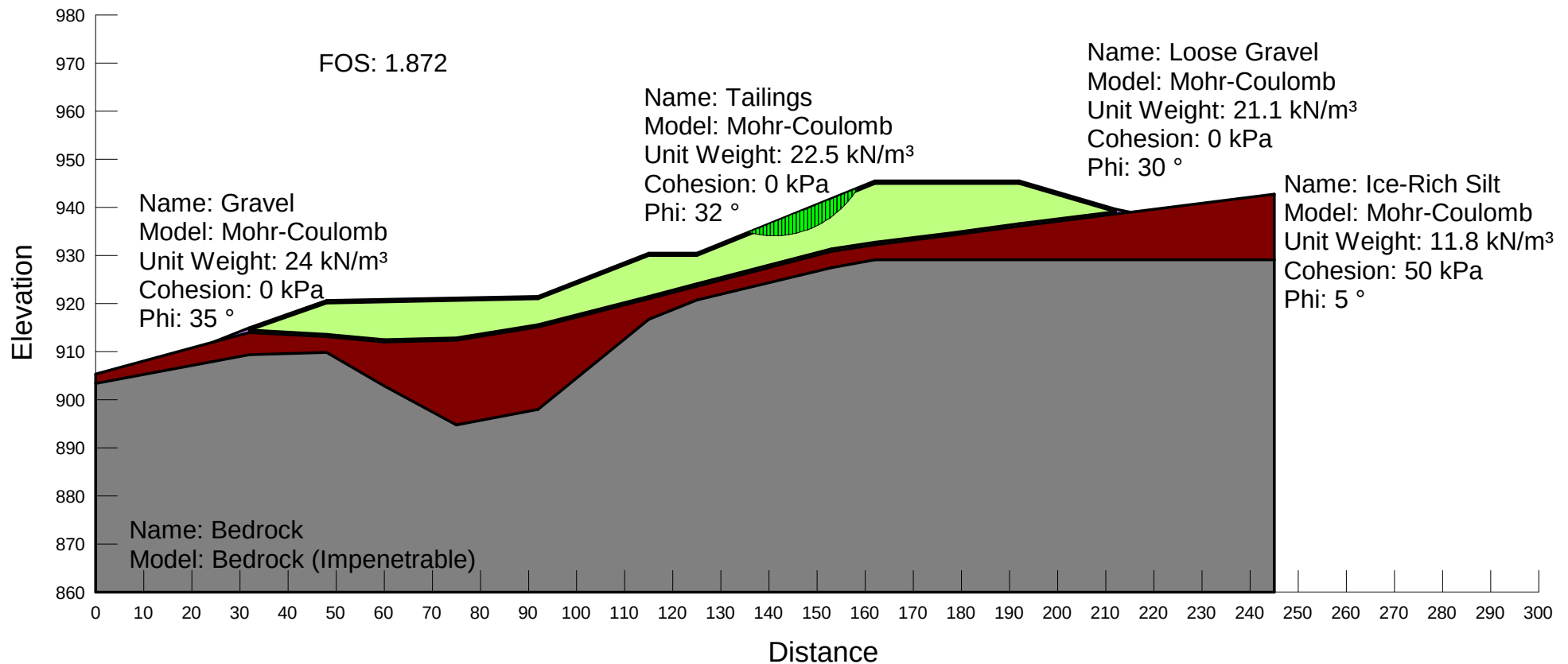
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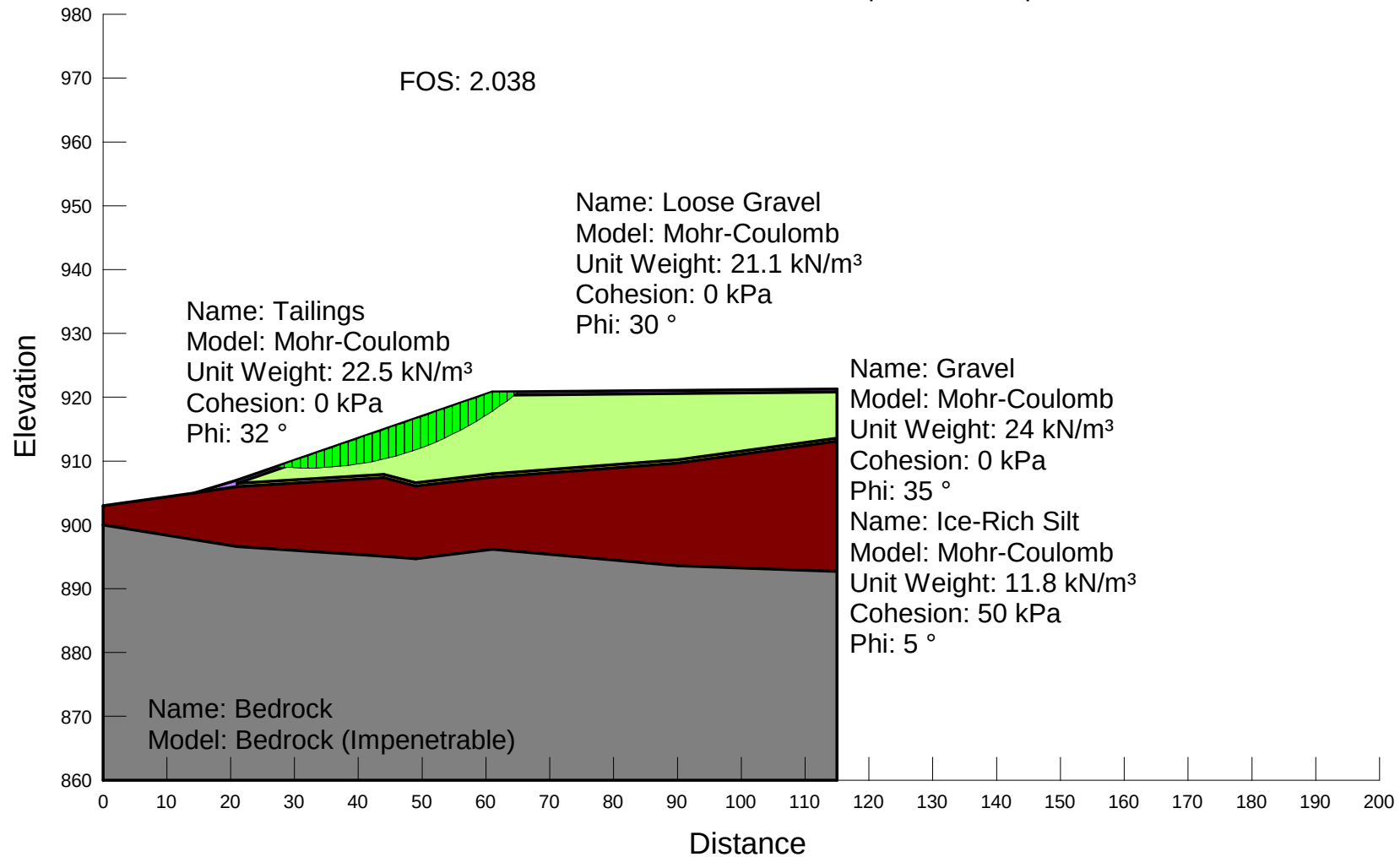
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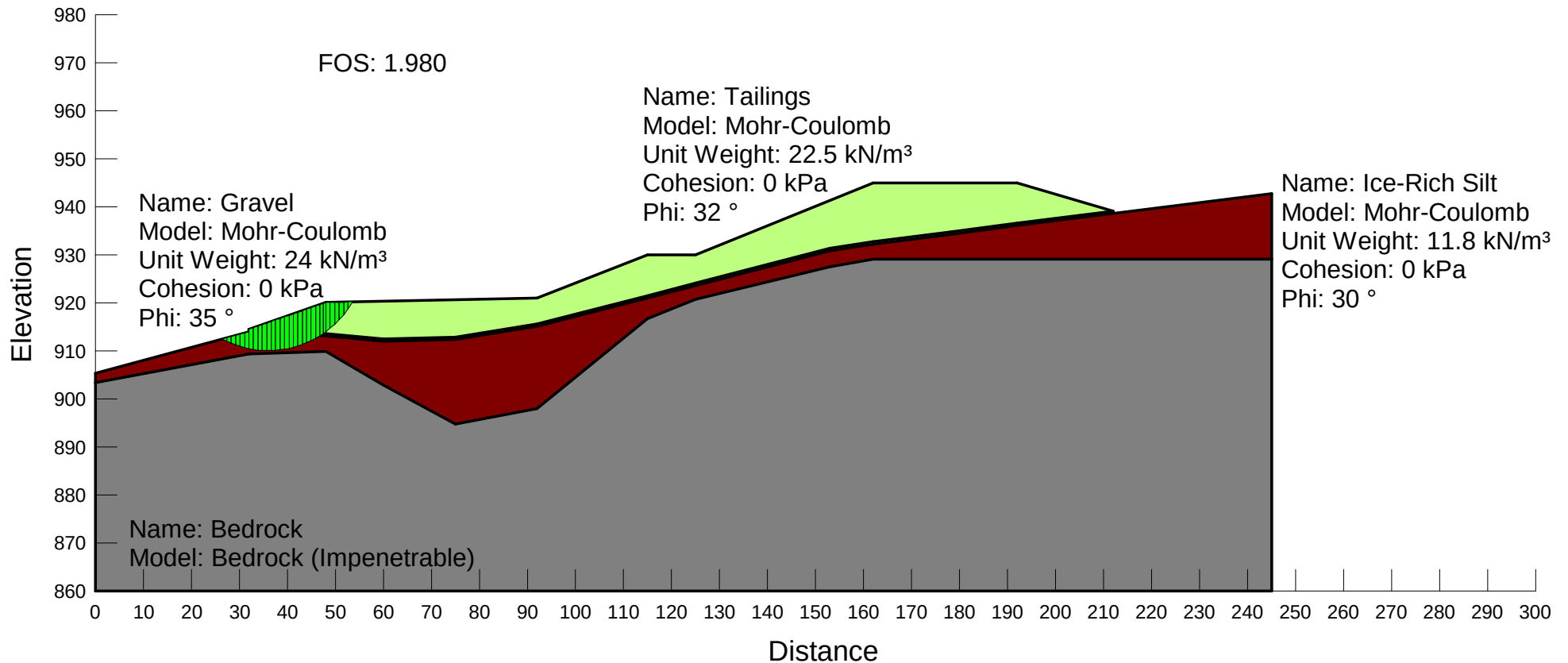
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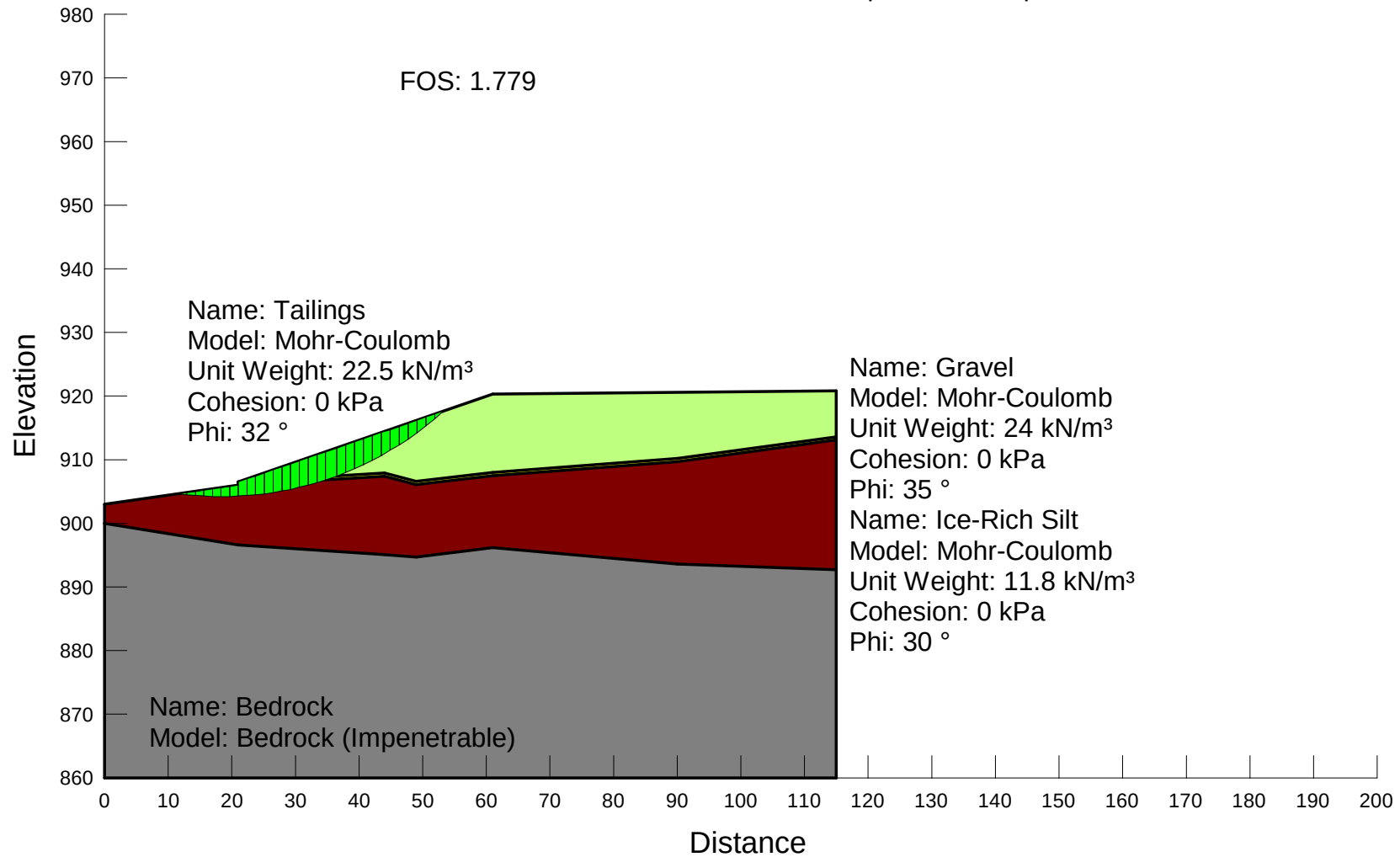
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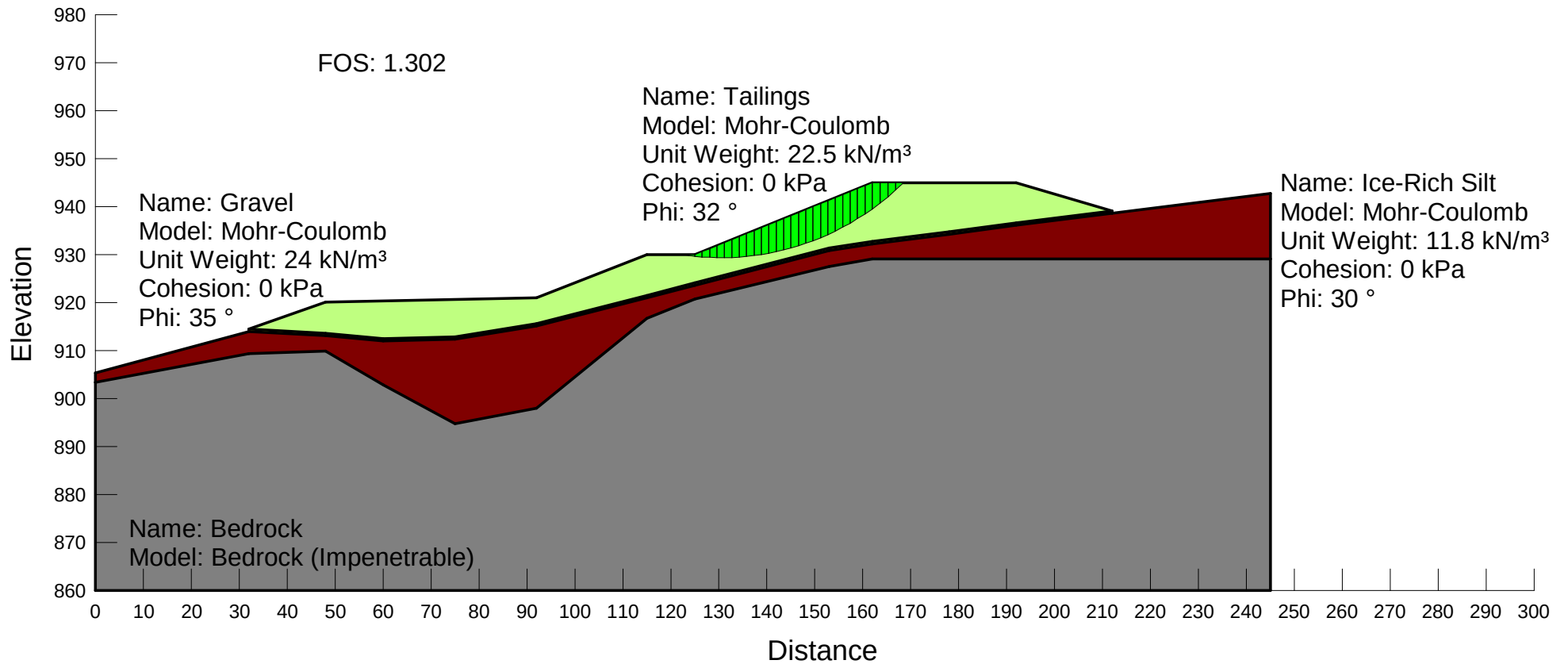
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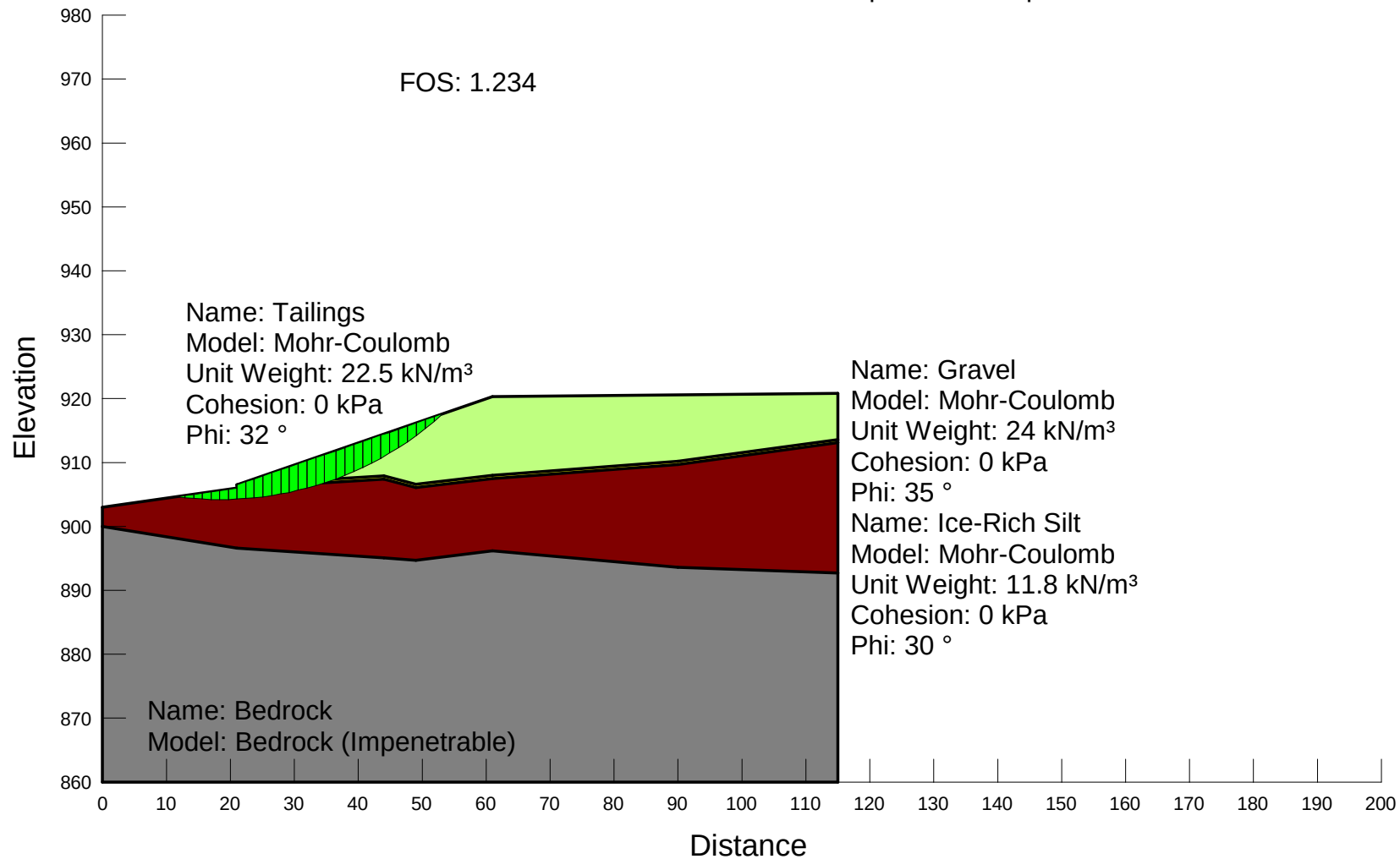
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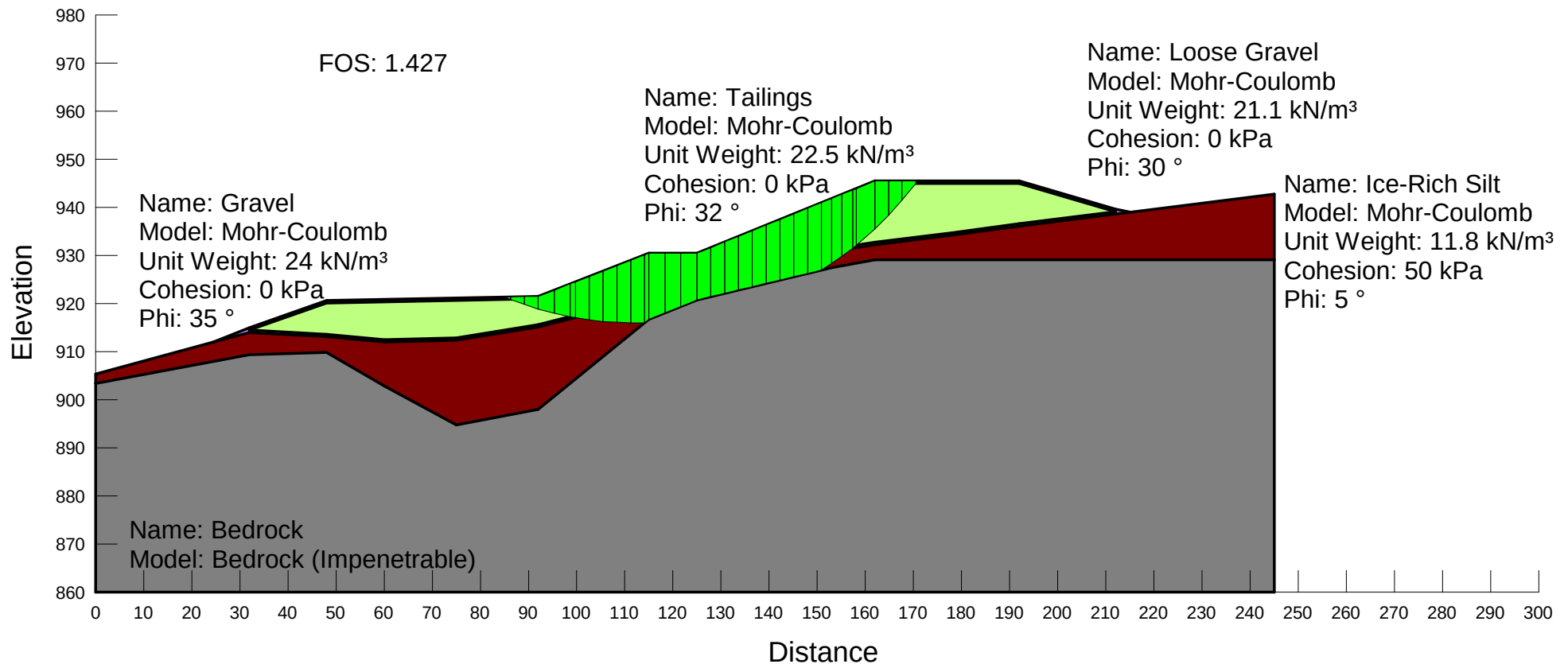
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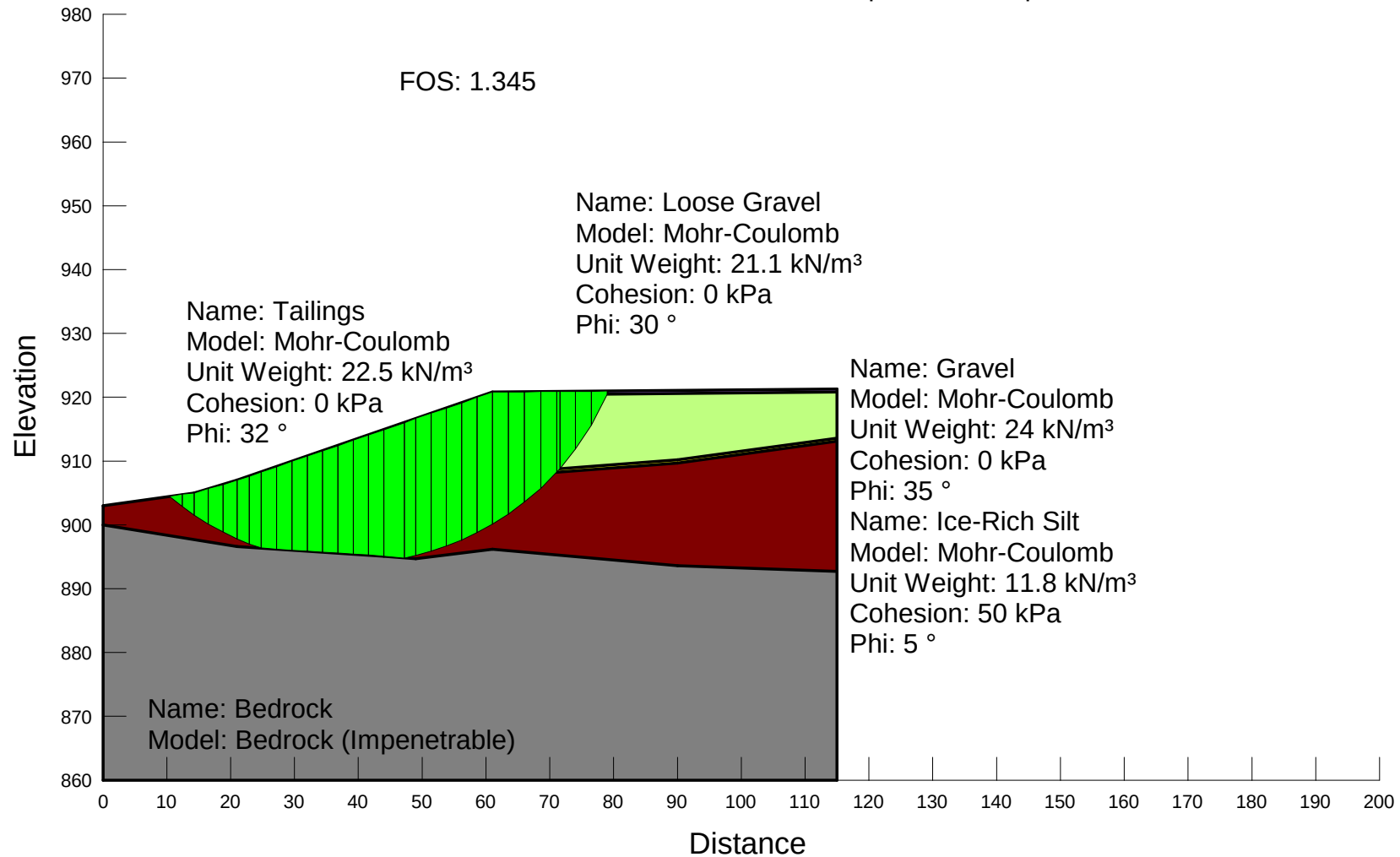
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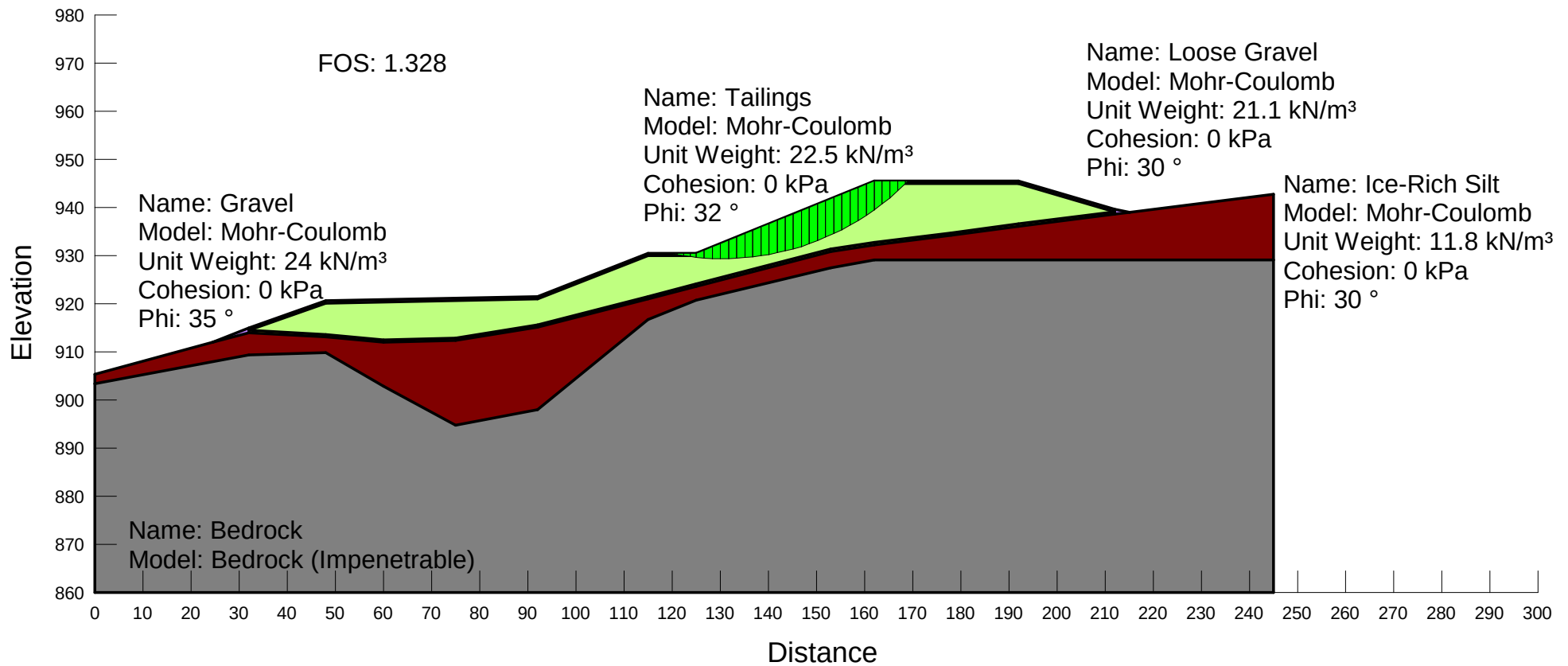
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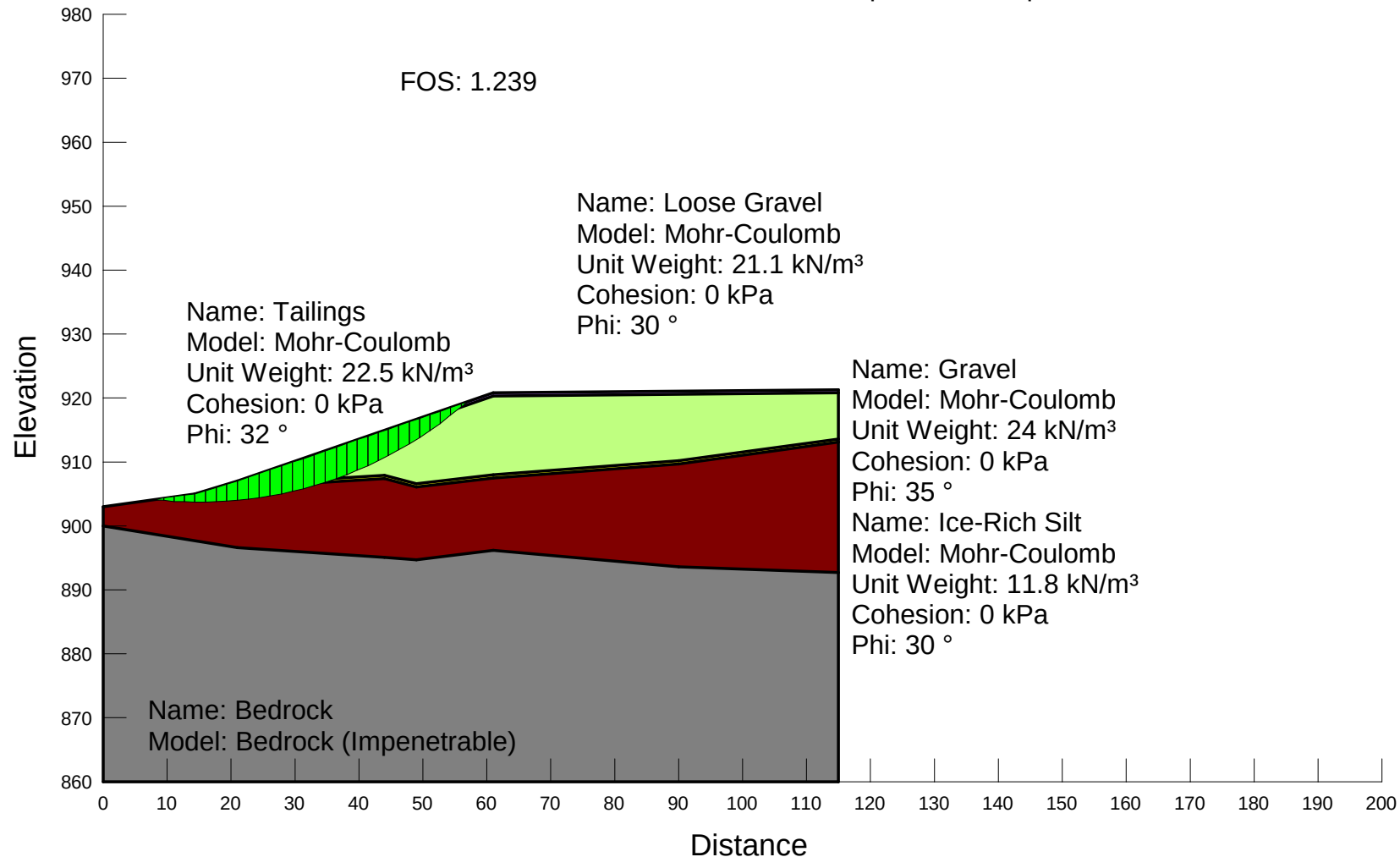
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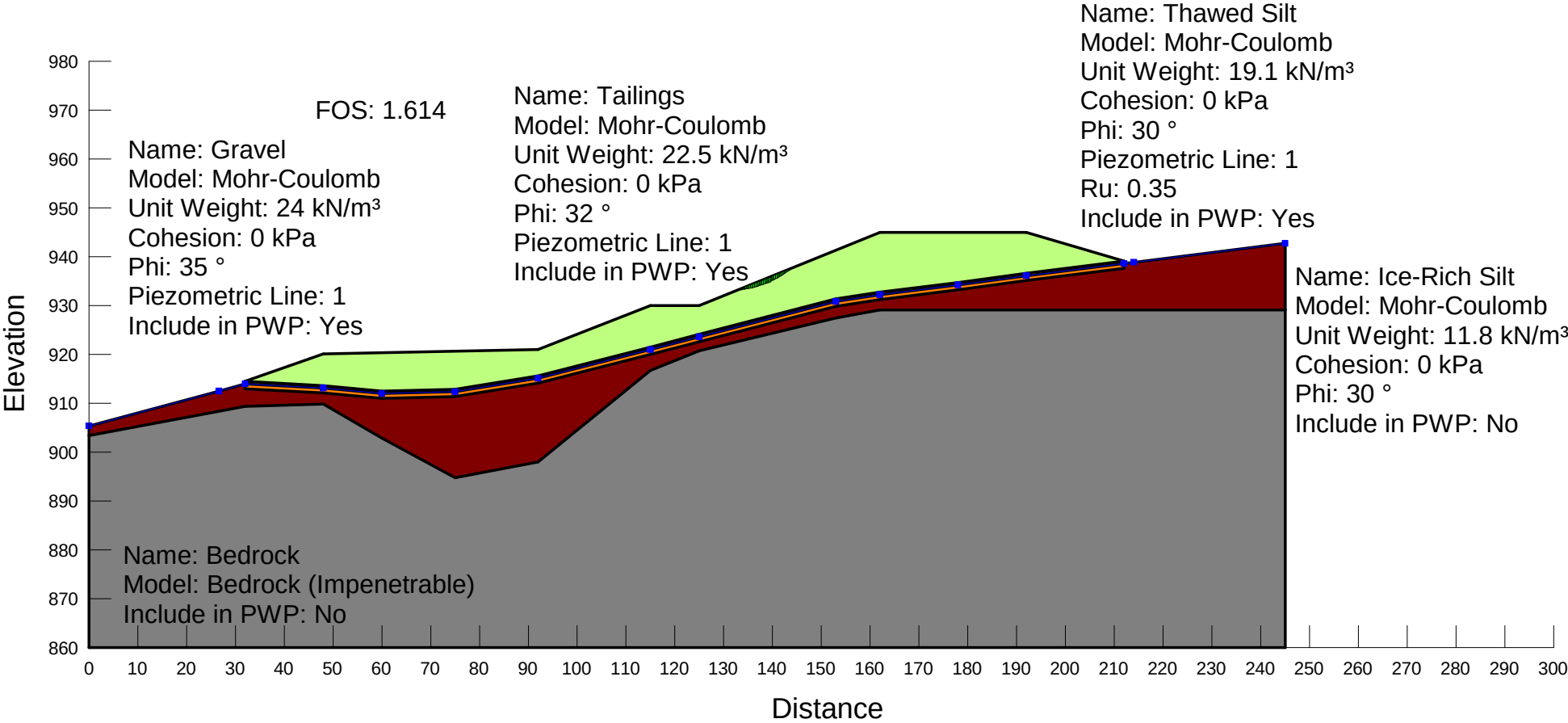
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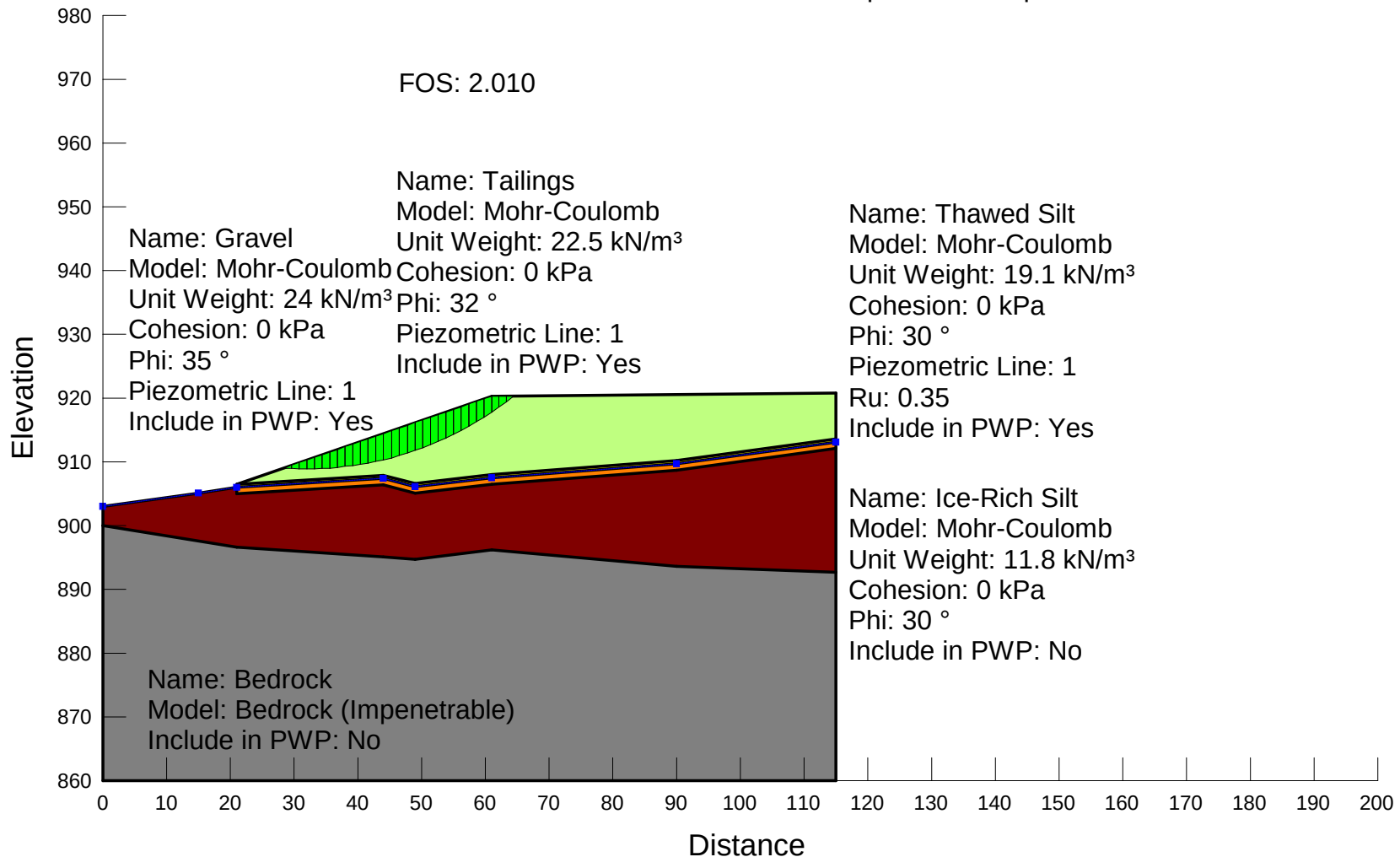
APPENDIX H

APPENDIX H SLOPE STABILITY RESULTS – PERMAFROST 1.0 M THAWED

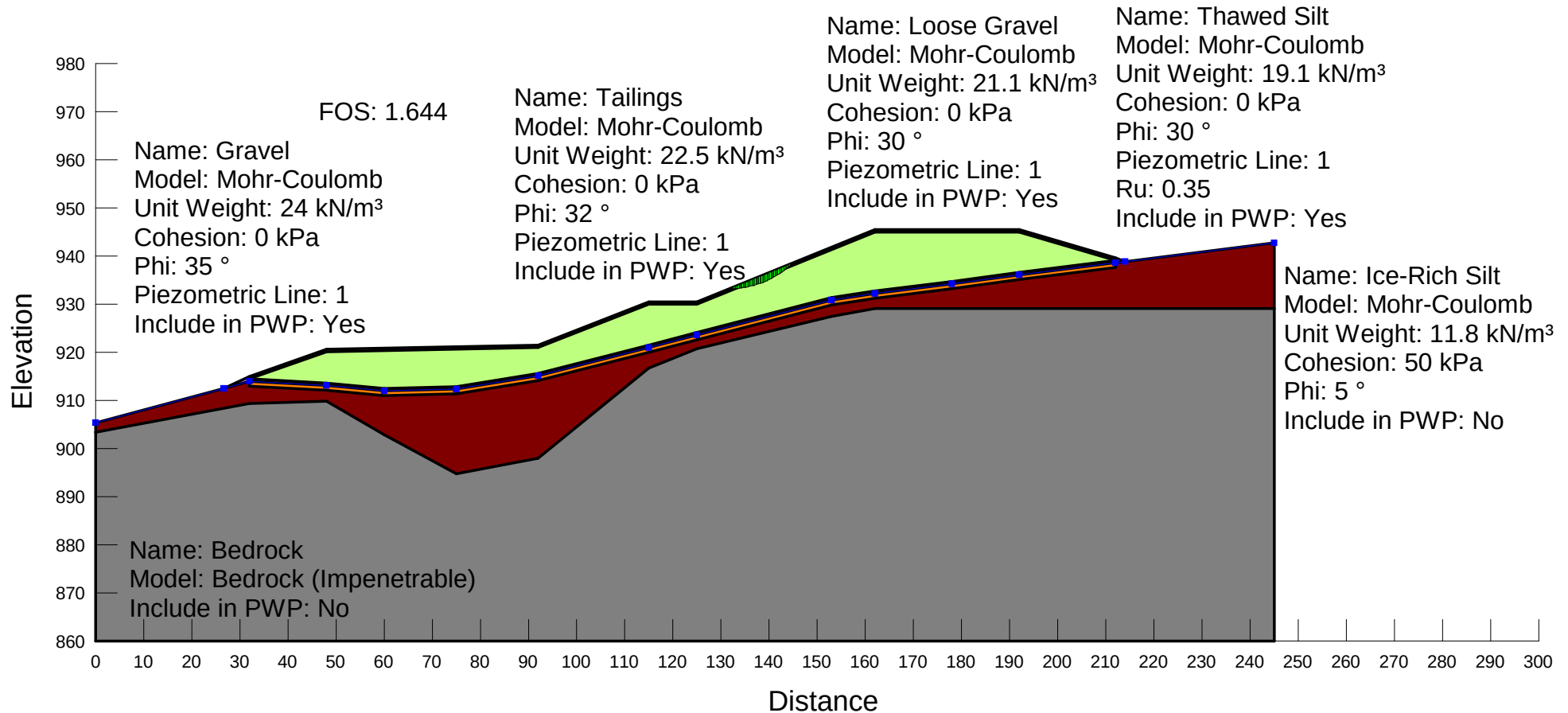
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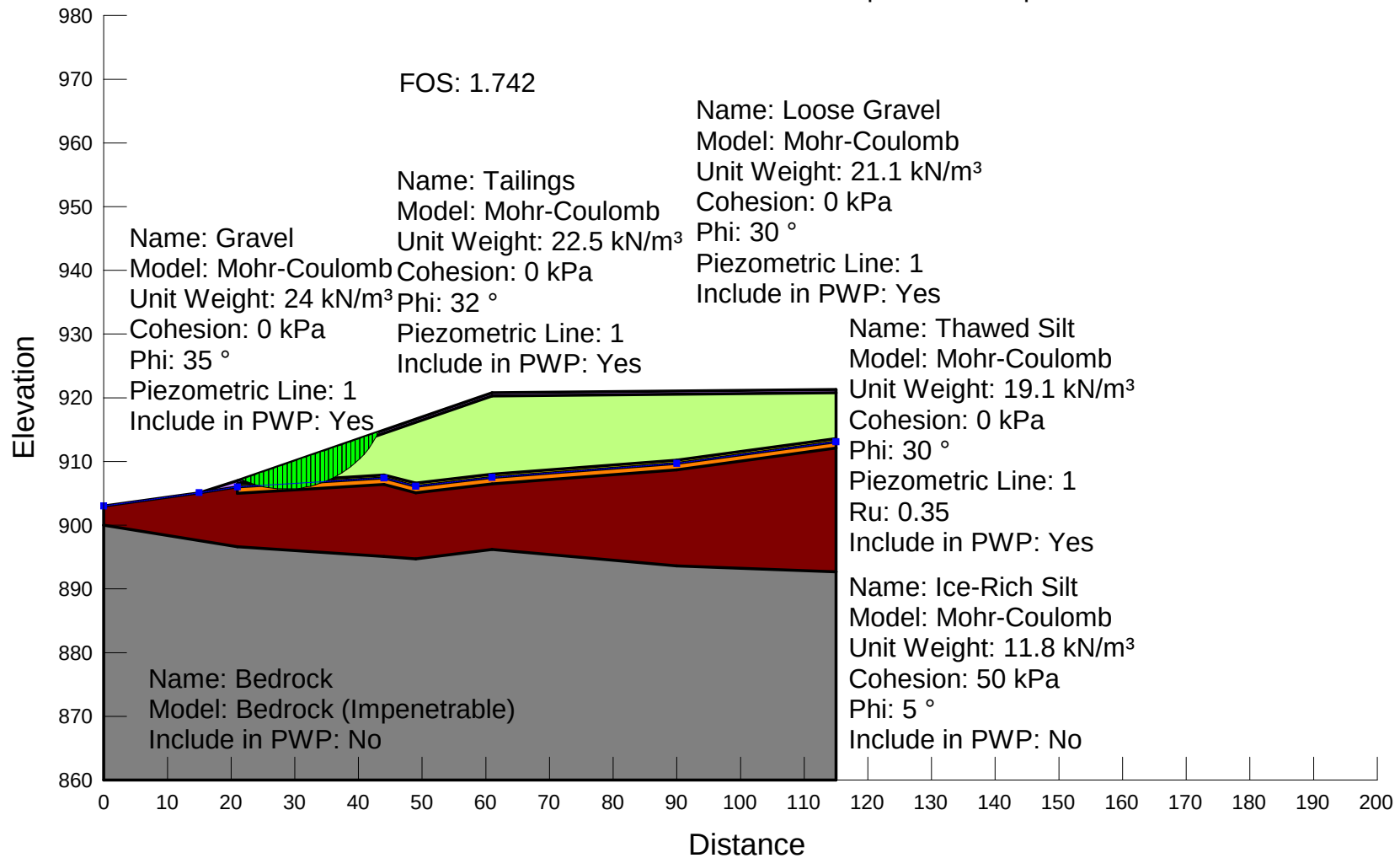
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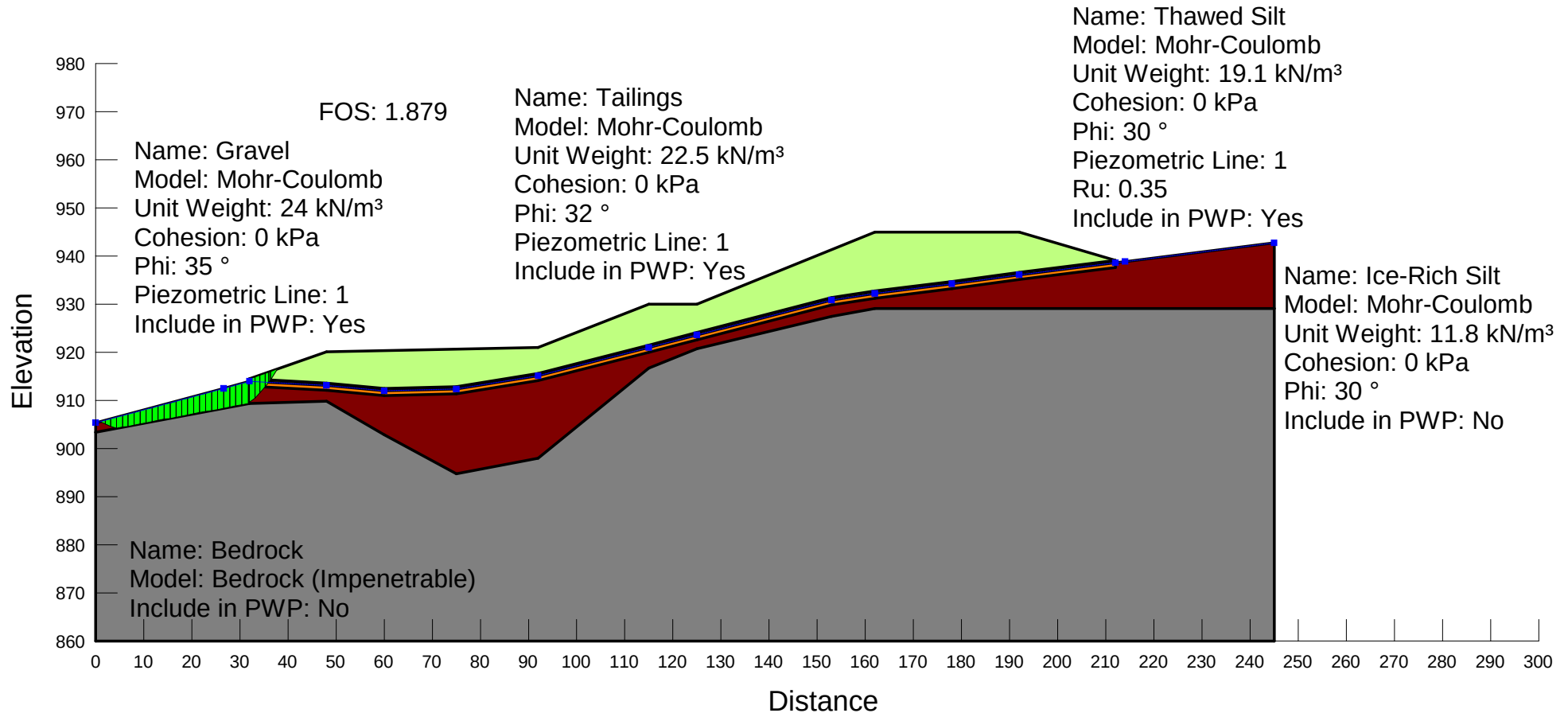
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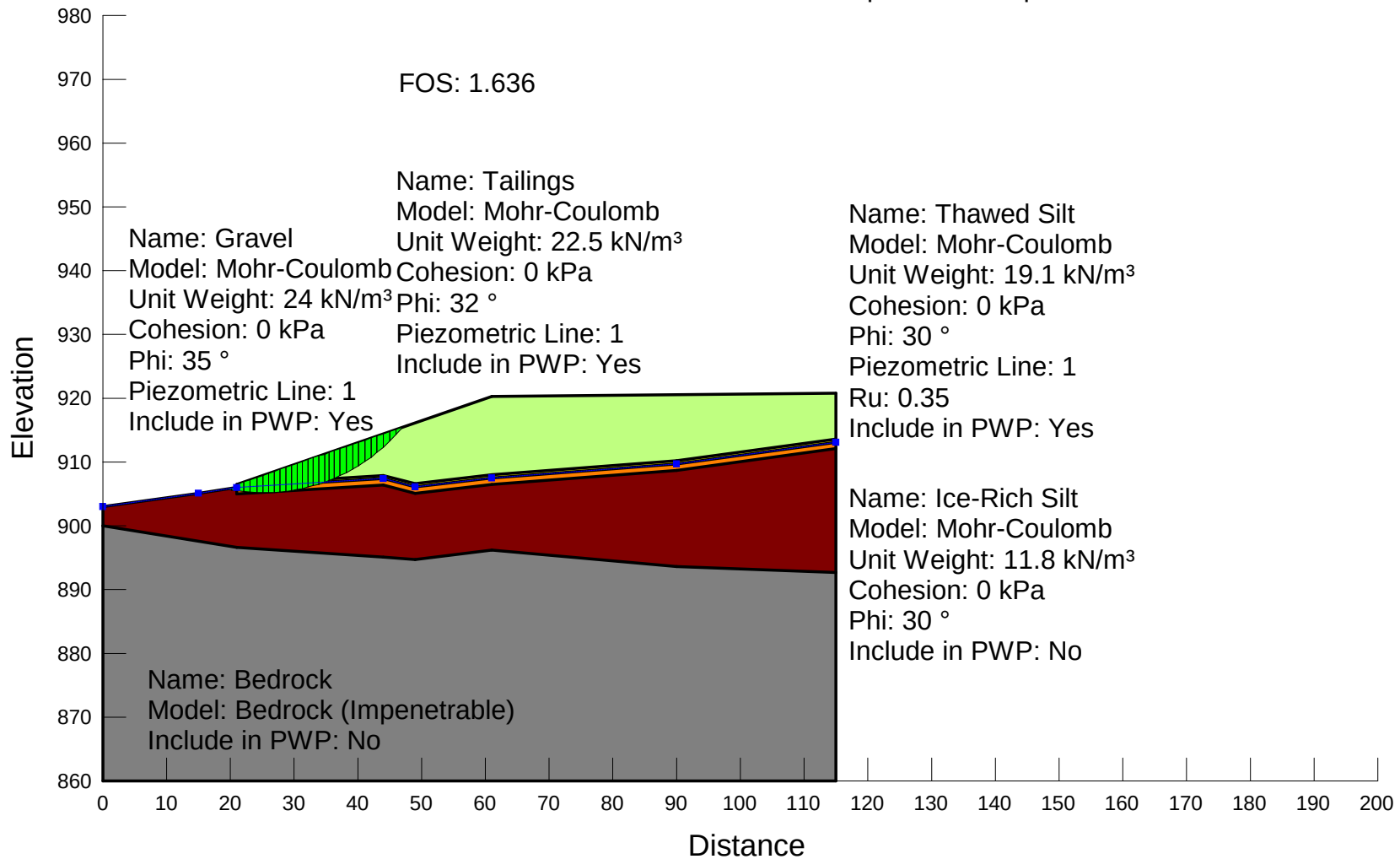
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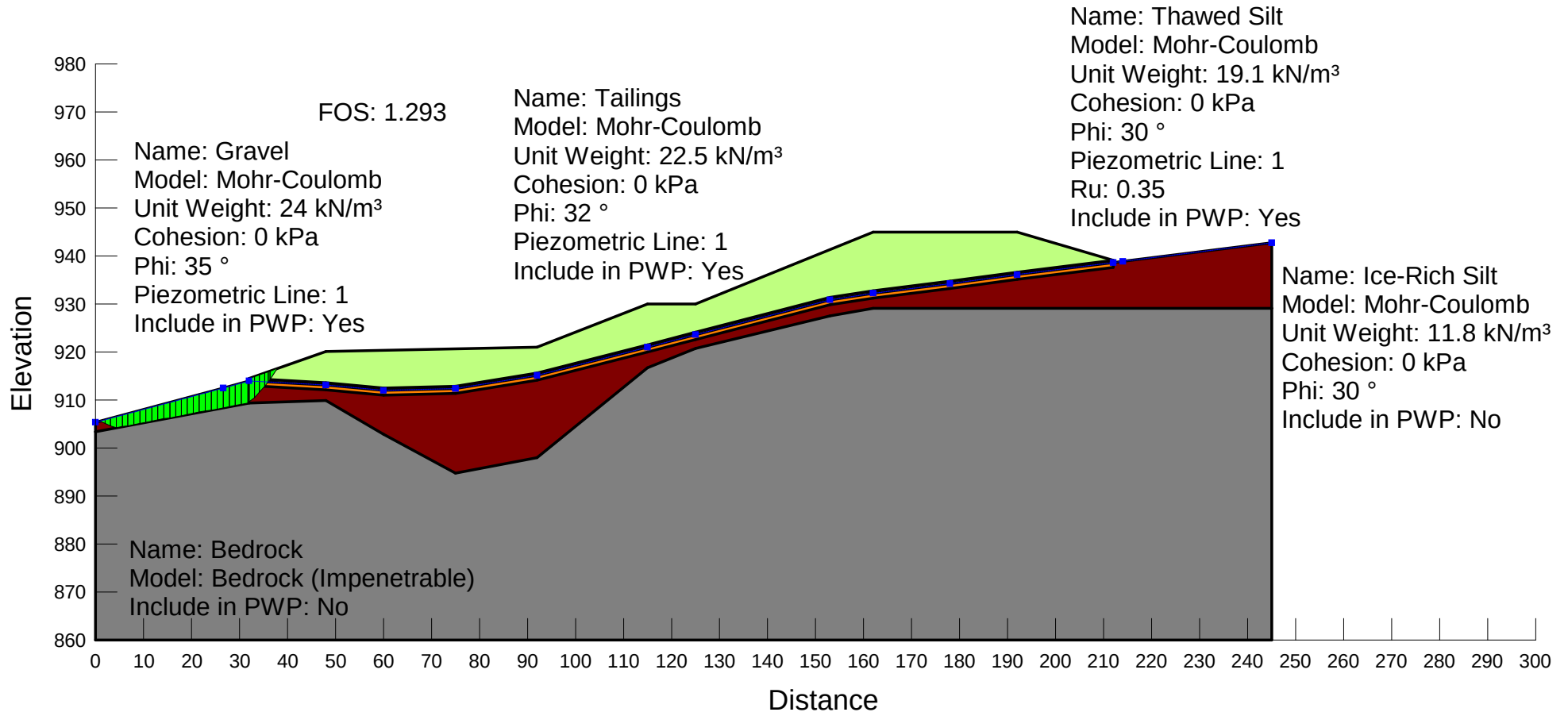
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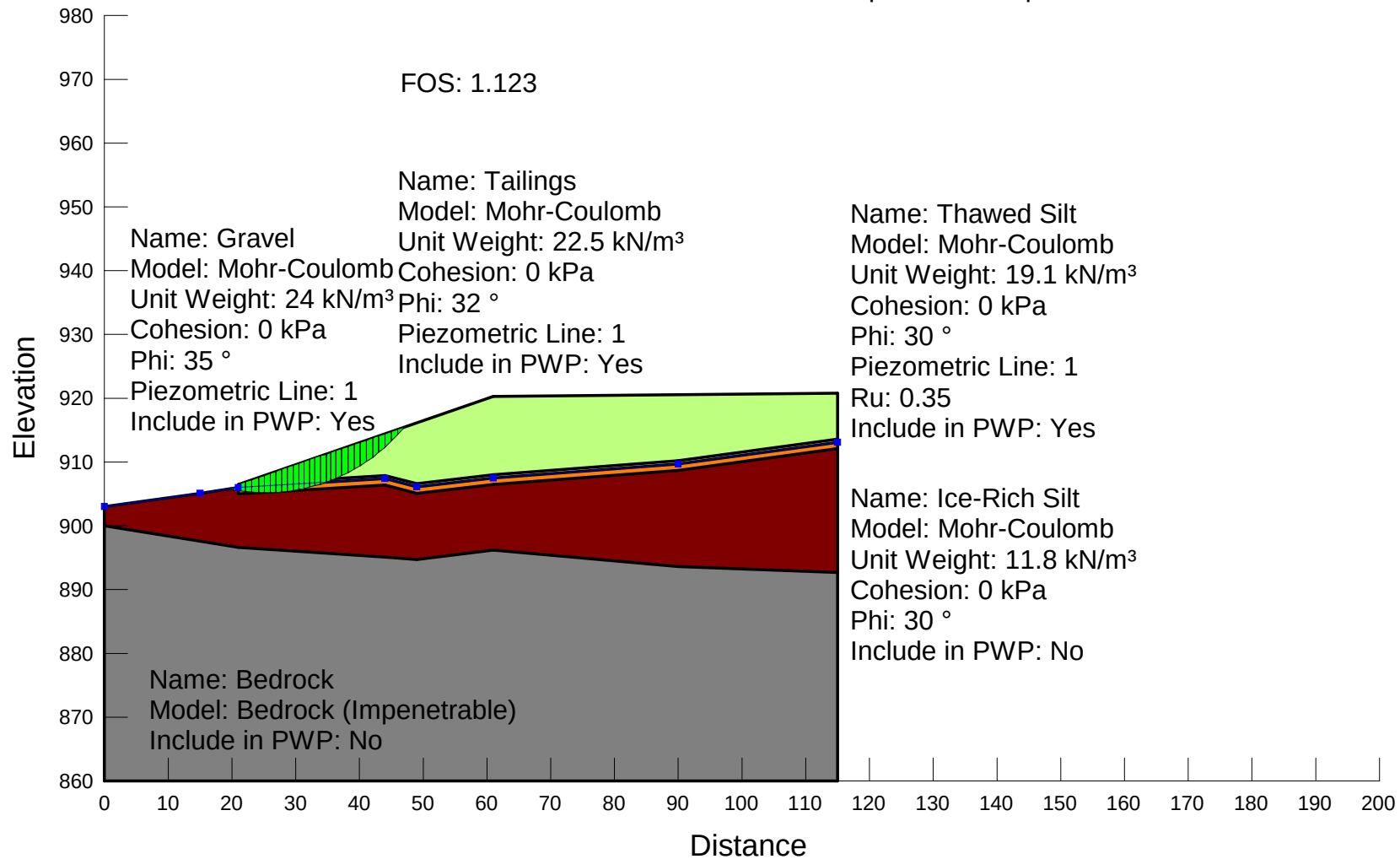
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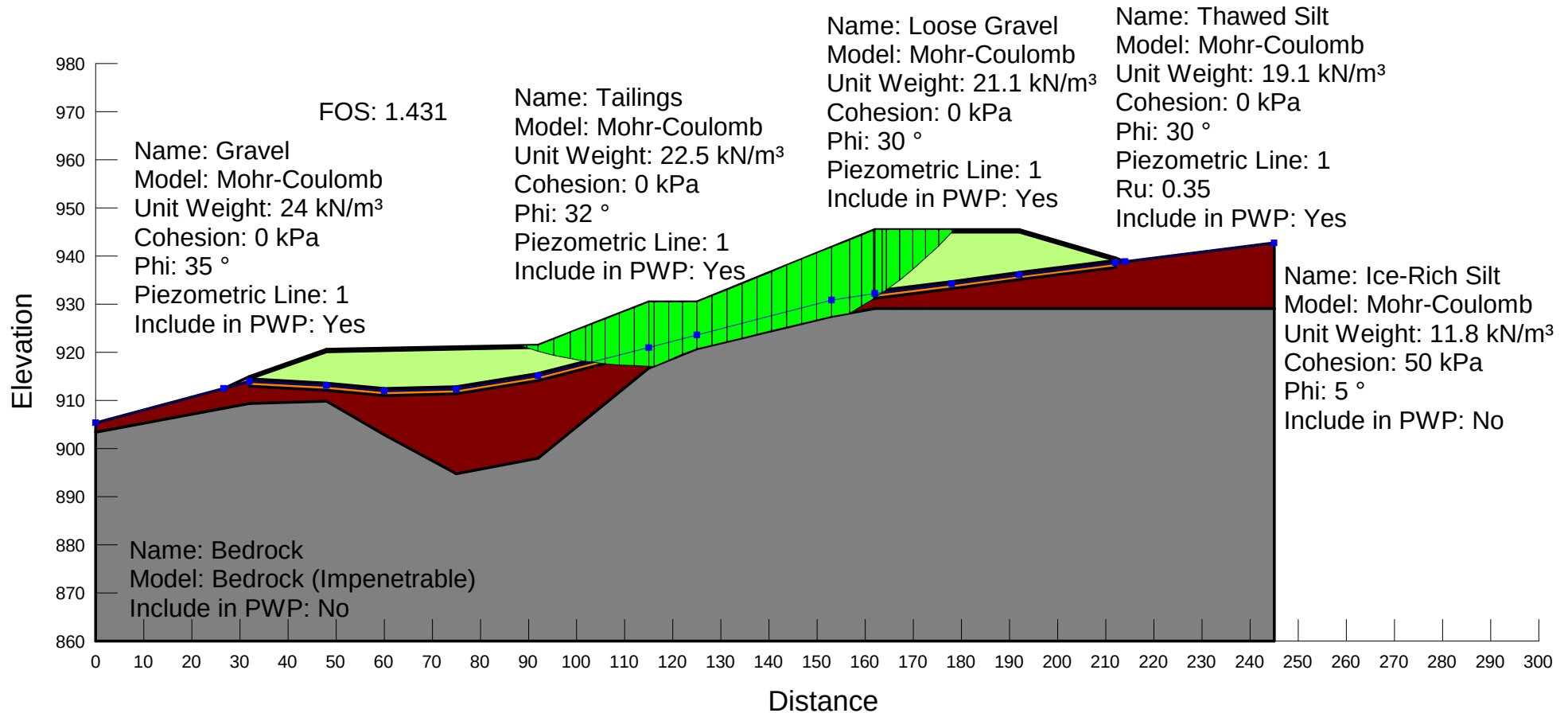
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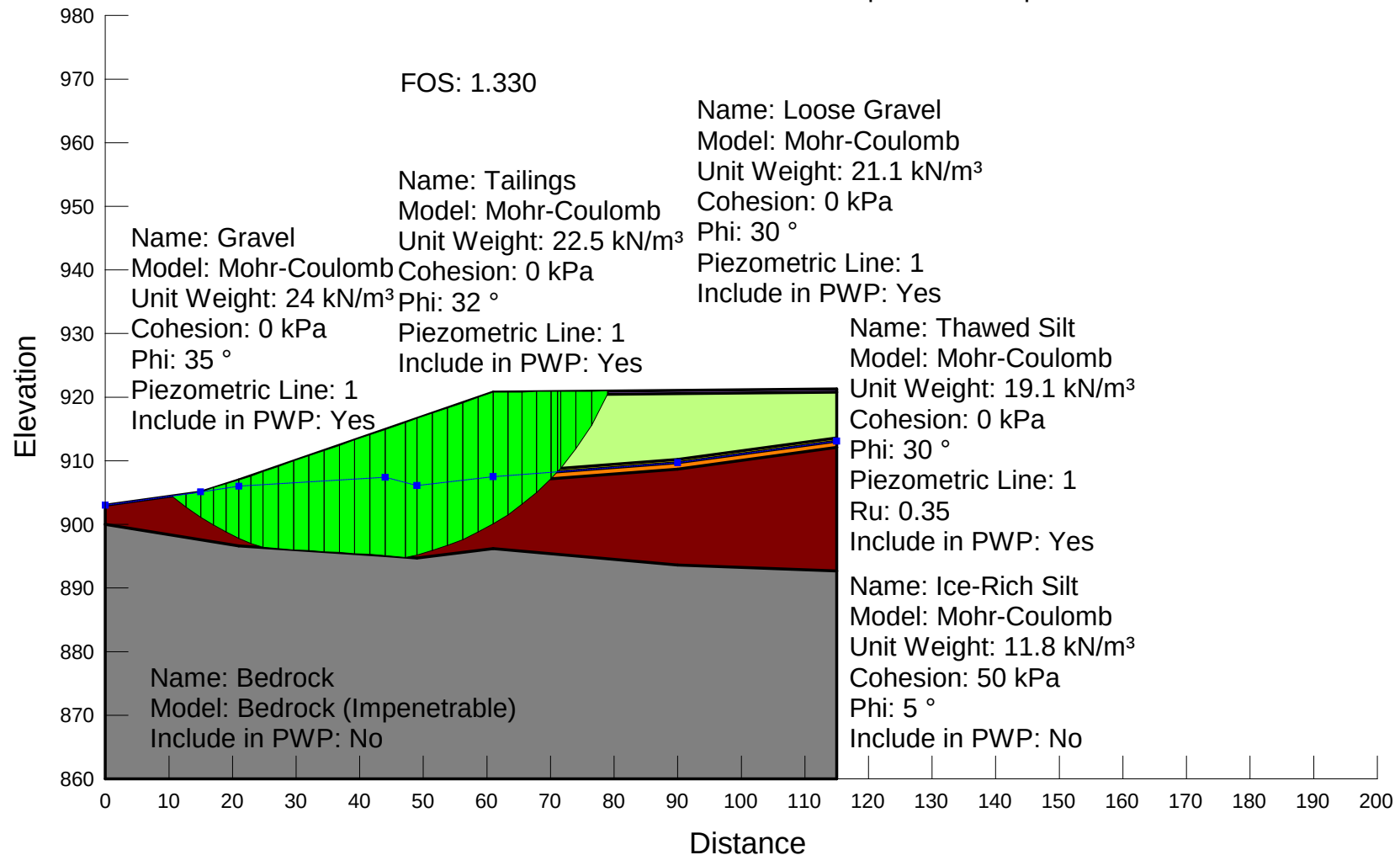
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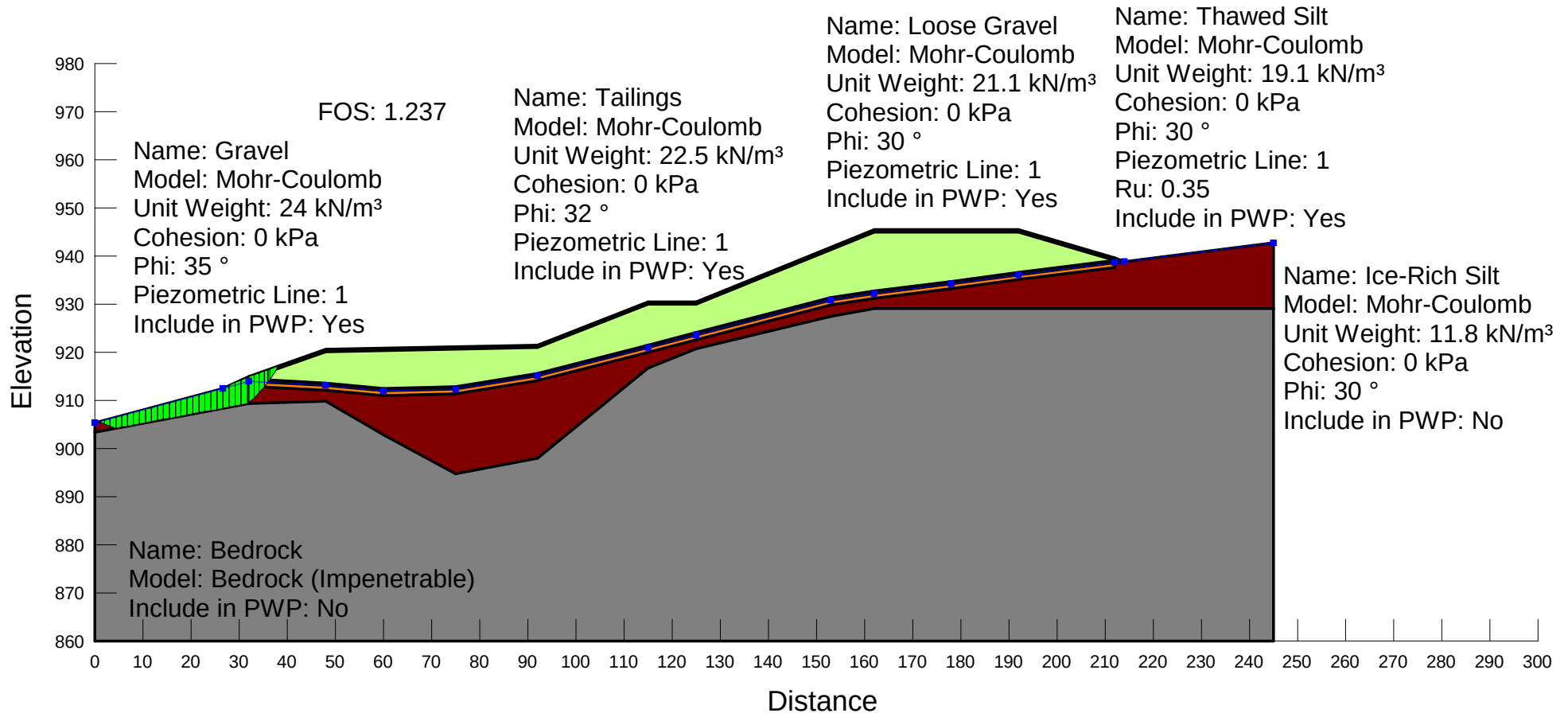
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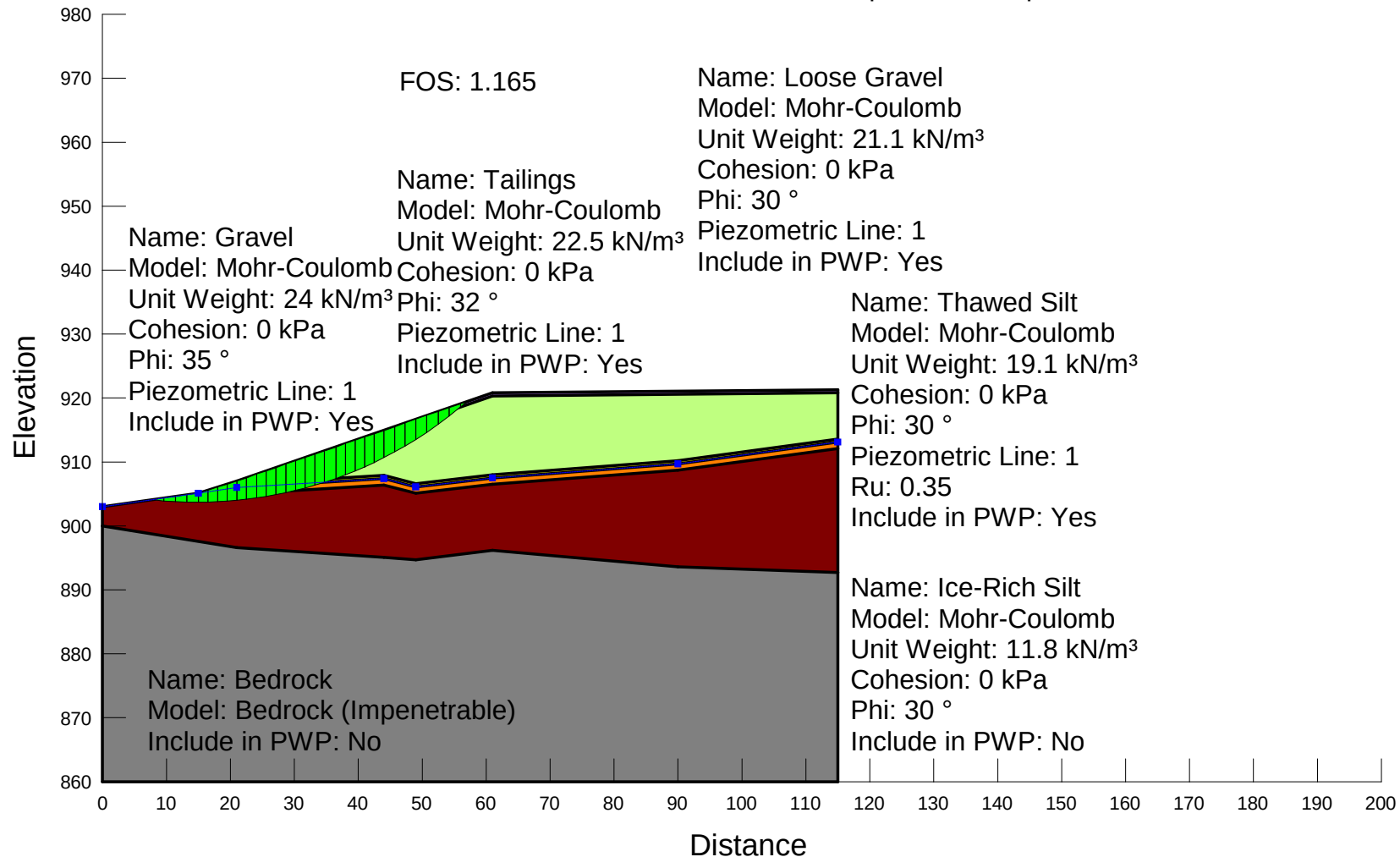
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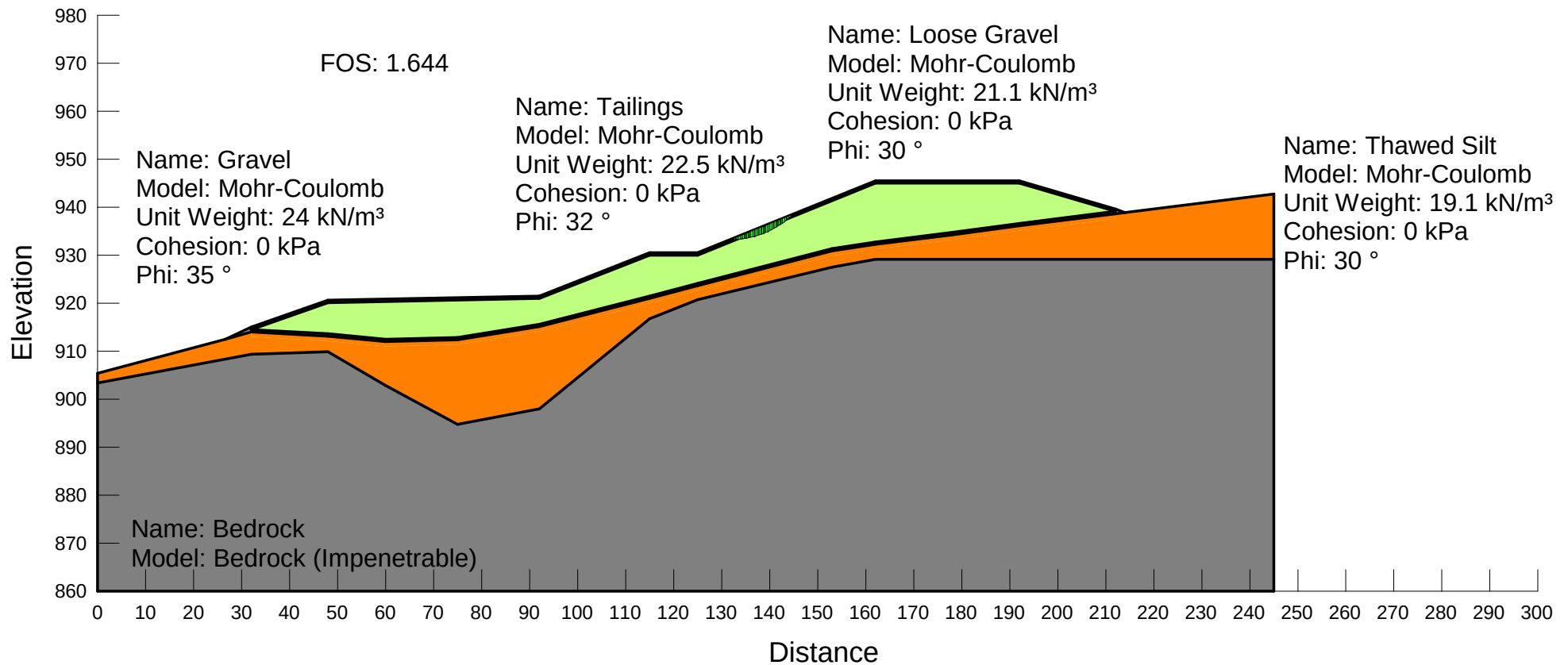
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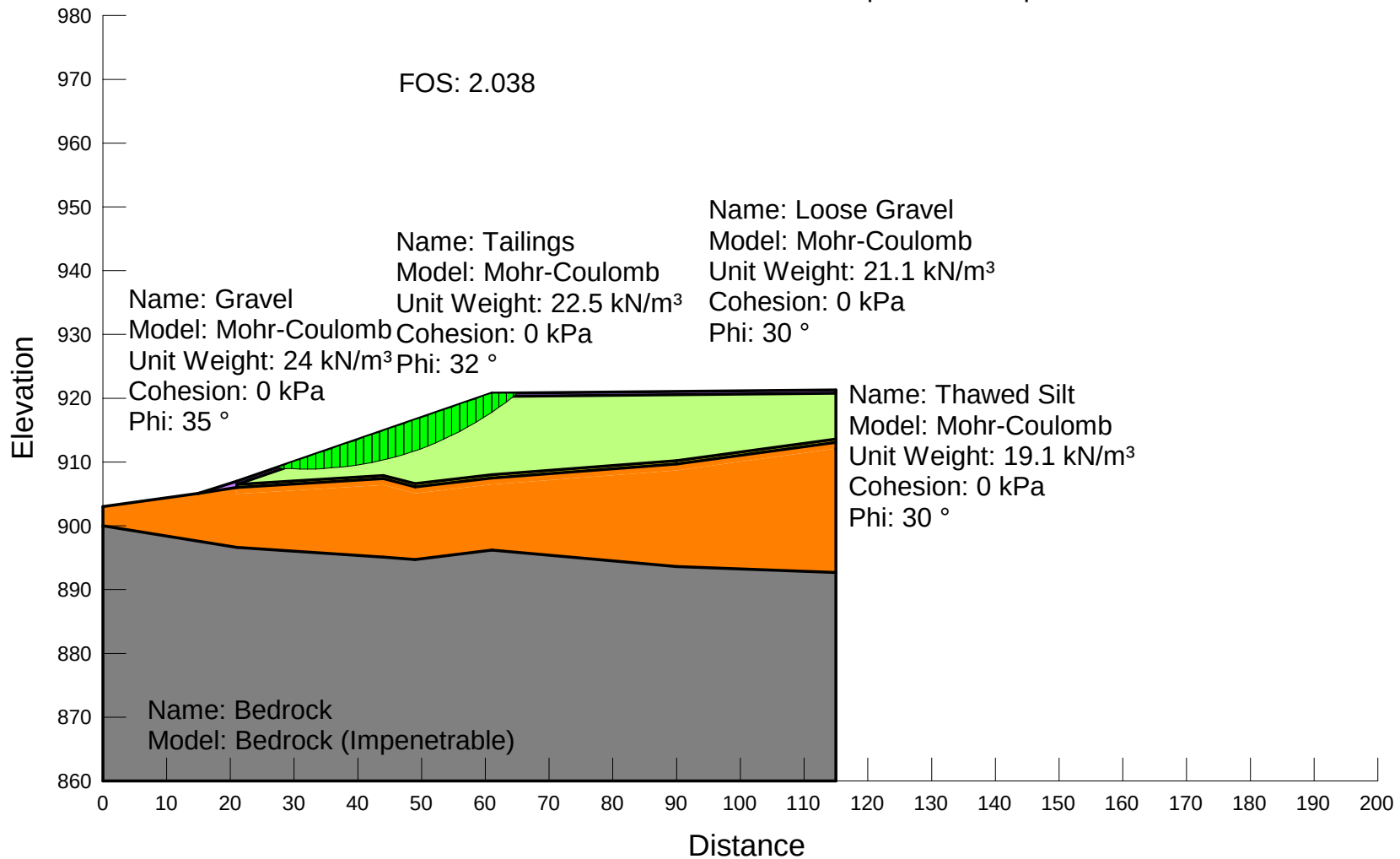
APPENDIX I

APPENDIX I SLOPE STABILITY RESULTS – FULLY THAWED PERMAFROST

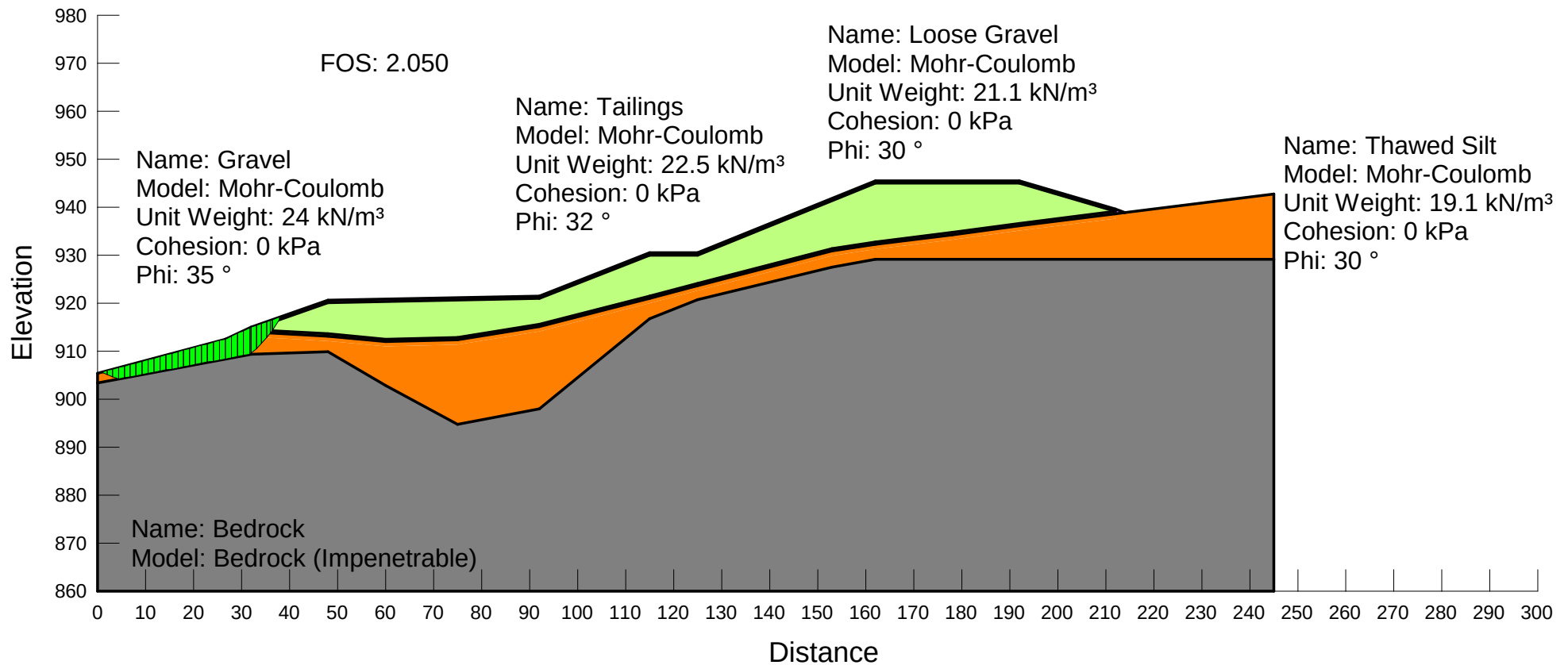
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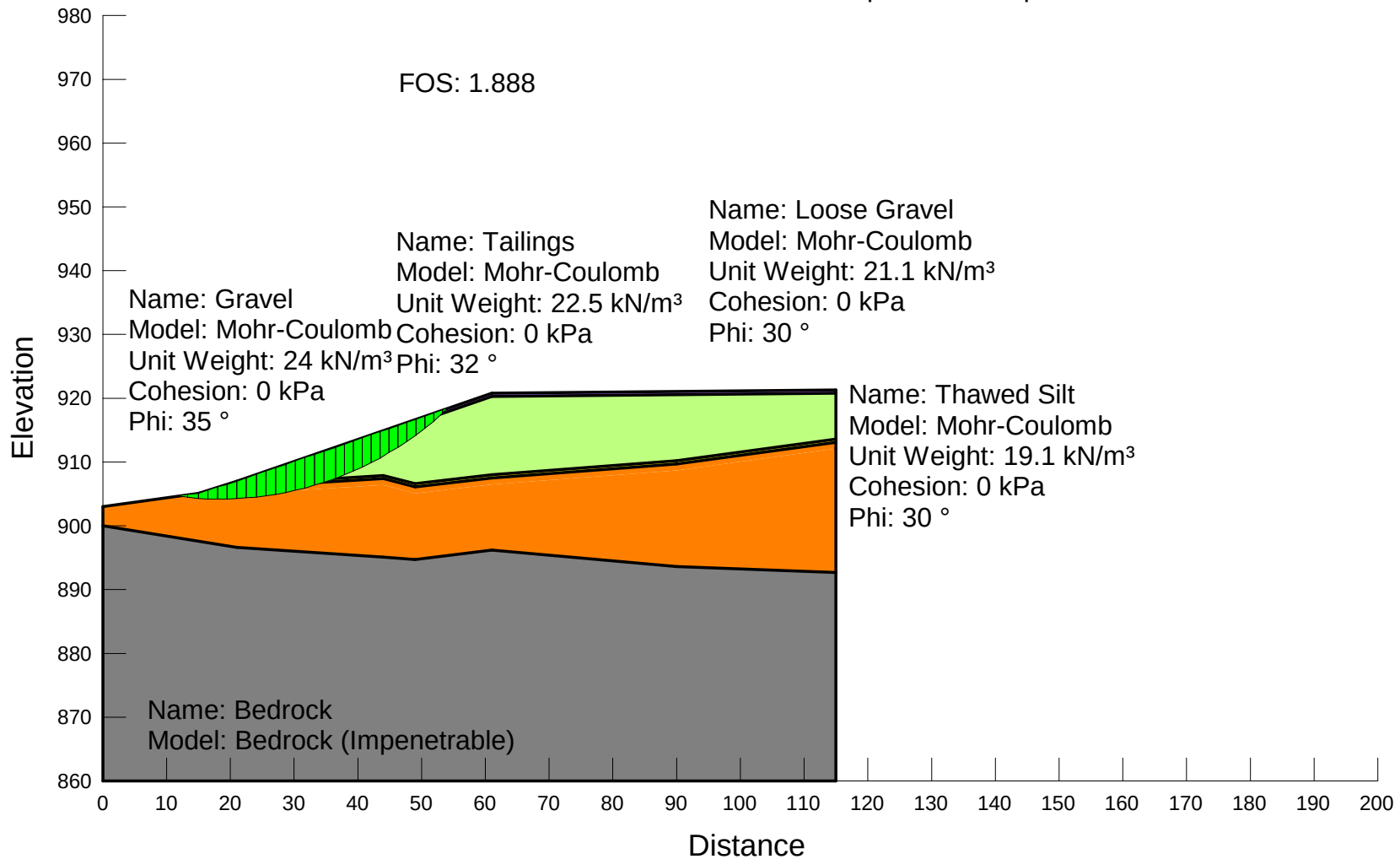
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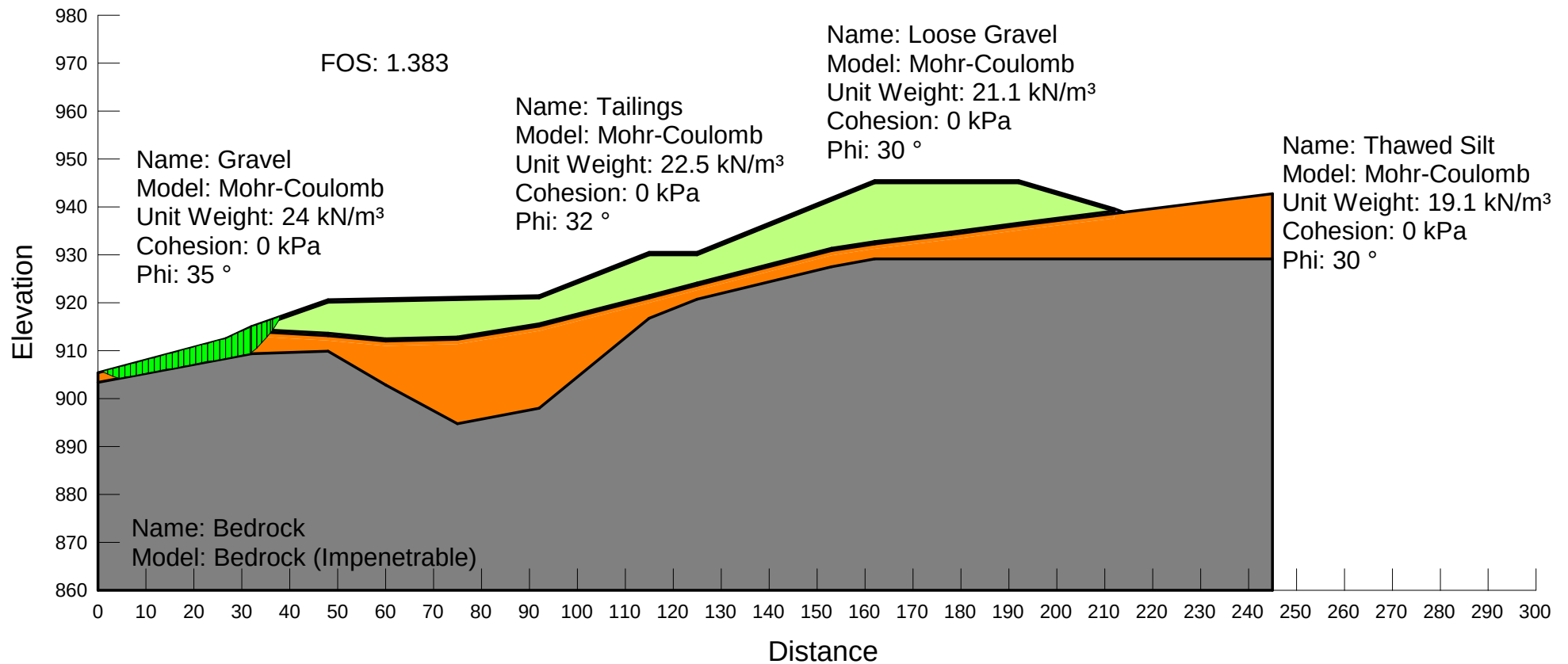
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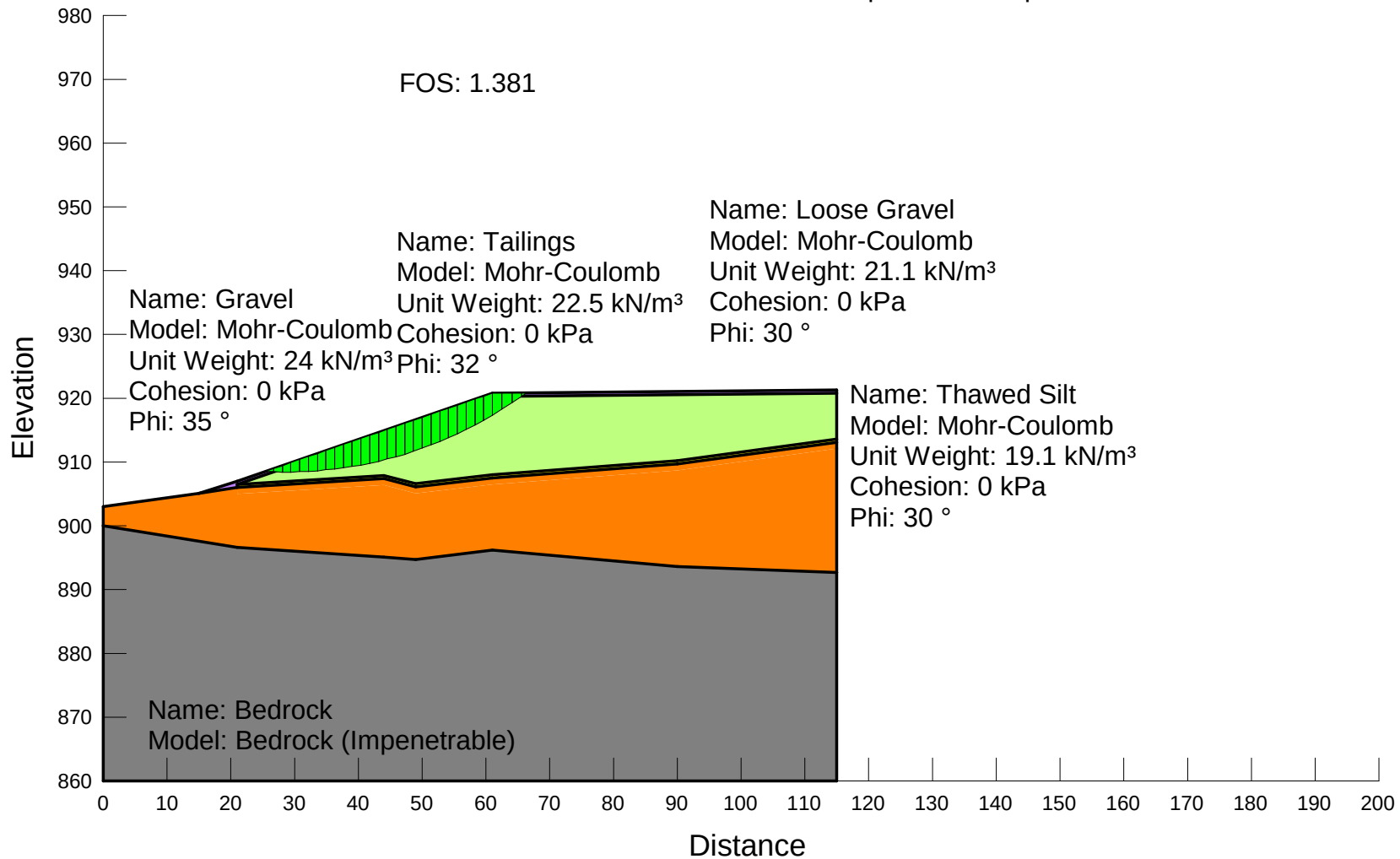
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Minimum Slip Surface Depth: 1 m



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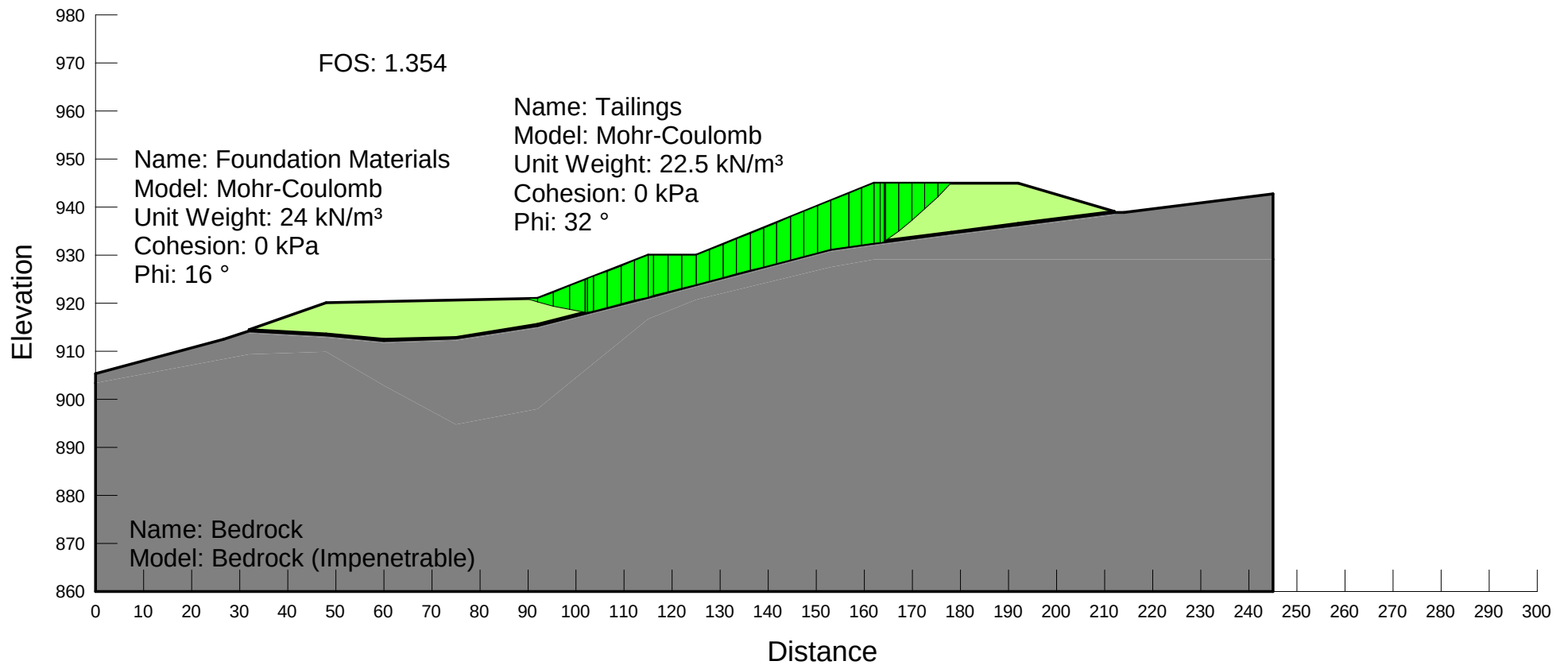
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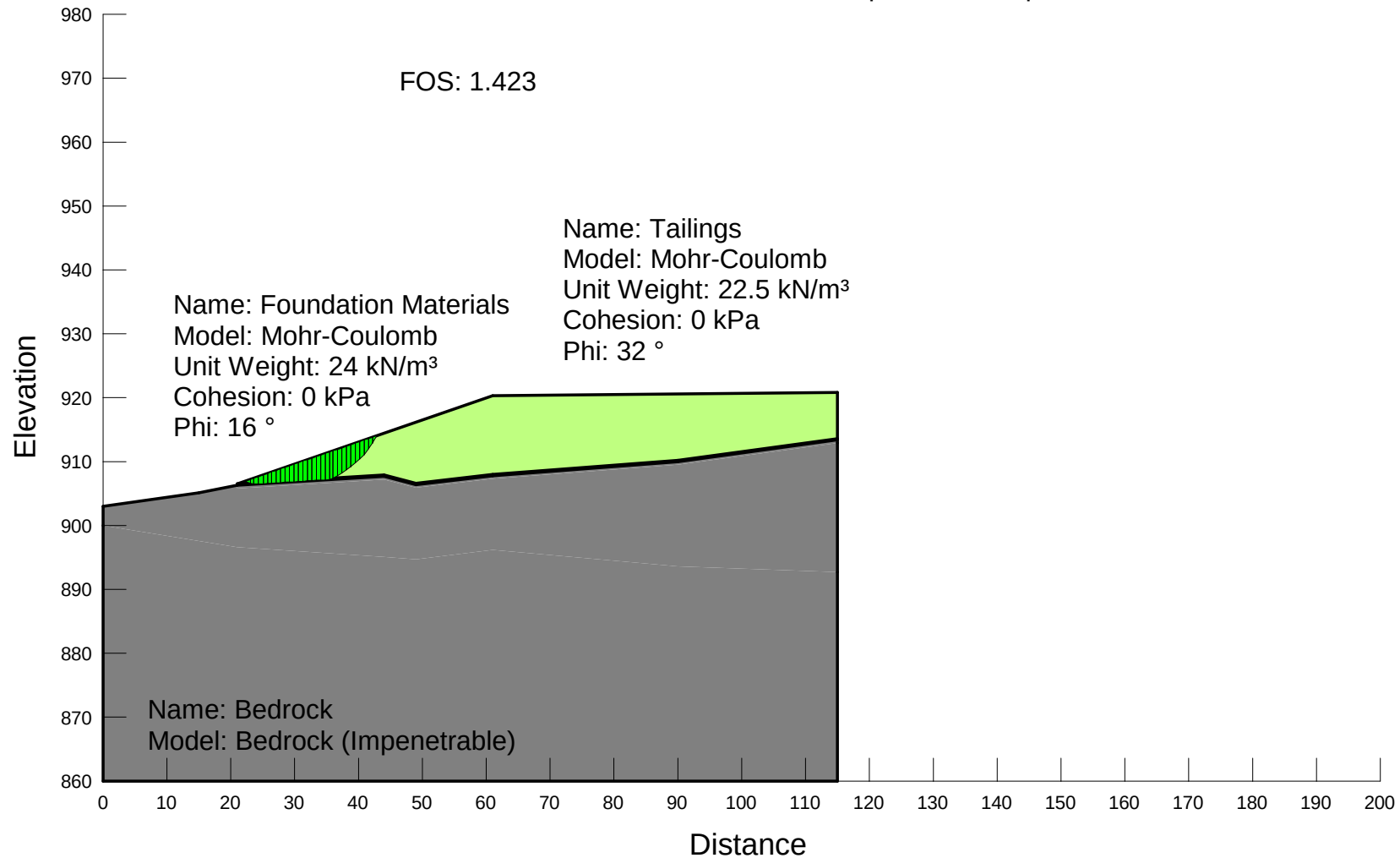
APPENDIX J

APPENDIX J SLOPE STABILITY RESULTS – DSTF FOUNDATION

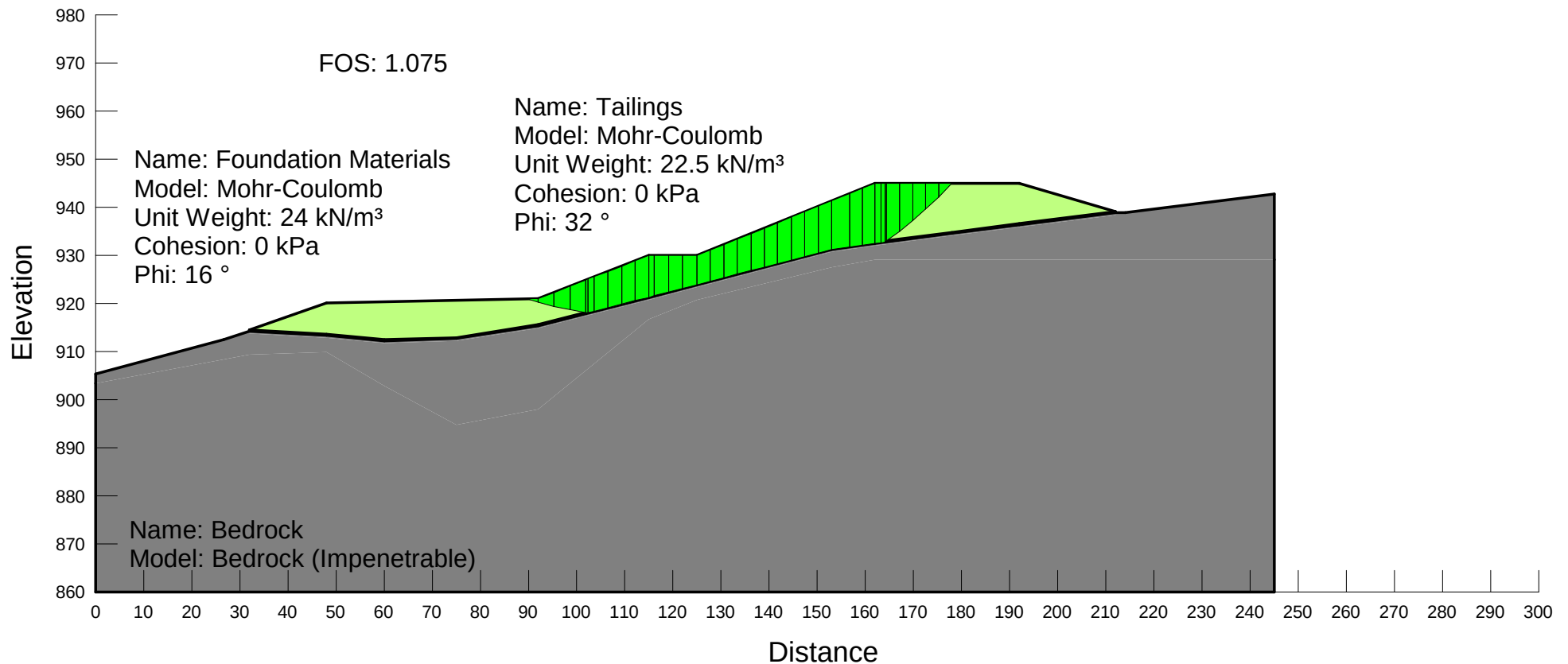
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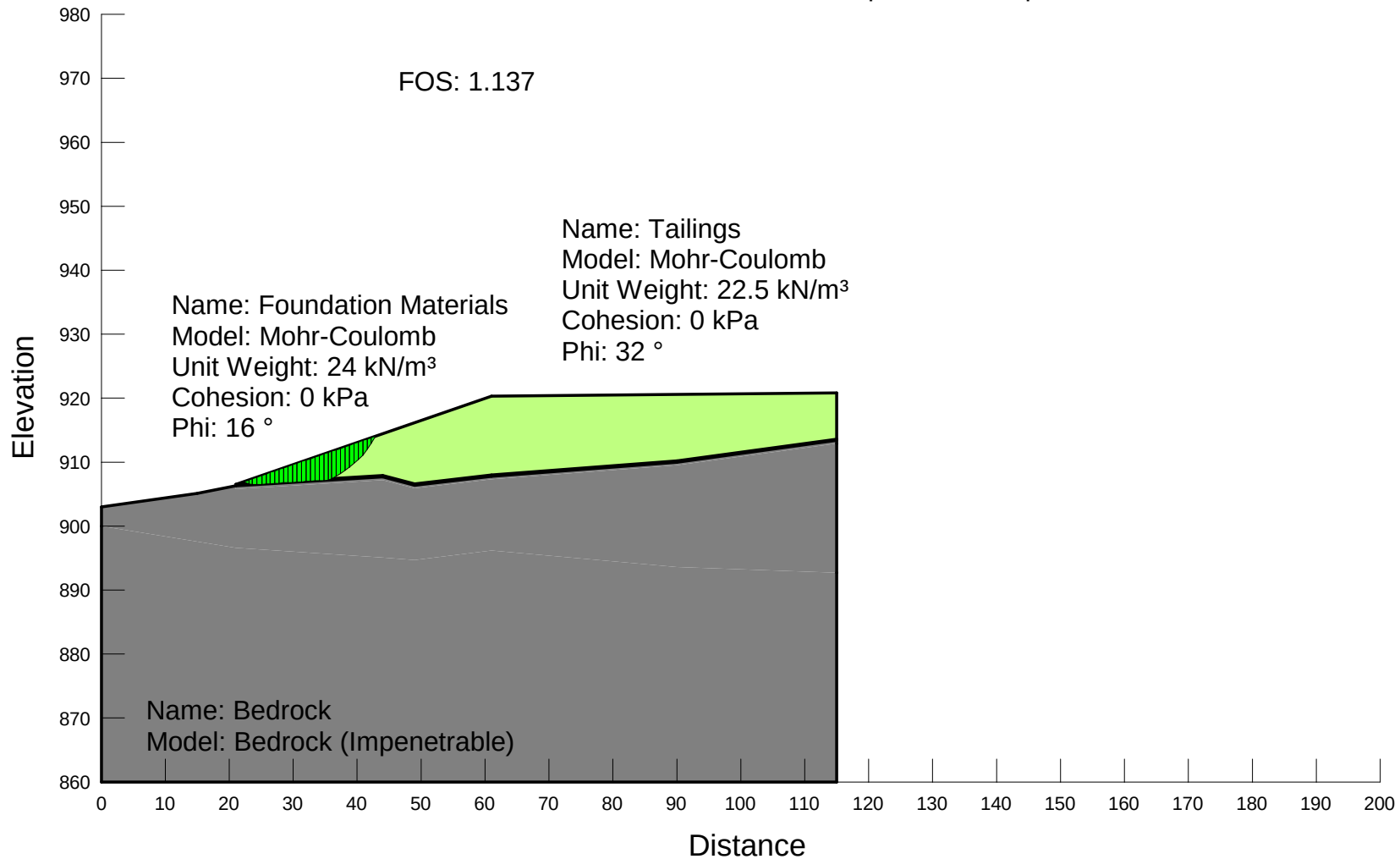
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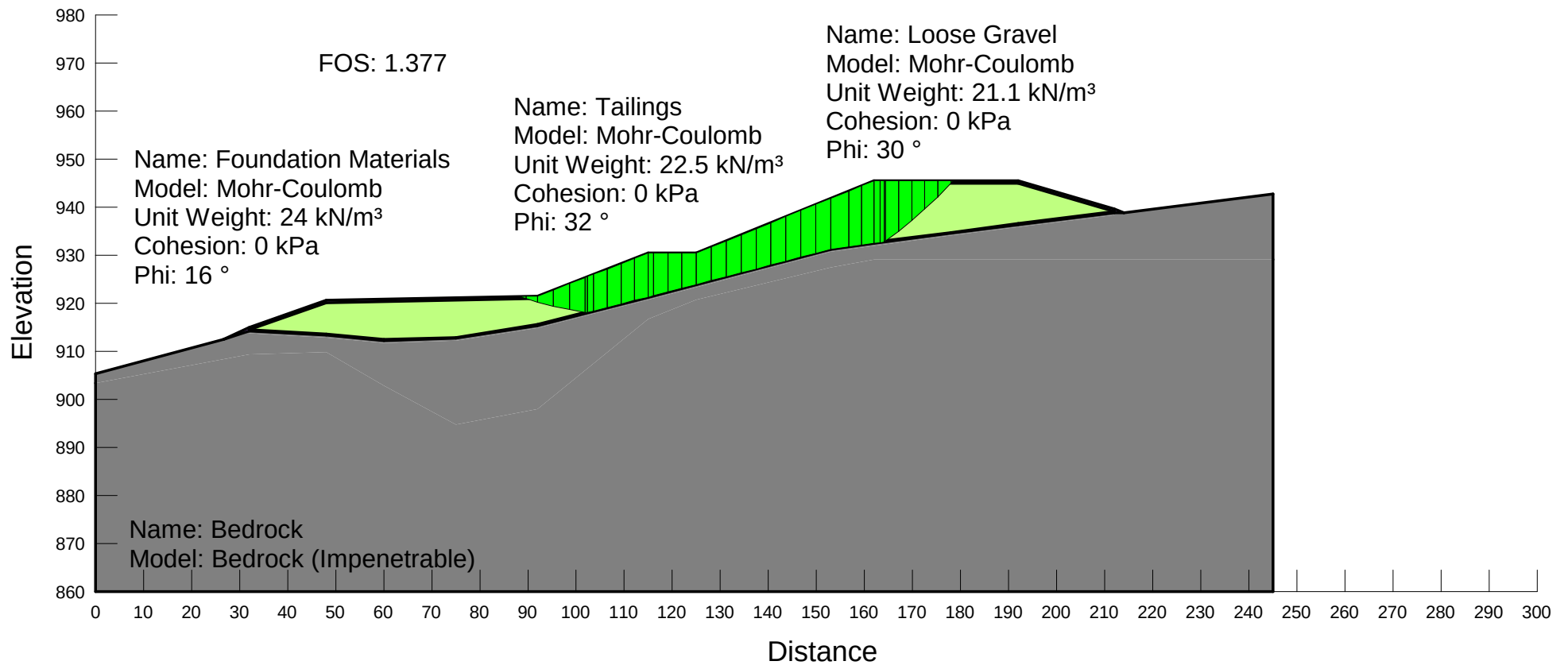
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Vertical Scale: 1250
Minimum Slip Surface Depth: 1 m



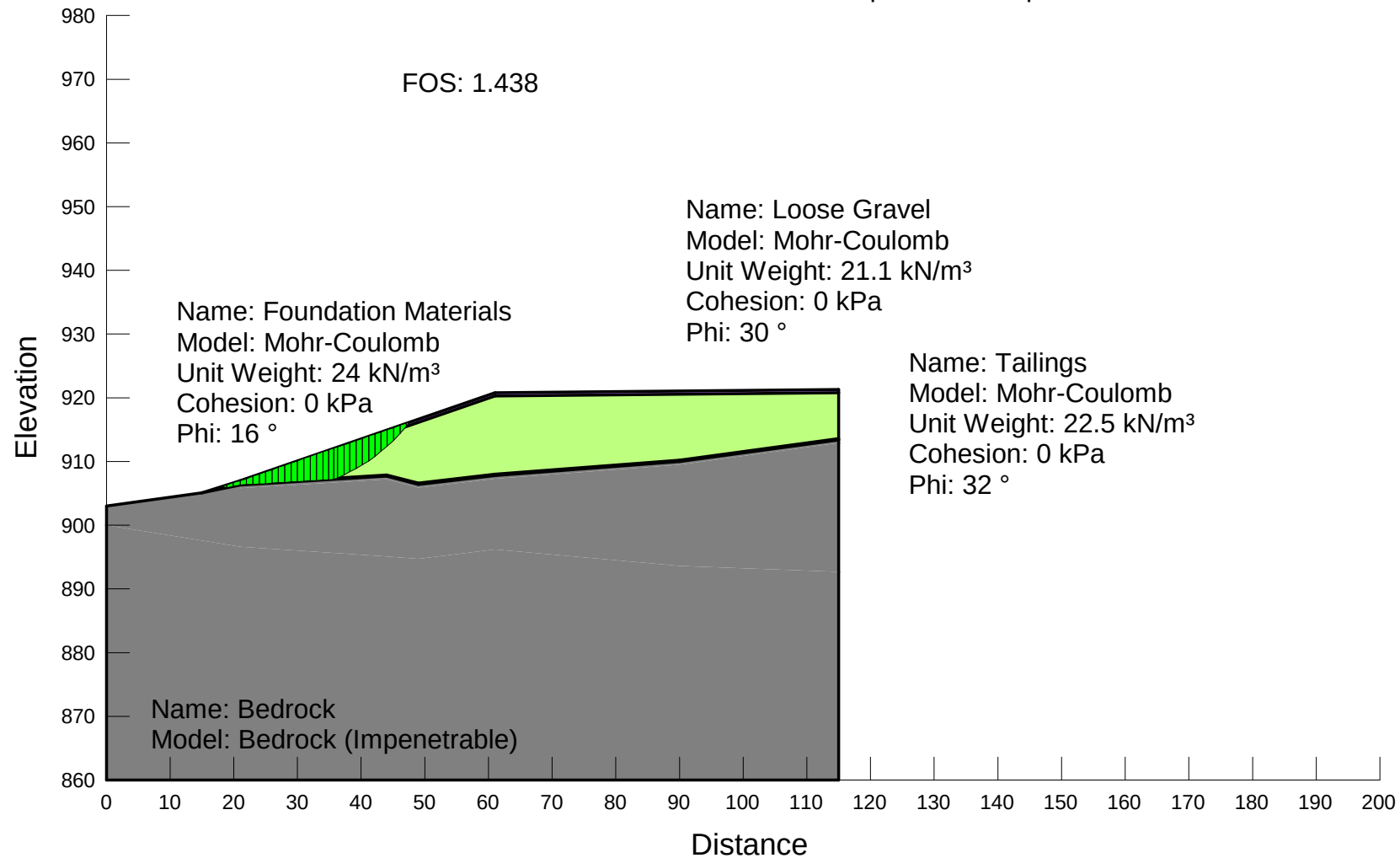
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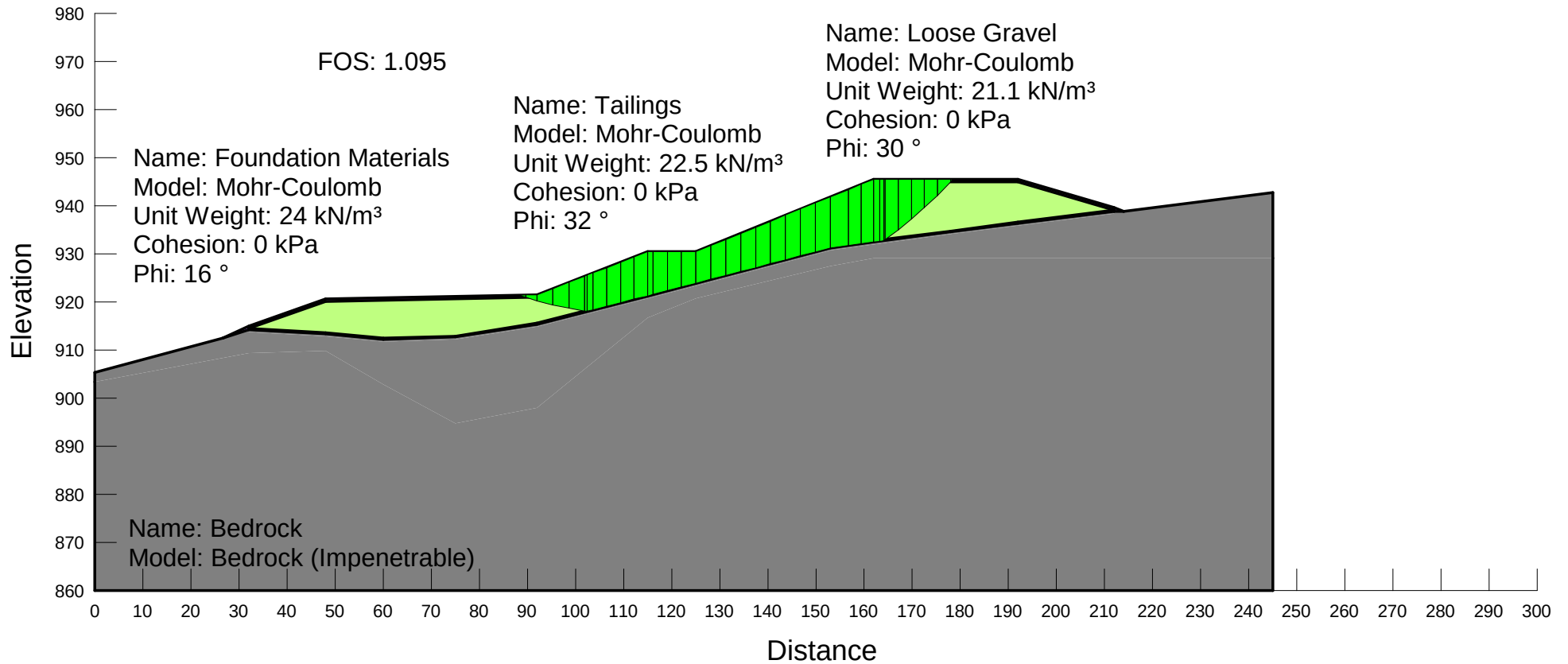
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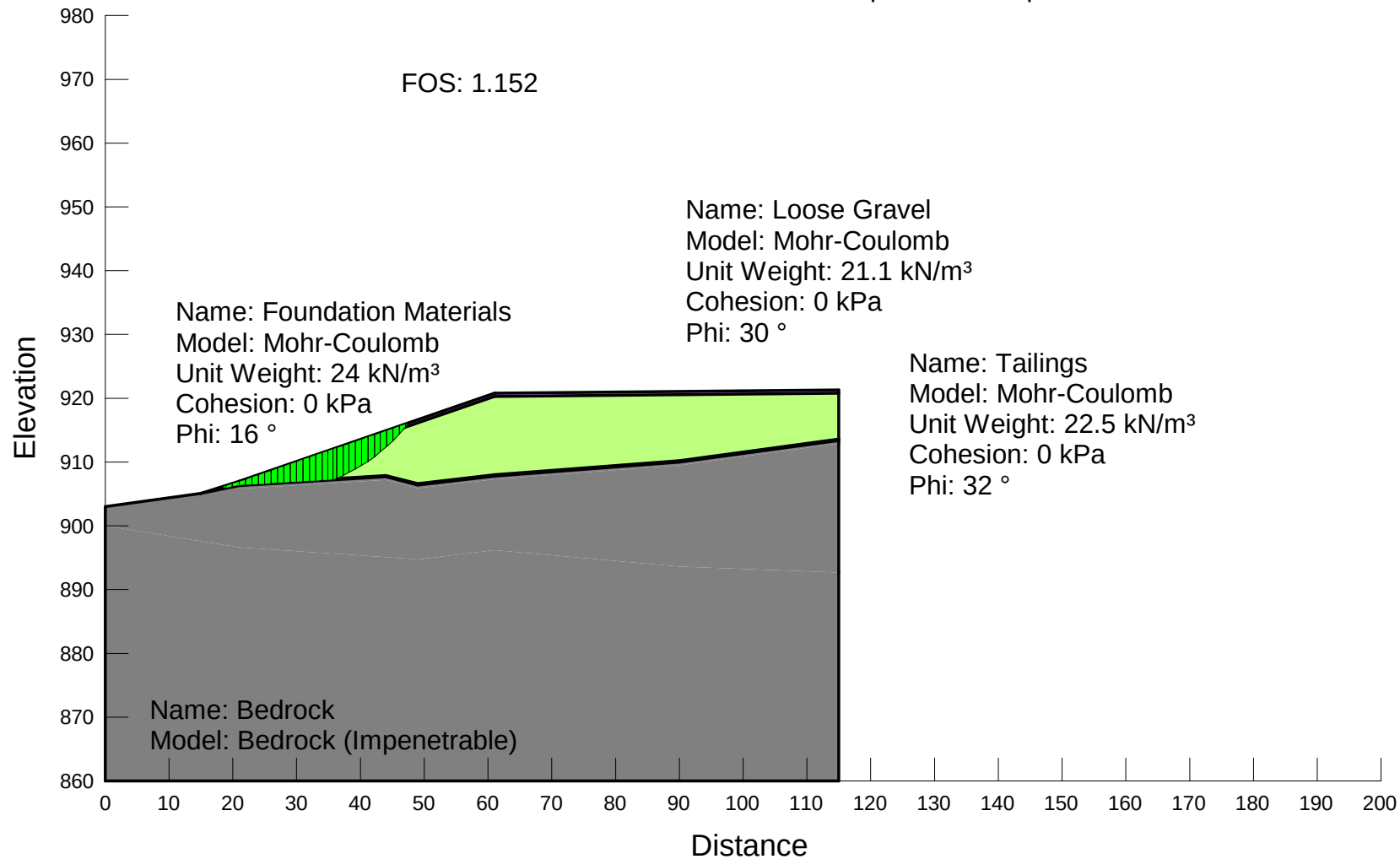
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Horizontal Scale: 1000
Vertical Scale: 1000
Minimum Slip Surface Depth: 1 m



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Vertical Scale: 1250
Minimum Slip Surface Depth: 1 m



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Minimum Slip Surface Depth: 1 m



Appendix B – Phase 2 Design Basis



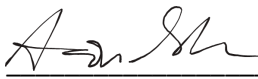
Dry Stack Tailings Disposal Facility – Phase 2

Project Design Basis

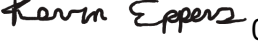
Rev.	Date (D-MM-YYYY)	Author (Name)	Approved (Name)	Description/Remarks
0	6/10/24	Aaron Marsh		Initial draft for Signature
1	7/29/24	Aaron Marsh		Revisions per ITRB Input, and adjustments to clarity

Prepared by: Aaron Marsh
Hecla Manager – Tailings
Dry Stack Tailings Disposal Facility Phase 2 Project Manager
Coeur d’Alene, ID

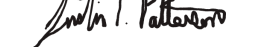
30 July 2024

Approved By:  07 / 30 / 2024

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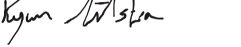
Richard Trimble, P.Eng.
Engineer of Record
Tetra Tech Canada

 07 / 30 / 2024

Shawn Pelechaty
Mill Manager
AKHM

 07 / 31 / 2024

Coralee Kirby
Health & Safety Manager
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 07 / 30 / 2024

Ryan Tilstra
Chief Engineer
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Brian Erickson
VP Alaska & Yukon Operations
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Ian MacIntyre, P.Eng.
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INTRODUCTION

This document presents the key project information in a consolidated design basis (CDB) for the dry stack tailings facility (DSTF) owned and operated by Alexco Keno Hill Mining Corp (AKHM) within the Keno Hill Silver District (KHSD), located near Keno City, Yukon. This document forms the basis for design for

1 REFERENCE INFORMATION

1.1 Design and Key Technical Reports

Key design reports are summarized in Table 1-1 and Table 1-2 summarizes key Knowledge Base¹ documents for the DSTF as of the date of Design Basis Memorandum (DBM) issue. Table 1-3 lists applicable permits.

Table 1-1: Key Dry Stack Tailings Disposal Facility Design Reports

Report Issue Date (Author)	Report Title
2024 (TT)	Phase II Expansion Detailed Design – Revision 1. Dry Stack Tailings Facility. Keno Hill District Mine Site, Yukon.
<i>To be populated at a later time</i>	

Table 1-2: Key Knowledge Base Documents

Report Issue Date (Author)	Report Title
<i>Table to be added to and updated at a later time.</i>	

1.2 Regulatory Permits, Standards, and Guidelines

AKHM has obtained permits from the following Regulatory Agencies and First Nations groups:

- Yukon Workers' Safety and Compensation Board (WCB)
- Yukon Department of Energy, Mines and Resources (EMR)
- Yukon Water Board (YWB)
- The First Nation of Nacho Nyak Dun (NND)

The following permits/approvals pertain to the DSTF, all of which are managed by AKHM.

Table 1-3: Applicable Permits

Entity	Permit	Revision Date
EMR	Quartz Mining License QML -0009	27 November 2019
YWB	Water License QZ18-044	22 July 2020
EMR	AKHM Waste Rock Management Plan Rev 6.5	October 2021
EMR	AKHM Mill Development and Operations Plan Rev 7	May 2024
EMR	Tailings Characterization Plan Rev 7	October 2023

¹ A Knowledge Base document is one that supports the safe management of a tailings facility by describing the fundamental elements of the site, including site characterization and baseline knowledge of the social and environmental context (GISTM 2020).

Table to be added to and updated at a later time.

Additional key regulations, standards and design guidelines are summarized in Table 1-4.

Table 1-4: Regulations, Standards, and Guidelines References

Regulation / Standard / Guideline	Agency / Author	Document	Version and/or Date
Regulation	WCB	Part 15 – Surface and Underground Mines or Projects	May 2006
Guideline	EMR	Guidelines for Mine Waste Management Facilities	Feb 2023
Table to be added to and updated at a later time.			

2 CHANGES TO KEY DESIGN BASIS WITH TIME

Some key components of the design basis have changed with time as the DSTF has grown in size, Hecla and AKHM have adjusted their risk tolerances alongside improvements to industry best management practices. A summary of key changes to the design basis is provided in Table 2-1.

Table 2-1: Summary of Key Changes to the Design Basis

Design Basis Item	Item	History of Design Basis
Table to be updated at a later time.		

3 DESIGN BASIS

Table 3-1 presents the key project design basis that shall be used when designing modifications to the DSTF.

Table 3-1: Design Basis

Design Basis Item	Design Basis	Reference / Source
1	Survey & Property Information	
1.1	Coordinate System	• NAD83 CSRS / UTM Zone 8N AKHM
1.2	Units	• Metric units AKHM
1.3	Existing Ground Topography	• 2014 LiDAR AKHM
1.4	Property Line Setbacks	• Excavation near property line: Excavation in sand, clay, or gravel or other unconsolidated material shall not be carried on within a setback distance of 5 m (16 ft.) horizontal from the vertical plane of the property boundary. • Excavation at toe of face: Material excavated from the inside edge of the setback shall be cut so that the slope is not steeper than 1.5 horizontal to 1.0 vertical, and any material that sloughs in this area shall be left in place. WCB

Design Basis Item	Design Basis	Reference / Source
1.5 Right of Way	- The Duncan Creek Road Right of Way (ROW) is 60 m, centered on the road centerline. - Tailings shall not be stored within the ROW. - The outboard edge of the contact water ditch may be positioned at the edge of the ROW, i.e. 30 m from the road centerline. See Figure 3-1.	AKHM
2 General Site Management		
2.1 Borrow material	- Borrow material shall be Non-Acid and Metals Leaching (NAML) material that complies with AKHM's Waste Rock Management Plan. - Preference shall be given to alluvial deposits to minimize long-term geochemical risks	AKHM
2.2 Laydown	- The design shall provide estimated size of required construction laydown. The laydown area shall account for: - Borrow material processing and stockpiling of: - Produced material, - Oversize fraction, and - Undersize fraction. - Stockpile areas for cut timber.	AKHM
3 Definitions		
3.1 Contact Water	Water that comes into contact with tailings, concentrate, or other byproducts of the mining and milling process that would produce water that does not meet applicable water quality standards.	AKHM
3.2 Inflow Design Flood	The Inflow Design Flood (IDF) is the largest flood event that can be safely passed.	AKHM
3.3 Environmental Design Flood	The Environmental Design Flood (EDF) is the largest flood that can be managed without release of untreated contact water to the environment.	AKHM
3.4 Critical Duration	- The critical duration of a storm event is defined as the length of time that the inflow into the system exceeds the outflows from the system. - Different components of the water management system may have different critical durations. For example, the critical duration of a conveyance channel is going to be extremely short to reflect that ditches are to be designed to convey peak flows. On the other hand, the critical duration for a storage pond will be longer because the storage capacity of the pond buffers peak flows such that discharge capacity can be less than the inflow capacity.	AKHM
3.5 Freeboard	Vertical distance between water level and lowest edge of adjacent containment	AKHM
4 Climate and Hydrology		
4.1 Precipitation data source	Site data as appropriate, supplemented with information from the Mayo Airport.	AKHM

Design Basis Item		Design Basis	Reference / Source
5 Contact Water System Design Storms			
5.1	IDF – Permanent Structures	- Larger of: 200-yr critical duration event (EMR Table 4-2 for a Class II facility) 500-yr (0.5% Annual Exceedance Probability [AEP]) peak instantaneous flow² (AKHM).	EMR/AKHM
5.2	IDF – Temporary Structures	The IDF for temporary structures shall be selected such that the probability of the event occurring over the life of the temporary facility is less than or equal to the probability of the permanent structure IDF occurring in a 75-year period.	AKHM
5.3	EDF – Permanent Structures	100-yr critical duration event (EMR Table 4-2 for a Class II facility)	EMR
5.4	EDF – Temporary Structures	The EDF for temporary structures shall be selected such that the probability of the event occurring over the life of the temporary facility is less than or equal to the probability of the permanent structure EDF occurring in a 75-year period.	AKHM
5.5	Ice Design Event	1/5-year (20% AEP) ice-buildup as practicable. Implications of this requirement shall be reviewed and approved by AKHM prior to implementation in the design.	AKHM
6 Non-Contact Water Design Storms			
6.1	Non-Contact Water Diversion System Design Flood event	500-yr (0.5 AEP) peak instantaneous flow	AKHM
7 Tailings Stack – Geometric Requirements			
7.1	Ultimate DSTF elevation	- El. 945 m per the Phase 2 Expansion Detailed Design Report to avoid immediate needs to modify permits. - Design analyses shall consider the potential for increasing the height to the maximum geometric limits subject to other requirements described herein.	AKHM
7.2	Ultimate DSTF crest width	Min. 20 m for placement of material.	AKHM
7.3	Ultimate DSTF outer slope	- Ultimate DSTF Maximum Outer Slope: As required to obtain minimum factors of safety (see Section 9 of this table). - Benches shall not be constructed unless necessary for geotechnical stability; if required, benches shall have a cross slope of not less than 5% to facilitate drainage.	AKHM
7.4	Capacity	- The project shall designed to be constructed in two phases: Phase 2 East and Phase 2 West. Phase 2 East shall be constructed first. - Phase 2 East Capacity: 151,000 metric tones - Phase 2 West capacity: The design shall maximum available capacity within the allowable construction limits	AKHM

² “Peak instantaneous flow” means the peak of the estimated flood hydrograph, as opposed to a flow that is averaged over a period of time.

Design Basis Item	Design Basis	Reference / Source
8 Access		
8.1 Purpose	- Allow vehicles to enter DSTF Phases 1 and 2 without tracking tailings outside containment. - Able to accommodate the following vehicle types: 40-tonne articulated haul trucks - Light vehicles - Tracked equipment	AKHM
8.2 Access	- Access to the placement area must be from the west side of the facility. Vehicles may not enter and exit the facility on the east side. - Design shall include locking gates to prevent unauthorized transition between DSTF and perimeter “clean” roads.	AKHM
8.3 Grade	Max 12% grade.	AKHM
8.4 Road Cross Slope	- Uniform cross slope towards an appropriate water conveyance system. - Min 5%, max 8%.	
8.5 Road Width	Minimum 6m clear, or as approved by AKHM for design vehicle turning radii.	AKHM
8.6 Guarding	- Space shall be provided to construct guardrails, jersey barriers, or berms along edges where there is danger of vehicle rollover. - Guardrails/Jersey barriers require 1 m width - Berms shall be at least as tall as mid-axel height of largest design vehicle— assume berm width is three times the height.	AKHM
8.7 Design Speed	25 km/h	AKHM

Design Basis Item		Design Basis	Reference / Source
9 Tailings Stack – Geotechnical Stability			
9.1	Design Geometry	Stability analyses shall consider the potential for vertical expansion of the DSTF up to the maximum geometric limits allowed by outside slope limits and minimum crest width.	AKHM
9.2	Factors of Safety – Two-dimensional (2D)	- Allowable static FS during initial construction (with no risk of breach or flow failure): ≥ 1.3 (AKHM). - Allowable operating and long-term static FS: ≥ 1.5 (AKHM) - Post-earthquake ≥ 1.2 (AKHM) - If post-earthquake limit equilibrium analysis results in a FS < 1.2, then conduct full dynamic deformation analysis using an appropriate software (e.g., FLAC). If results from the FLAC deformation analysis show acceptably low deformation, then an FS between 1.0 and 1.2 is acceptable provided, however, that the final FS meets applicable regulatory requirements. Acceptably low deformation must be decided on a case-by-case basis with final approval by the Accountable Executive Officer. (AKHM) - Pseudo-static > 1.0, if applicable. (EMR)	AKHM/EMR
9.3	Factors of Safety – three-dimensional (3D)	3D analysis may be used in design where the presence of confinement is well supported by site investigations and is expected to have a notable influence on stability in that area. - There is no standard industry guidance for 3D Factor of Safety criteria. Therefore, this will be assessed specific to each analysis based on the specific conditions and uncertainty of the area in question.	AKHM
9.4	Maximum Design Earthquake (MDE)	- Expected performance of the tailings stack under the MDE load: No major collapse and/or uncontrolled release of tailings. Damage to infrastructure and disruption to operations may occur, necessitating repairs. - Operations Return period: 2,475 years (2% probability of occurrence in 50 years). (EMR) - Closure same as operations unless long-term performance of the liner system is required to manage seepage from the facility, in which case the design event is the Maximum Credible Earthquake (MCE). (EMR)	AKHM/EMR
9.5	Operating Basis Earthquake (OBE)	- Expected performance of the tailings stack under the OBE load: Remain functional with no major repairs to key infrastructure or components (e.g. liner system). - Return period: 475 years (10% probability of occurrence in 50 years). - Only applicable for component of the DSTF where a deformation analysis is required to justify design criteria.	AKHM

Design Basis Item	Design Basis	Reference / Source
9.6 Permafrost Degradation	- Design shall anticipate differential settlement due to permafrost degradation and shall design applicable components (e.g., ditches, benches) to accommodate anticipated settlement. - Minimum FS for differential settlement estimates: 3.0. The implications of this requirement shall be discussed with AKHM prior to implementing any design changes. - Design shall minimize, to the extent practicable, long-term requirements for managing and repairing the effects of differential settlement.	AKHM

Design Basis Item	Design Basis	Reference / Source
10 Groundwater and Seepage Management		
10.1 Containment System	- Tailings shall be underlain by a containment system consisting of a low-permeability liner with above- and below-liner drainage. - Adequate protection shall be provided to the low-permeability liner to prevent damage caused by aggregates (e.g., angular particles damage the liner). - The liner shall be capable of withstanding differential movement associated with permafrost degradation and consolidation of any foundation materials not removed during construction. “Containment” is defined as the space above the liner and within the inside edge of the liner anchor trench. - Details shall be provided describing how new containment systems are to be tied into existing systems. - Designs must specify the minimum cover thickness over the liner and the maximum equipment size allowed on the protected liner.	AKHM/EMR
10.2 Groundwater	The design shall incorporate methods to monitor, and collect as necessary, water from the below-liner drain system.	AKHM
10.3 Monitoring	The design shall incorporate methods for monitoring the effectiveness of the containment and drainage systems.	AKHM
10.4 Above and Below Liner Drains	- Foundation drainpipes to be designed so that in the event of complete failure of the pipe, the other components of the drain will be able to pass the long-term design flow. - Drains shall be installed as required to prevent excessive uplift from the foundation or cross-containment gradients into the foundation. - Designs shall provide the ability to separate above and below liner/foundation drain flows to maintain the ability to keep the source waters separated for testing and management.	AKHM
10.5 Drain Systems	- The design flow for drain systems shall be at least 10 times greater than the anticipated flow rate. - Drain systems shall include redundant components so that if one component (e.g., pipe) fails, the secondary component (e.g., surrounding drain gravel) has adequate capacity to convey the design flows. - Buried pipes shall be designed such that they shall not deform more than 7.5% under expected loads (Plastic Pipe Institute).	AKHM

Design Basis Item	Design Basis	Reference / Source
11 Surface Water Management – Contact Water		
11.1 Catchment Area	- Design catchment area for the EDF and IDF flood routing is to include: - DSTF containment limits. - Existing and planned access roads within and adjacent to the DSTF. - Any adjacent areas with contact water that currently naturally grade towards the DSTF containment limits. - Other areas as directed and approved by AKHM.	AKHM
11.2 Contact Water Routing	Collect and route contact water to the Mill Pond via an appropriate system of sumps, ditches, and pipelines. Use gravity systems whenever practicable.	AKHM
11.3 Ditch Geometry	- Minimum grade 1% but maximize grade where practicable to reduce sedimentation and ice build-up in ditches. - V-ditches where practicable to minimize sediment and ice-build up. - Maintain a minimum of 300mm of freeboard above design flows; freeboard shall be increased as necessary to account for ice buildup.	AKHM
11.4 Ditch Maintenance	- Ditches shall be provided with an adjacent accessway (3m wide at cross slope between 5% and 10%) to allow ditches to be cleaned with an excavator. - Ditch lining material shall be covered with a minimum of 300mm of granular cover material to provide protection from equipment (does not supersede confinement requirements for GCL, if applicable).	AKHM

Design Basis Item		Design Basis	Reference / Source
12 Water Management – Sumps			
12.1	Sump design life	Sumps to be used throughout mine operations: 75-year design life. Closure designs to be developed in the future.	AKHM
12.2	Definitions of Containment	- Physical containment shall be provided around the sumps to the IDF water level plus minimum freeboard. Physical containment can be provided by any barrier to prevent surface flow release. - Top of seepage containment (e.g., top of low-permeability barrier): EDF water level plus 300 mm.	AKHM
12.3	Sediment Storage	- Invert of outlet pipe shall be 300 mm above base of pond to provide some sediment storage capacity. - Operations, Maintenance, and Surveillance (OMS) manual shall include requirement to monitor and clean out sumps to minimize the potential for sediment transport to the mill pond.	AKHM
12.4	Freeboard	Maintain a minimum of 300mm of freeboard above IDF water level; freeboard shall be increased as necessary to account for ice buildup	AKHM
12.5	Vehicle Access	- Vehicle access shall be provided such that the entire base of the pond is within 6 m of the adjacent edge of travel way (accounting for appropriate guarding) to allow a vac truck to remove the sediment from the pond. Exceeding the 6 m requirement must be specifically authorized by AKHM. - Access roads must have a minimum clear drivable width of 4 m on straightaways, and 5 m at corners.	AKHM
12.6	Pond Bottom Grade	The base of the pond shall have a minimum slope of 5% towards the decant end to facilitate cleaning and sediment removal.	AKHM

Design Basis Item	Design Basis	Reference / Source
13 Utilities		
13.1 All water-bearing utilities	- Minimum grade 1%; increase in areas where settlement is expected. - Non-pressure pipes shall be designed to flow half-full at maximum design flows.	AKHM
13.2 Utilities that convey contact-water	- All utilities that convey contact-water shall be leak-tight where located outside of containment. - Gravity pipes and culverts conveying contact water should not be pressurized.	AKHM
13.3 Buried Utilities	- Designs shall account for traffic loading from largest vehicle reasonably expected to be onsite. - Designs shall account for deadloads from tailings placement for current and reasonably foreseeable future expansions of the DSTF, e.g., if the height is increased to geometric limits. - Shall be sized to convey the largest anticipated flow, including reasonably foreseeable future actions that may increase the required capacity.	AKHM
13.4 Frost Protection	Frost protection shall be provided for any buried pipeline (contact or non-contact water) that may otherwise be expected to freeze	AKHM
13.5 Utility penetrations of containment systems	- Utilities that penetrate containment systems (e.g., geomembrane liner) must be designed to create a water-tight seal. - If multiple penetrations are required, penetrations shall be spaced at appropriate intervals to allow for installation of pipe boots, seals, or other systems, as appropriate. - Liner penetrations shall be avoided as practicable.	AKHM
14 Instrumentation		
14.1 Instrumentation cables	- Cables, lysimeter tubes, and other similar “cords” shall be consolidated as practicable and routed to termination points at the perimeter of the facility. - Individual cables/cords shall be permanently labeled to ensure accurate connections and data recording.	AKHM
14.2 Instrumentation termination points	- The locations for instrumentation termination points shall be approved by AKHM. - Termination points shall be provided with appropriate visual indicators and guarding to minimize the risk of equipment damage. - Multiple termination points are acceptable if approved by AKHM.	AKHM

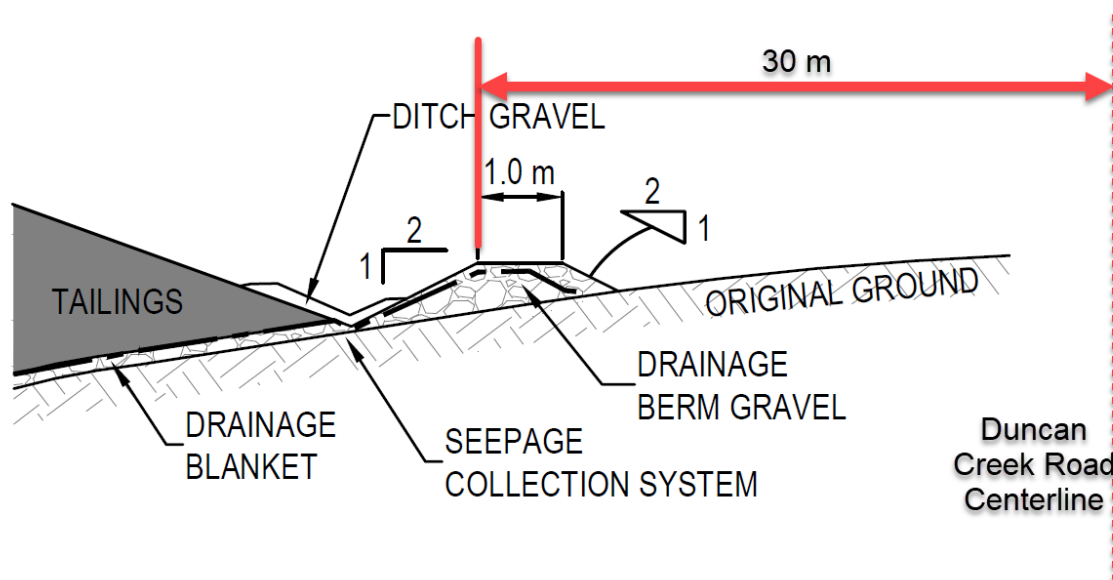


Figure 3-1: Right of Way Offset

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Document History



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Appendix C – DSTF Phase 2 East Issued for Construction Drawings

DRY STACK TAILINGS FACILITY

PHASE 2 EAST DESIGN

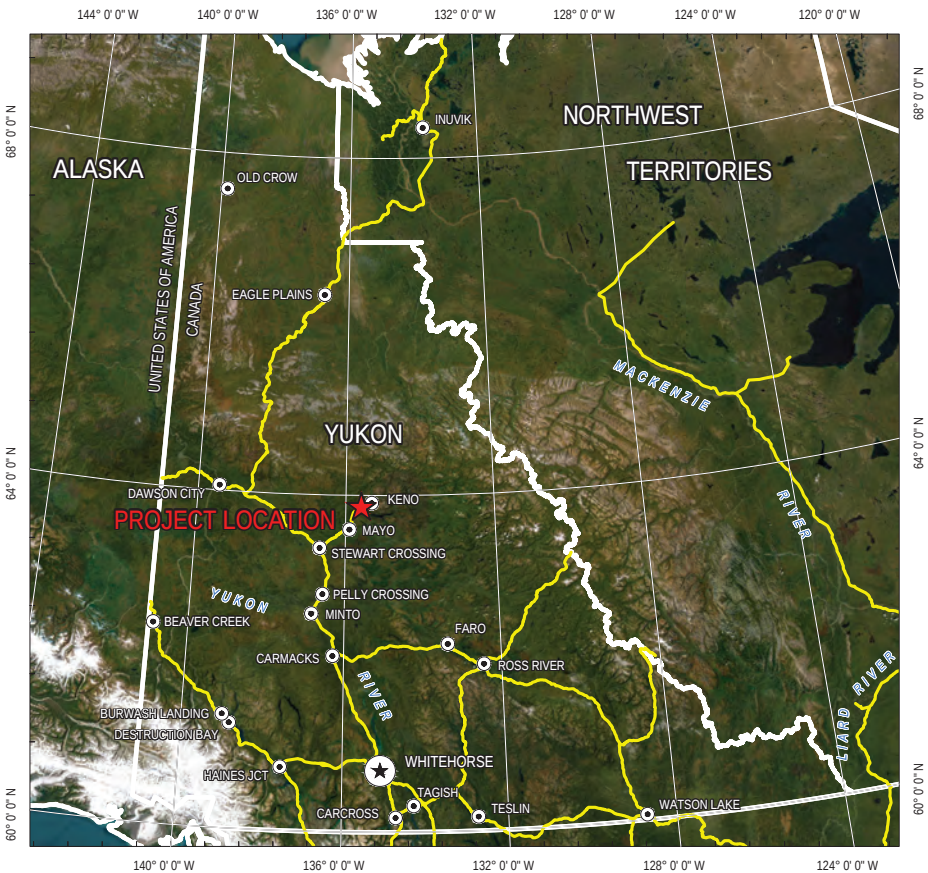
KENO HILL DISTRICT MILL SITE, YUKON

PREPARED FOR



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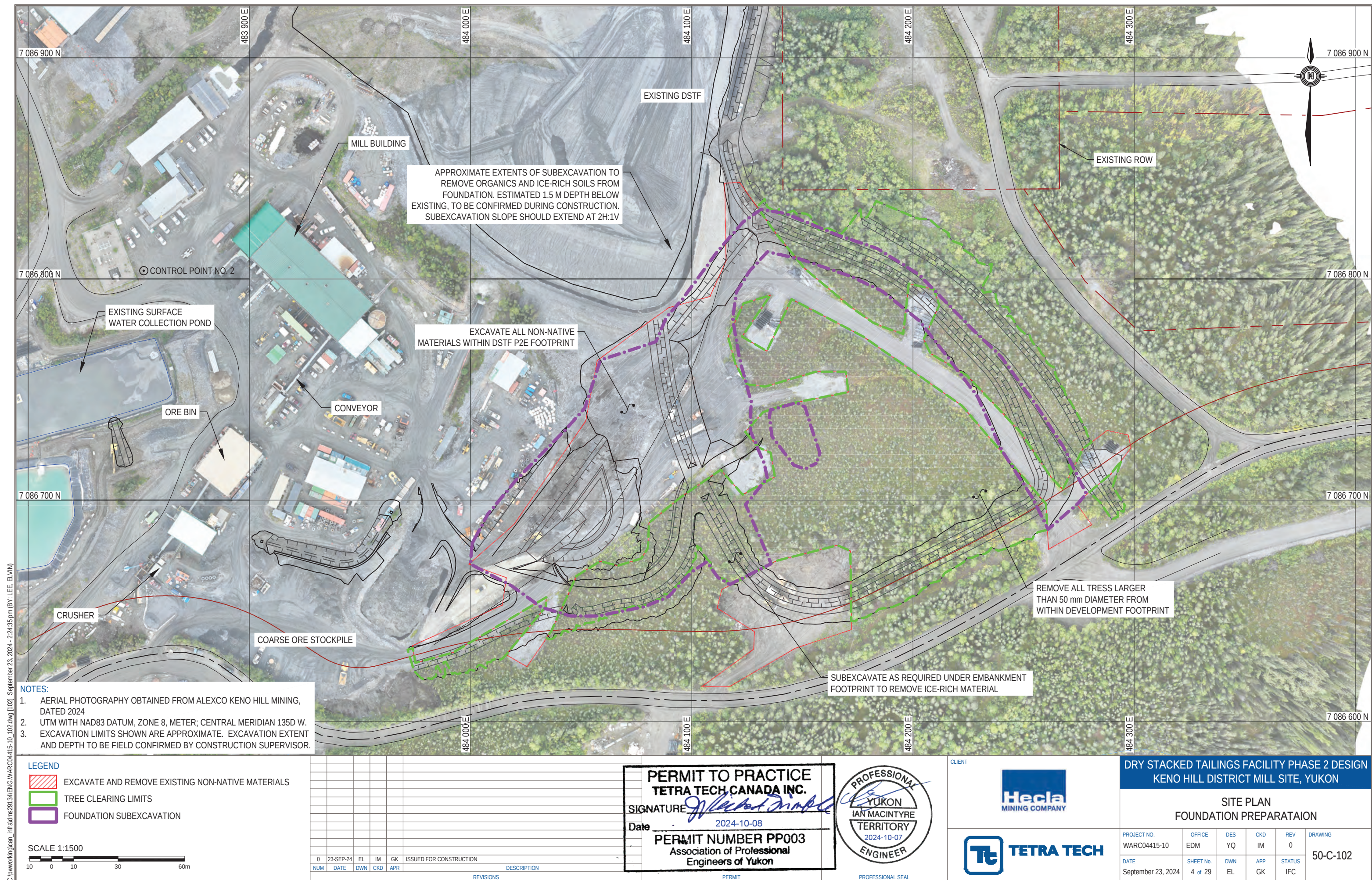
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50-C-101	SITE PLAN - POST CONSTRUCTION
50-C-102	SITE PLAN - FOUNDATION PREPARATION
50-C-103	SITE PLAN - DRAINAGE BLANKET AND SHEAR BERM
50-C-104	CROSS-SECTIONS A-A' AND B-B'
50-C-105	CROSS-SECTION C-C' AND D-D'
50-C-106	BUTTRESS SECTIONS - STATION -0+060 TO 0+160
50-C-107	BUTTRESS SECTIONS - STATION 0+180 TO 0+400
50-C-108	TYPICAL DETAILS
50-C-200	RUNOFF AND SEEPAGE COLLECTION - LAYOUT PLAN
50-C-201	COLLECTION SUMP AND SOUTH ACCESS ROADS - PLAN
50-C-202	COLLECTION SUMP OUTFALL - PLAN
50-C-203	COLLECTION DITCH AND ACCESS ROADS - PLAN 1 OF 4
50-C-204	COLLECTION DITCH AND ACCESS ROADS - PLAN 2 OF 4
50-C-205	COLLECTION DITCH AND ACCESS ROADS - PLAN 3 OF 4
50-C-206	COLLECTION DITCH AND ACCESS ROADS - PLAN 4 OF 4
50-C-207	UNDER TAILINGS DRAINAGE PIPE - PLAN
50-C-210	COLLECTION SUMP AND OUTFALL - PROFILE
50-C-211	DRYSTACK DRAIN & SOUTH ACCESS ROAD DITCH - PROFILES
50-C-212	COLLECTION SUMP - SECTIONS AND DETAILS
50-C-213	DITCH, VALVE & PIPE ROAD CROSSING - TYPICAL DETAILS
50-C-214	SUMP OUTFALL DITCH AND PLUNGE POOLS - TYPICAL SECTIONS AND DETAILS
50-C-215	MANHOLE, PIPE OUTFALL, AND PIPE BEDDING - TYPICAL SECTIONS AND DETAILS
50-C-216	DRYSTACK DRAIN - LAYOUT, SECTIONS, AND DETAILS
50-C-220	COLLECTION DITCH - PROFILE
50-C-221	ACCESS ROADS AND DITCH - PROFILES
50-C-222	COLLECTION DITCH AND ACCESS ROADS - TYPICAL SECTIONS
50-C-230	UNDER TAILINGS DRAINAGE PIPE - PLANS AND PROFILE
50-C-300	INSTRUMENTATION - PLAN VIEW
50-C-301	INSTRUMENTATION - DETAILS (1 of 2)
50-C-302	INSTRUMENTATION - DETAILS (2 of 2)
50-C-400	INITIAL TAILINGS DEPOSITION PLAN
50-C-401	INITIAL TAILINGS DEPOSITION - CROSS-SECTION AND TYPICAL DETAIL
50-C-500	PLAN VIEW SHOWING STATIONING - BUTTRESS AND ROADS
50-C-501	PLAN VIEW SHOWING STATIONING - DITCHES AND CONVEYANCE

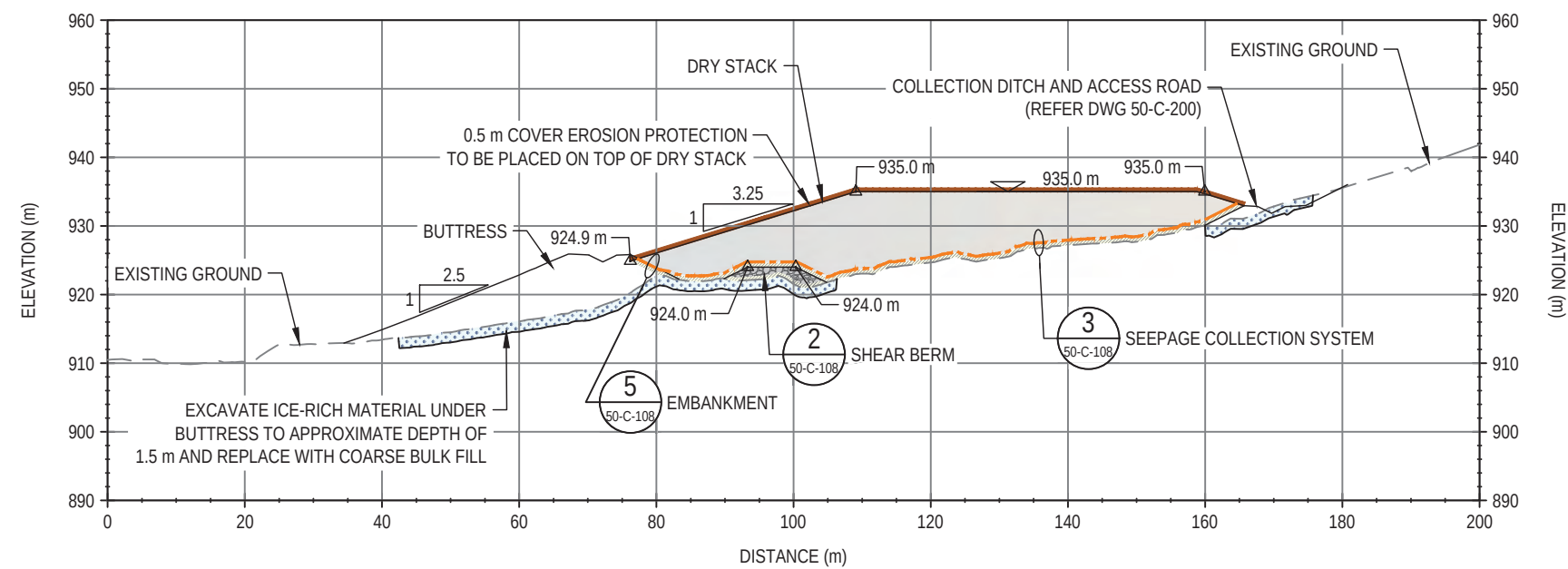
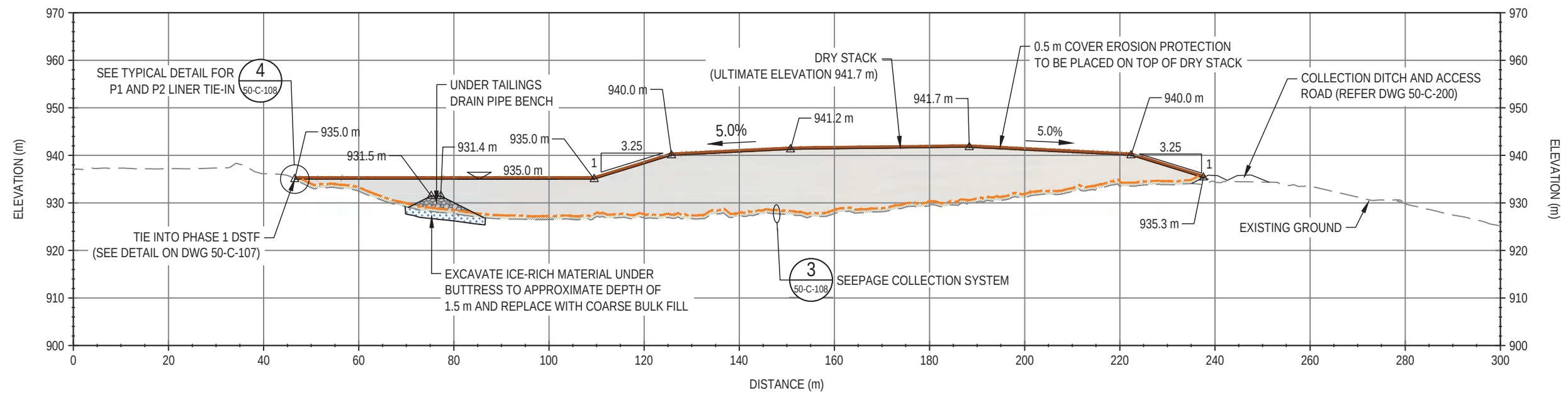


GENERAL LOCATION MAP OF THE YUKON TERRITORY
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SITE PLAN
SCALE = 1:10,000





SCALE 1:1000



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Date 2024-10-08

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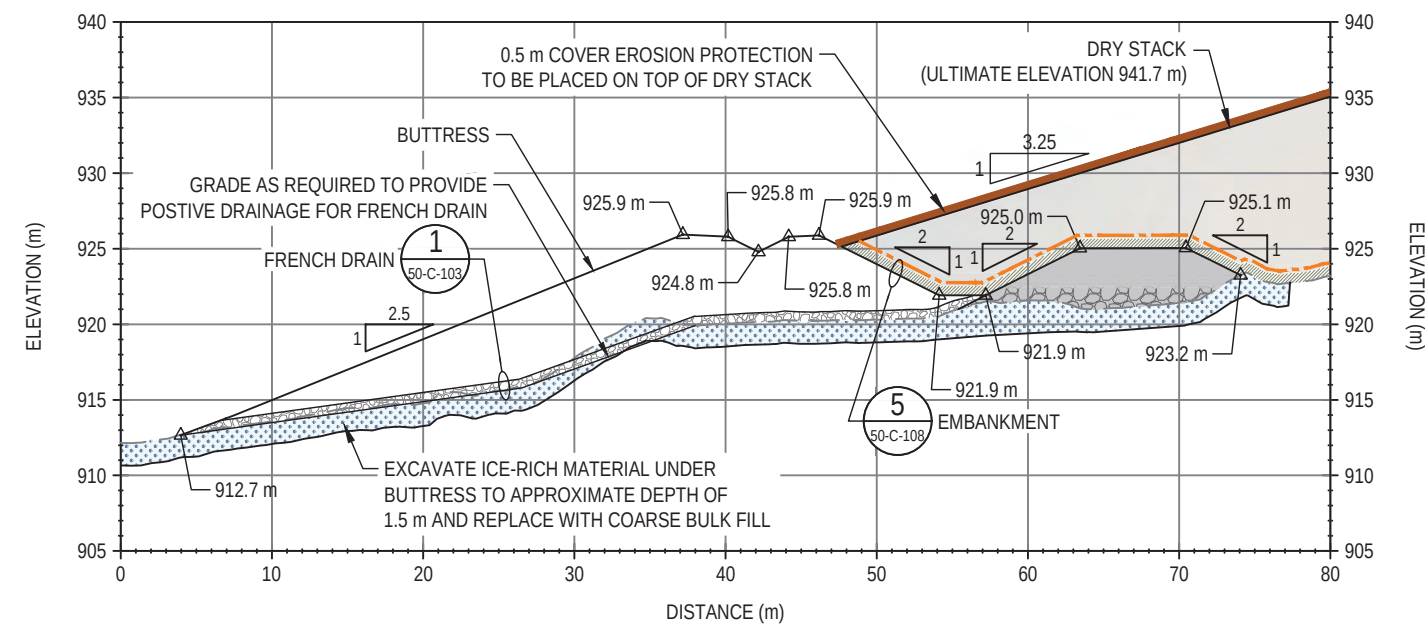
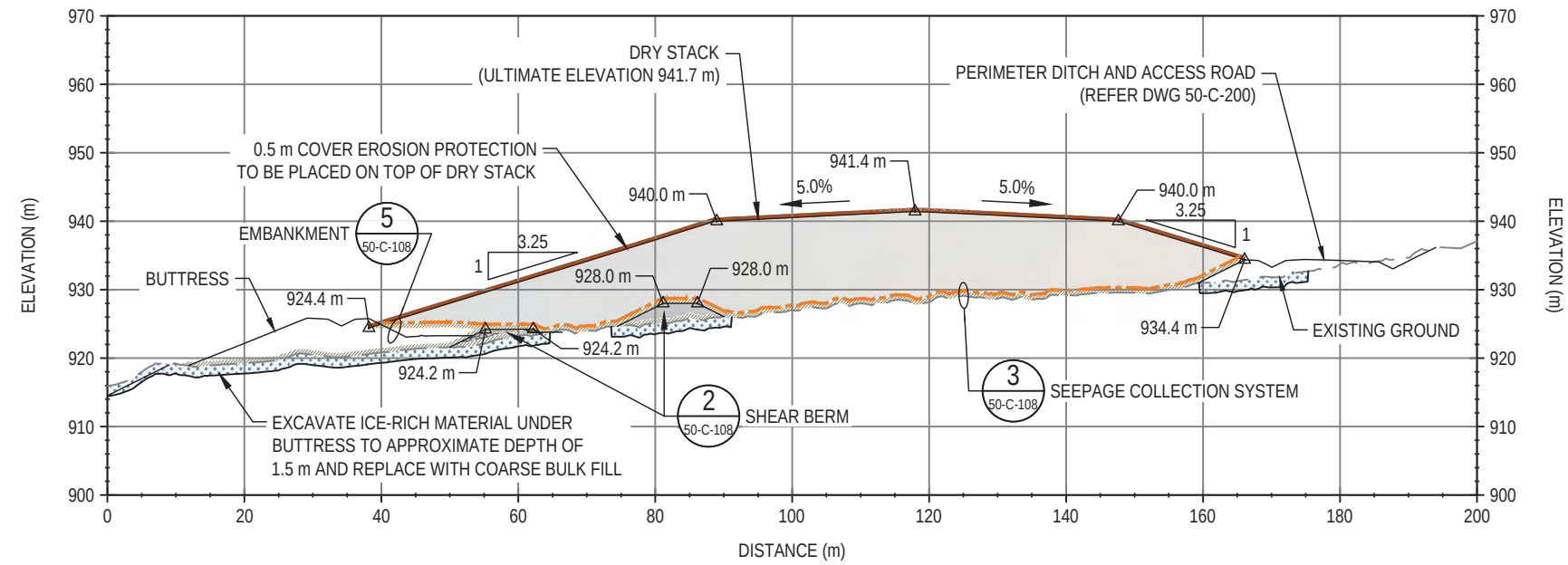
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DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

CROSS SECTIONS A-A' AND B-B'

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DATE September 23, 2024	SHEET No. 6 of 29	DWN EL	APP GK	STATUS IFC	

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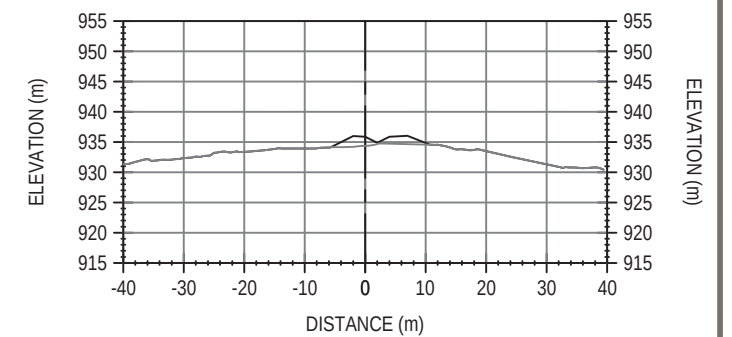
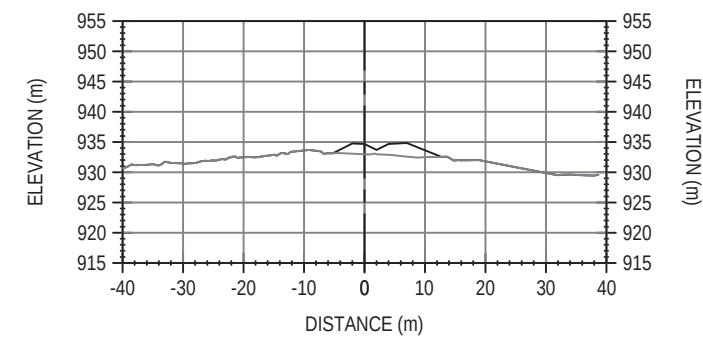
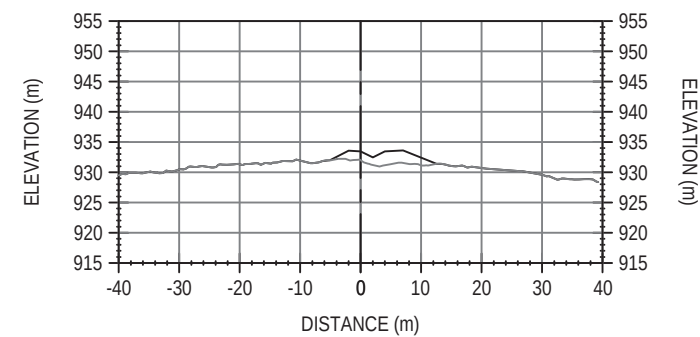
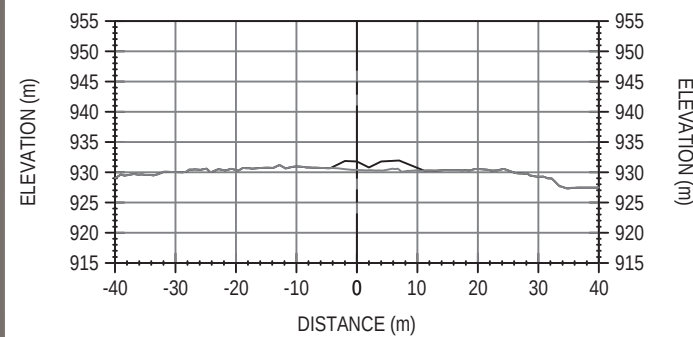
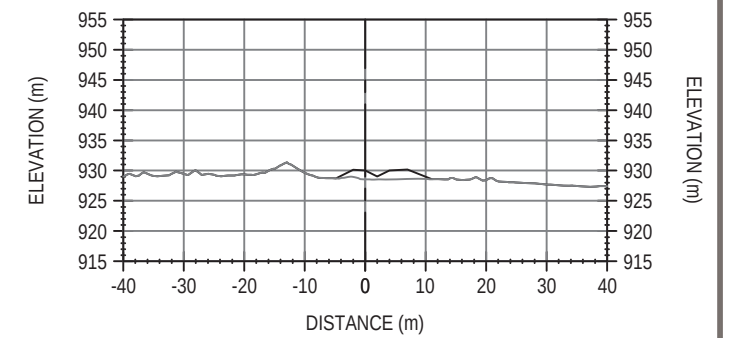
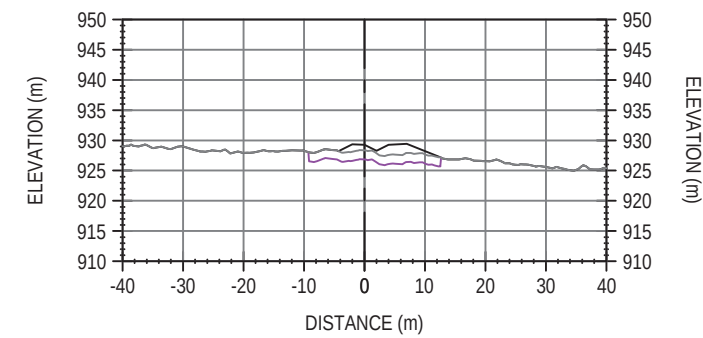
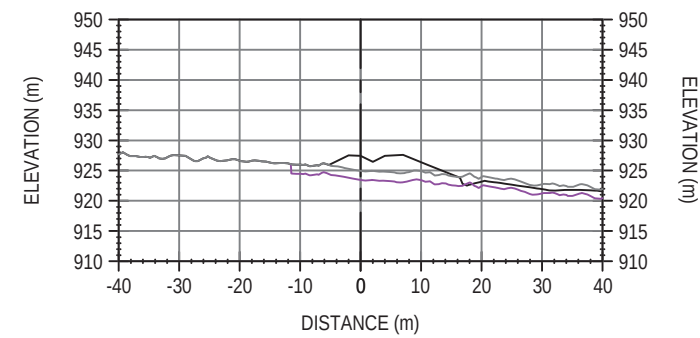
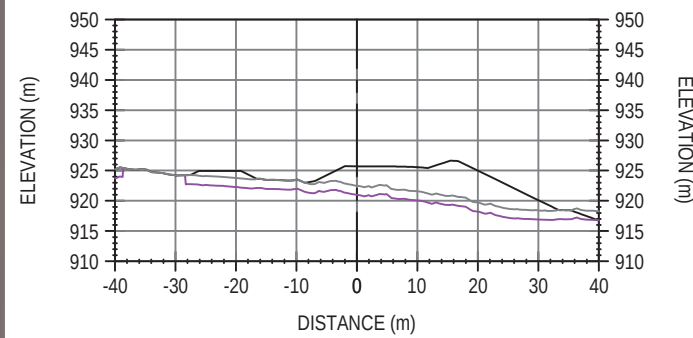
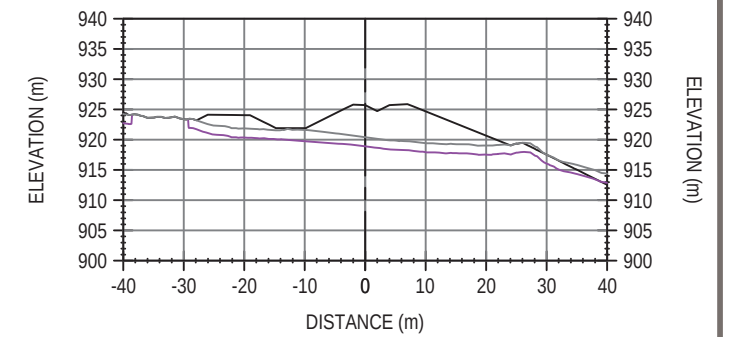
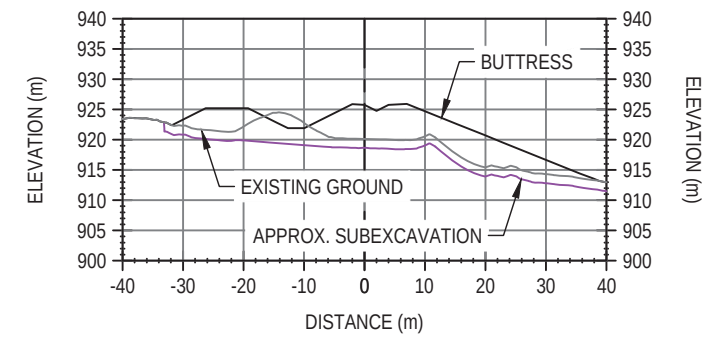
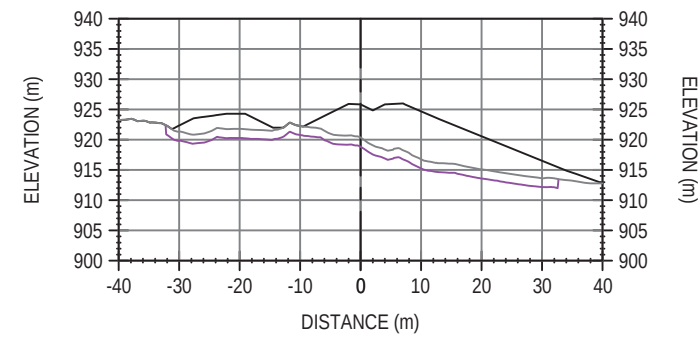
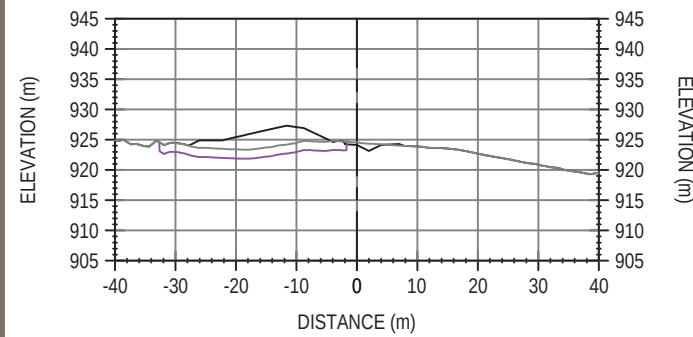
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DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

CROSS SECTION C-C' AND D-D'

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DATE September 23, 2024	SHEET No. 7 of 29	DWN EL	APP GK	STATUS IFC	



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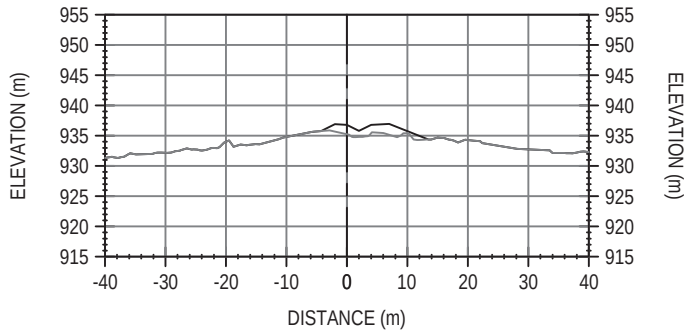
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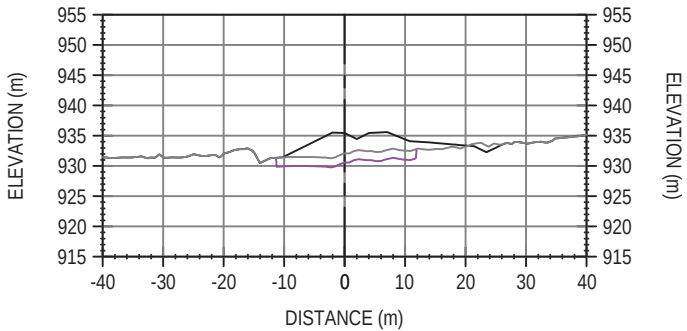
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KENO HILL DISTRICT MILL SITE, YUKON

BUTTRESS SECTIONS
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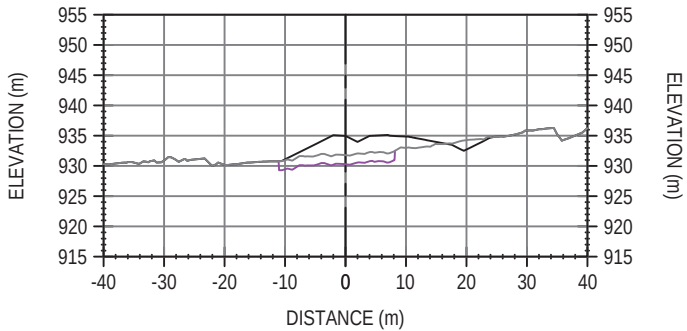
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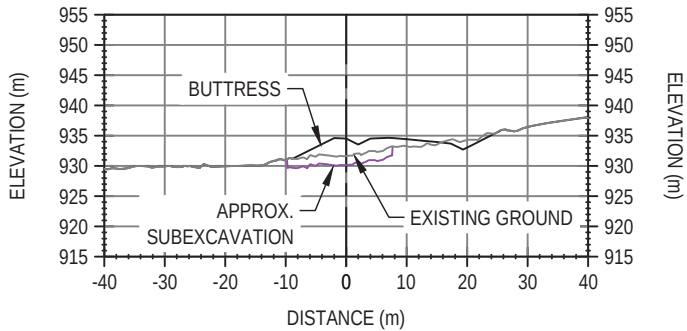
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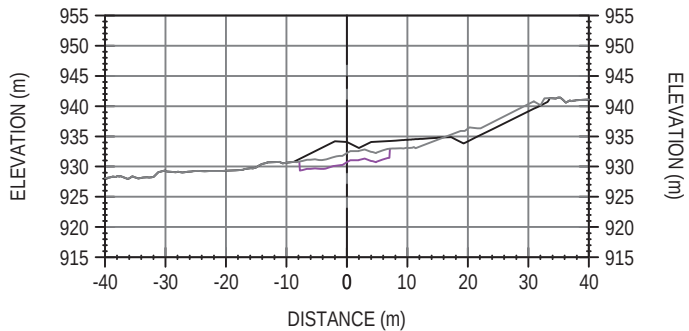
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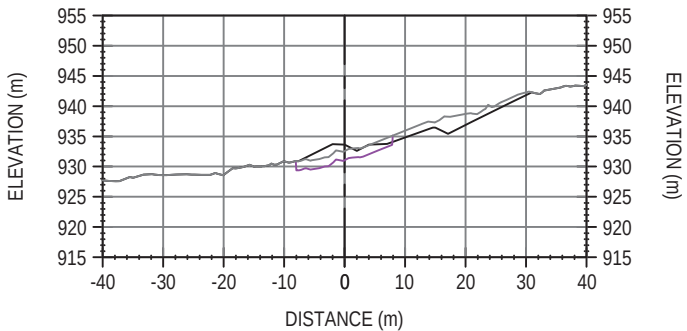
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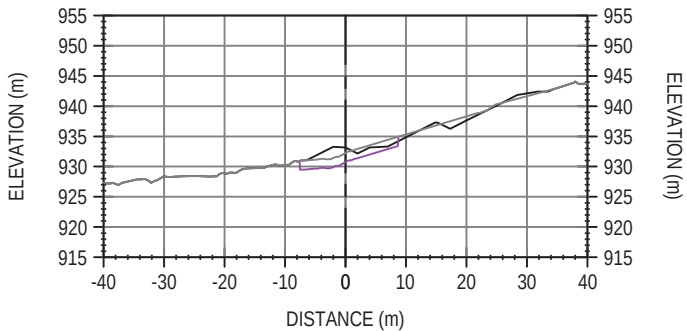
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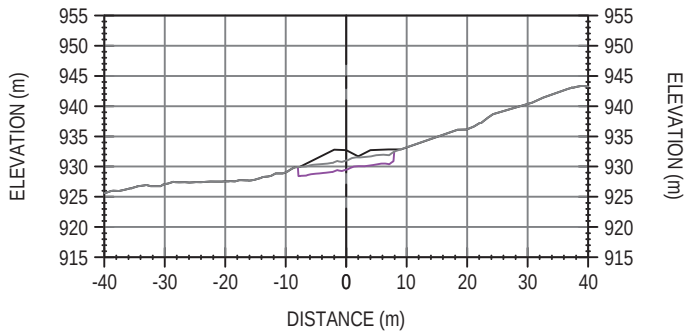
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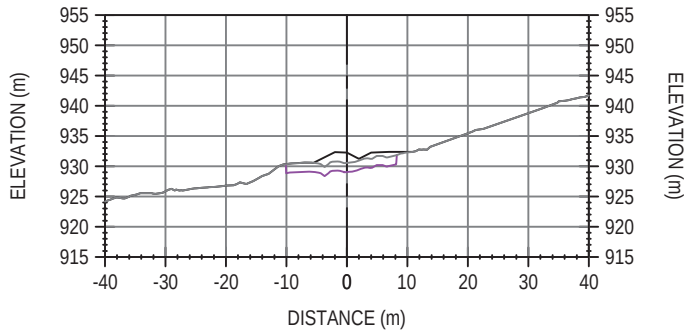
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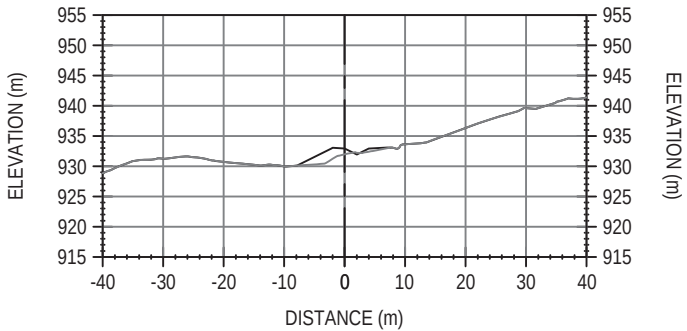
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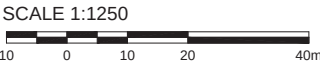
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REVISIONS					

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TETRA TECH CANADA INC.

SIGNATURE

Date 2024-10-08

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Association of Professional
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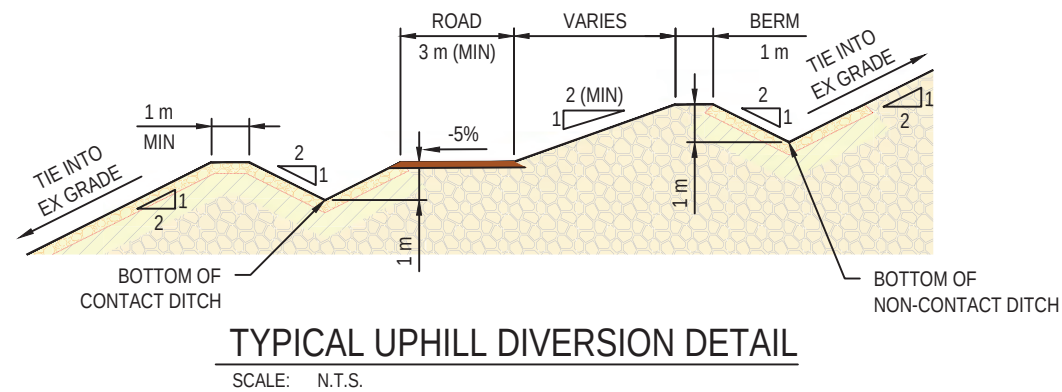
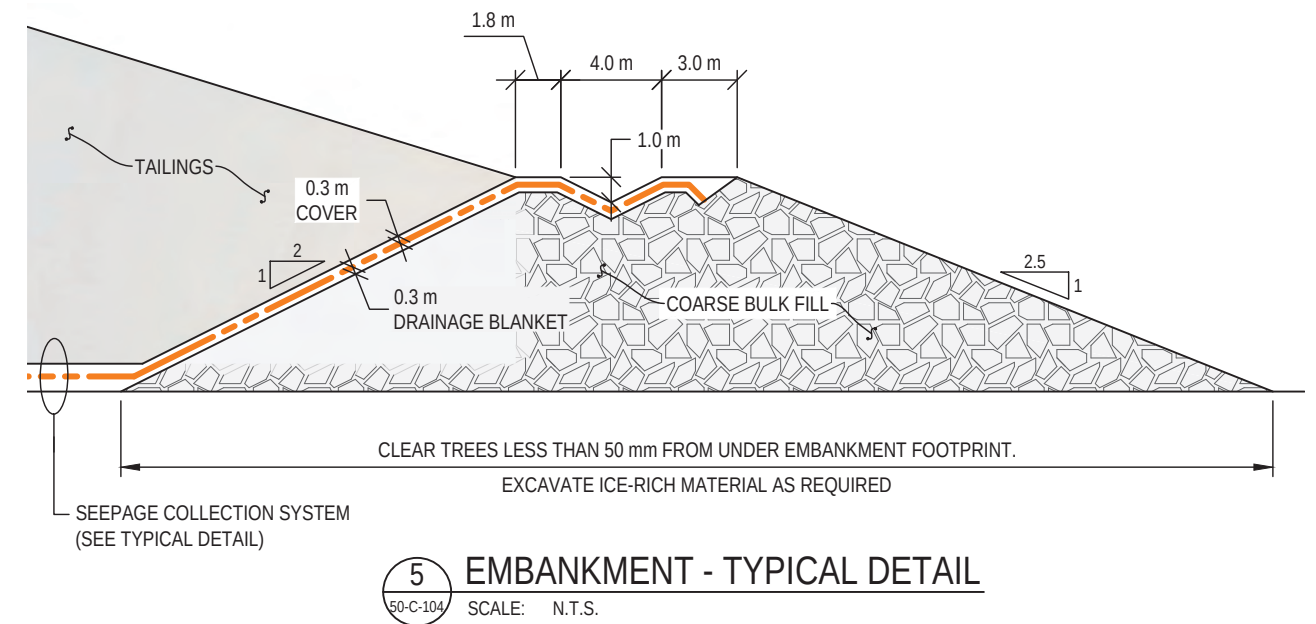
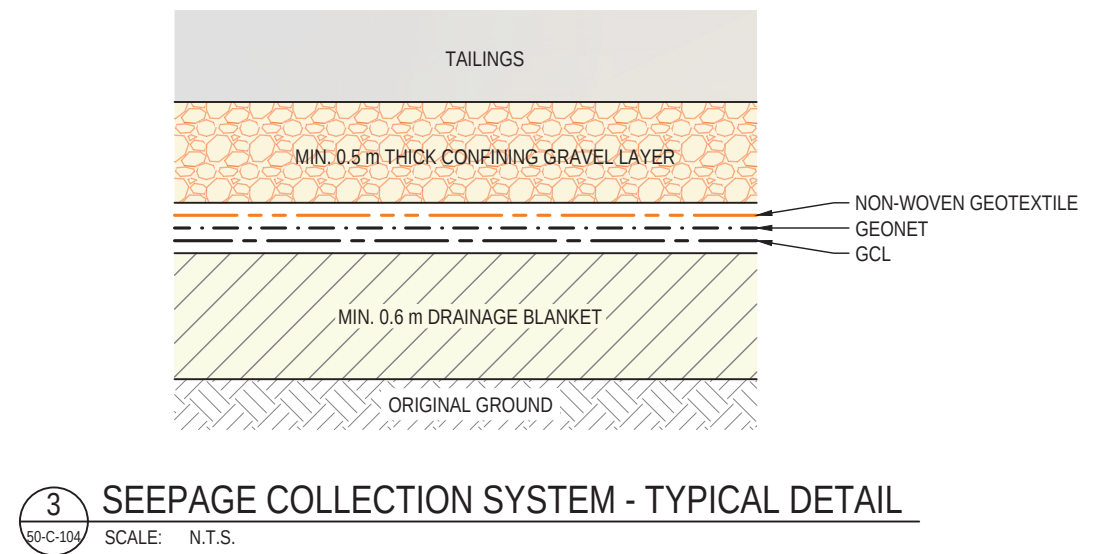
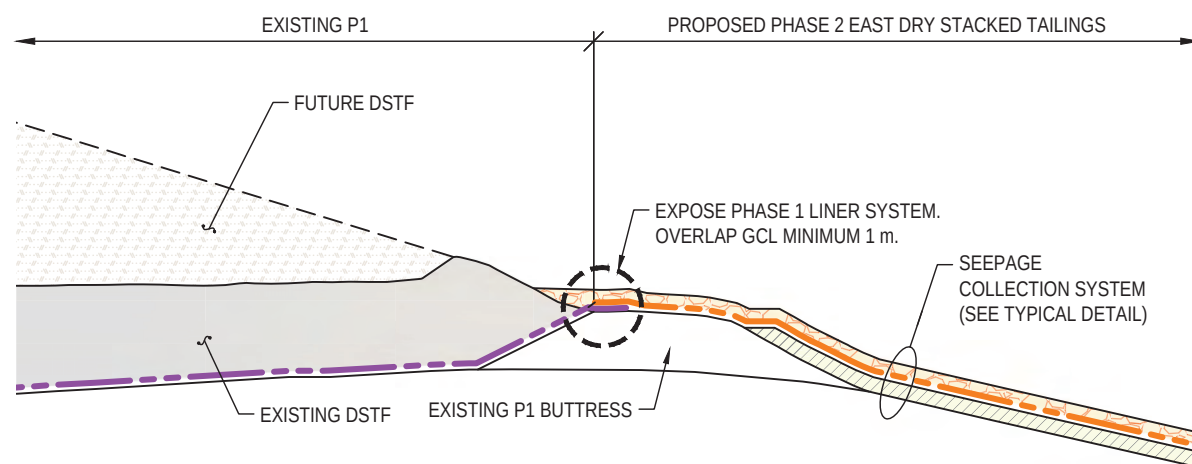
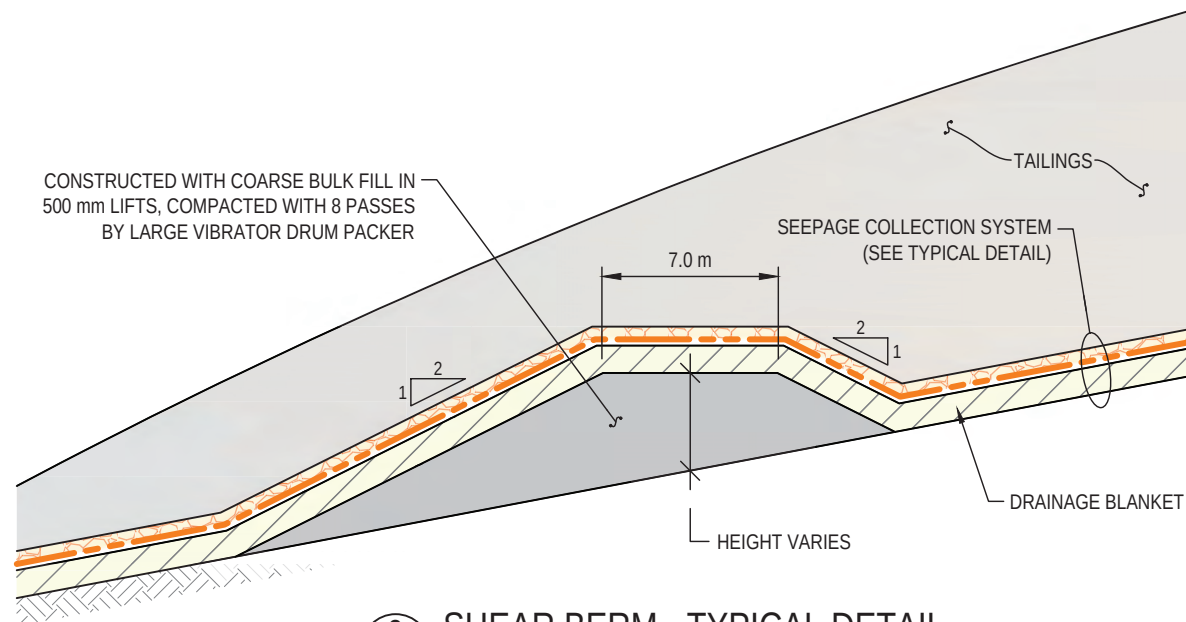


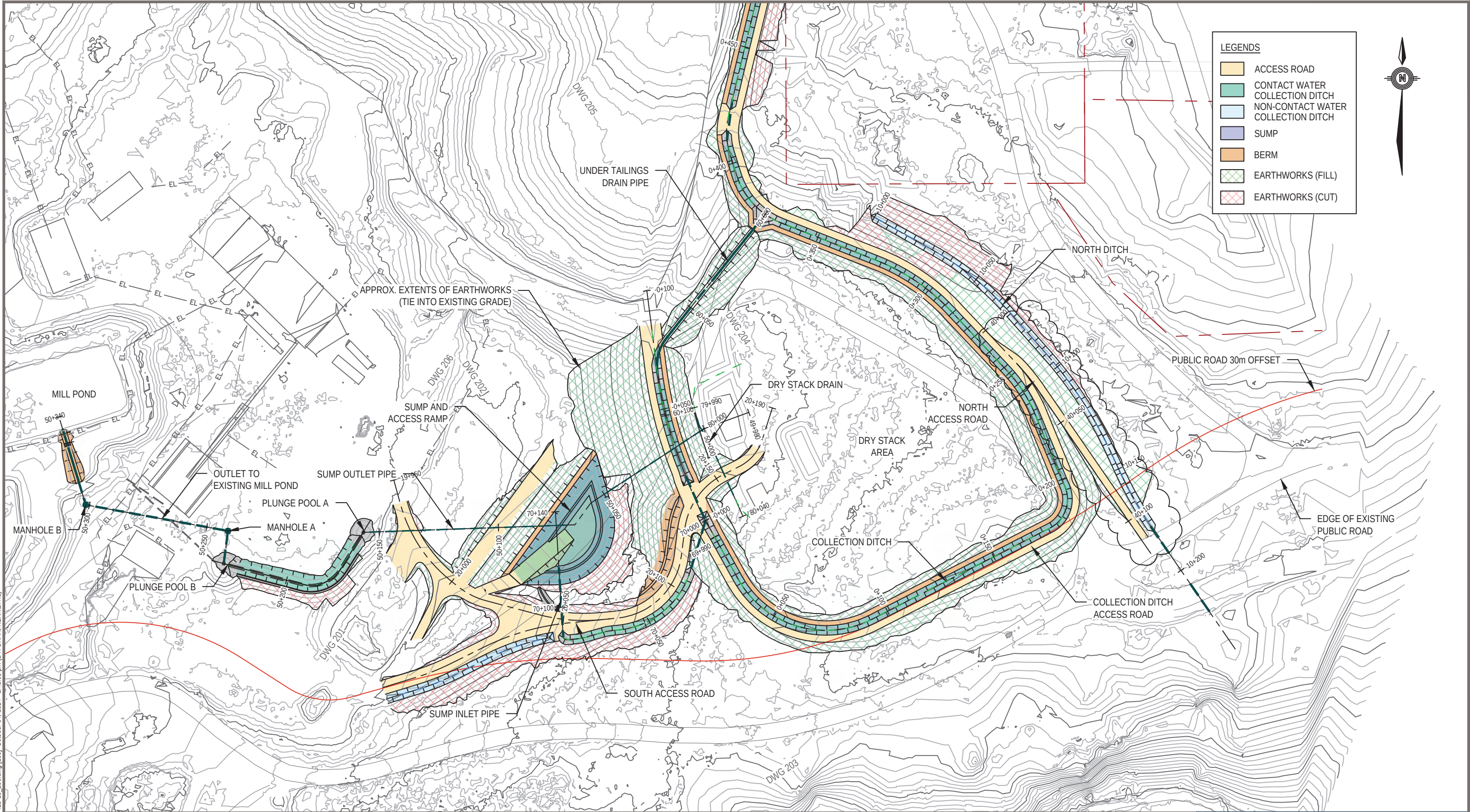
CLIENT

DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

BUTTRESS SECTIONS
STATION 0+180 TO 0+400

PROJECT NO. WARC04415-10	OFFICE EDM	DES YQ	CKD IM	REV 0	DRAWING
DATE September 23, 2024	SHEET No. 9 of 29	DWN EL	APP GK	STATUS IFC	50-C-107

[illegible]



- NOTES:
1. ALL REFERENCES TO HDPE PIPES SHALL REFER TO DR17 HDPE PIPE.
 2. ALL SPIRAL WOUND STEEL PIPES (SWSP) SHALL BE 12.5 mm IN GAUGE.



PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date **2024-10-08**
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

NUM	DATE	DWN	CKD	APR	DESCRIPTION
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION

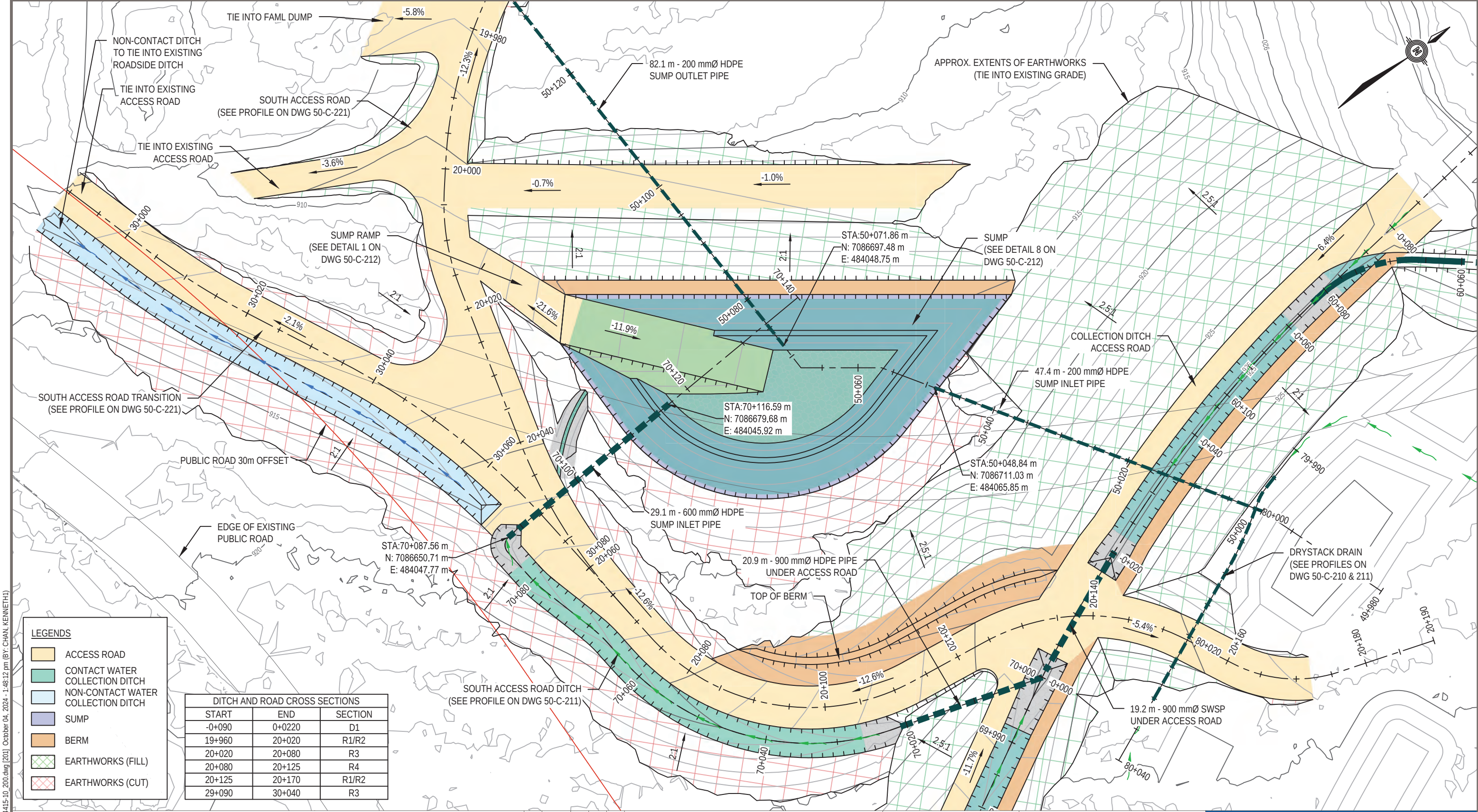


CLIENT

Hecla
MINING COMPANY

TETRA TECH

DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON					
RUNOFF AND SEEPAGE COLLECTION LAYOUT PLAN					
PROJECT NO. WARC04415-10	OFFICE VANC	DES KC	CKD JY	REV 1	DRAWING 50-C-200
DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC	

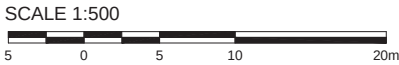


LEGENDS

- ACCESS ROAD
- CONTACT WATER COLLECTION DITCH
- NON-CONTACT WATER COLLECTION DITCH
- SUMP
- BERM
- EARTHWORKS (FILL)
- EARTHWORKS (CUT)

START	END	SECTION
-0+090	0+0220	D1
19+960	20+020	R1/R2
20+020	20+080	R3
20+080	20+125	R4
20+125	20+170	R1/R2
29+090	30+040	R3

- NOTES:**
- FOR TYPICAL ROAD AND DITCH SECTIONS, SEE DWG 50-C-222.
 - ALL HDPE PIPES SHALL BE DR17.



PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

NUM	DATE	DWN	CKD	APR	REVISIONS
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION
					DESCRIPTION
					REVISIONS

PROFESSIONAL
2024-10-08
YUKON
DAVID N. MOSCHINI
TERRITORY
ENGINEER

CLIENT

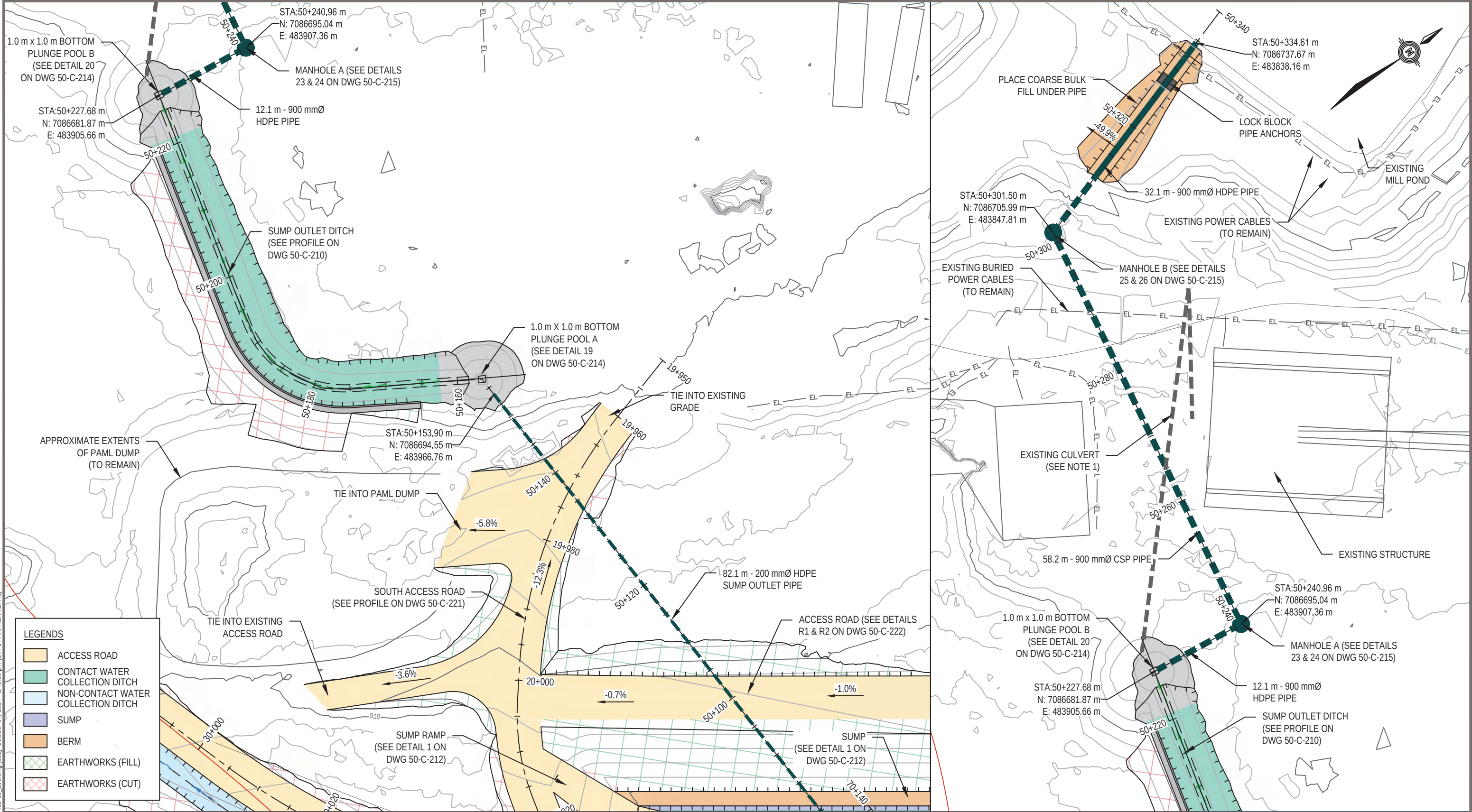
Hecla
MINING COMPANY

Tt TETRA TECH

DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

COLLECTION SUMP AND SOUTH ACCESS ROADS
PLAN

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	1	50-C-201
DATE	SHEET No.	DWN	APP	STATUS	
October 4, 2024	of	KC	DNM	IFC	



NOTES:

1. APPROXIMATE LOCATION OF EXISTING, POSSIBLY ABANDONED CULVERT (LOCATE AND CONFIRM DURING EXCAVATION, AND DECOMMISSION AS DIRECTED BY OWNER).

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date **2024-10-08**
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

NUM	DATE	DWN	CKD	APR	REVISIONS
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION

PROFESSIONAL
2024-10-08
YUKON
DAVID N. MOSCHINI
TERRITORY
ENGINEER

PROFESSIONAL SEAL

CLIENT

Hecla MINING COMPANY

TETRA TECH

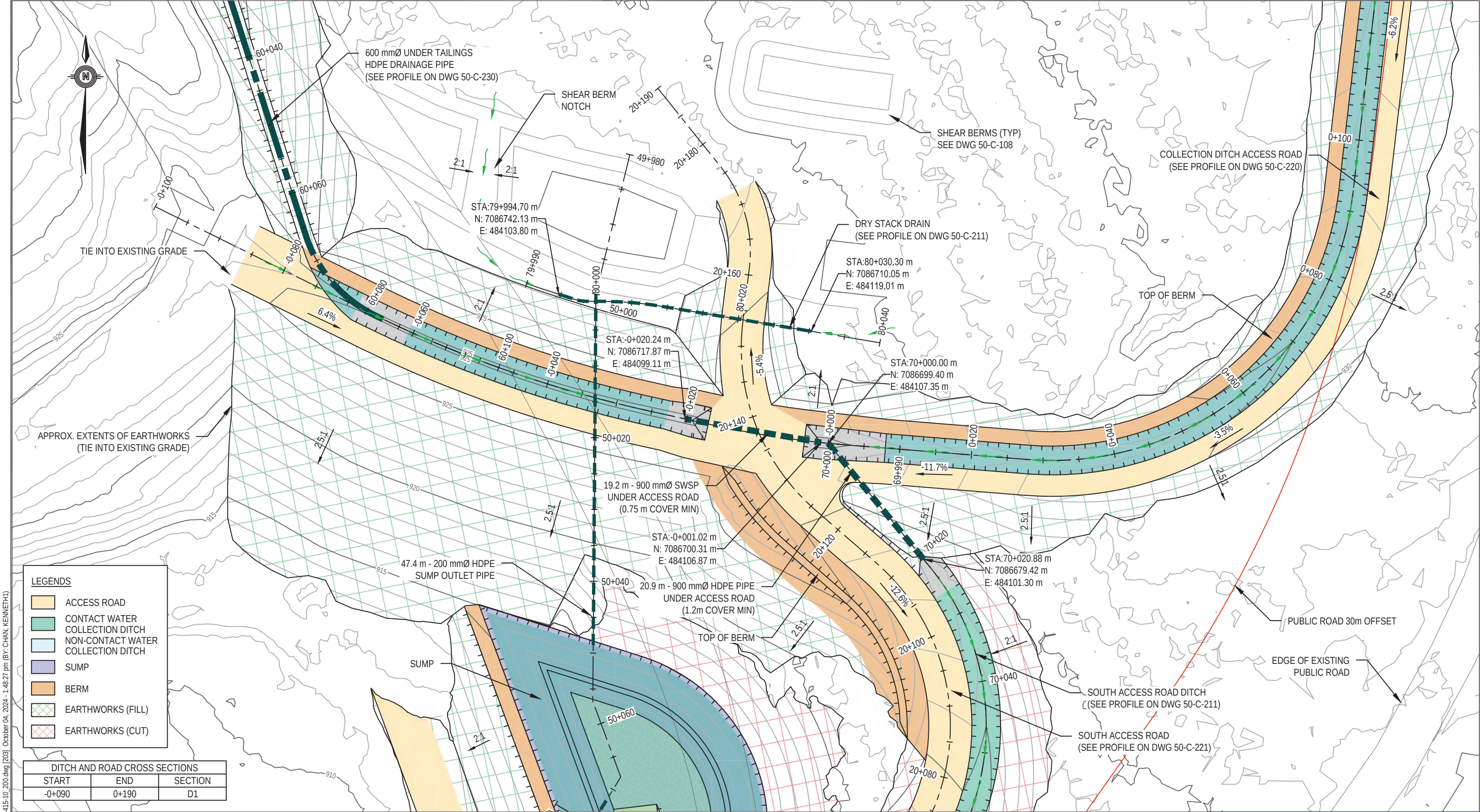
DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

COLLECTION SUMP OUTFALL PLAN

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	1	50-C-202

DATE	SHEET No. of	DWN	APP	STATUS
October 4, 2024		KC	DNM	IFC

C:\pwworking\can_infra\ms29134\ENG\WARC04415-10_200.dwg [2024, 1:48:20 pm] (BY: CHAN, KENNETH)



NOTES:

1. FOR TYPICAL ROAD AND DITCH SECTIONS, SEE DWG 50-C-222.

SCALE 1:500

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

NUM	DATE	DWN	CKD	APR	REVISIONS
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION

PROFESSIONAL SEAL

2024-10-08
YUKON
DAVID N. MOSCHINI
TERRITORY
ENGINEER

CLIENT

Hecla
MINING COMPANY

TETRA TECH

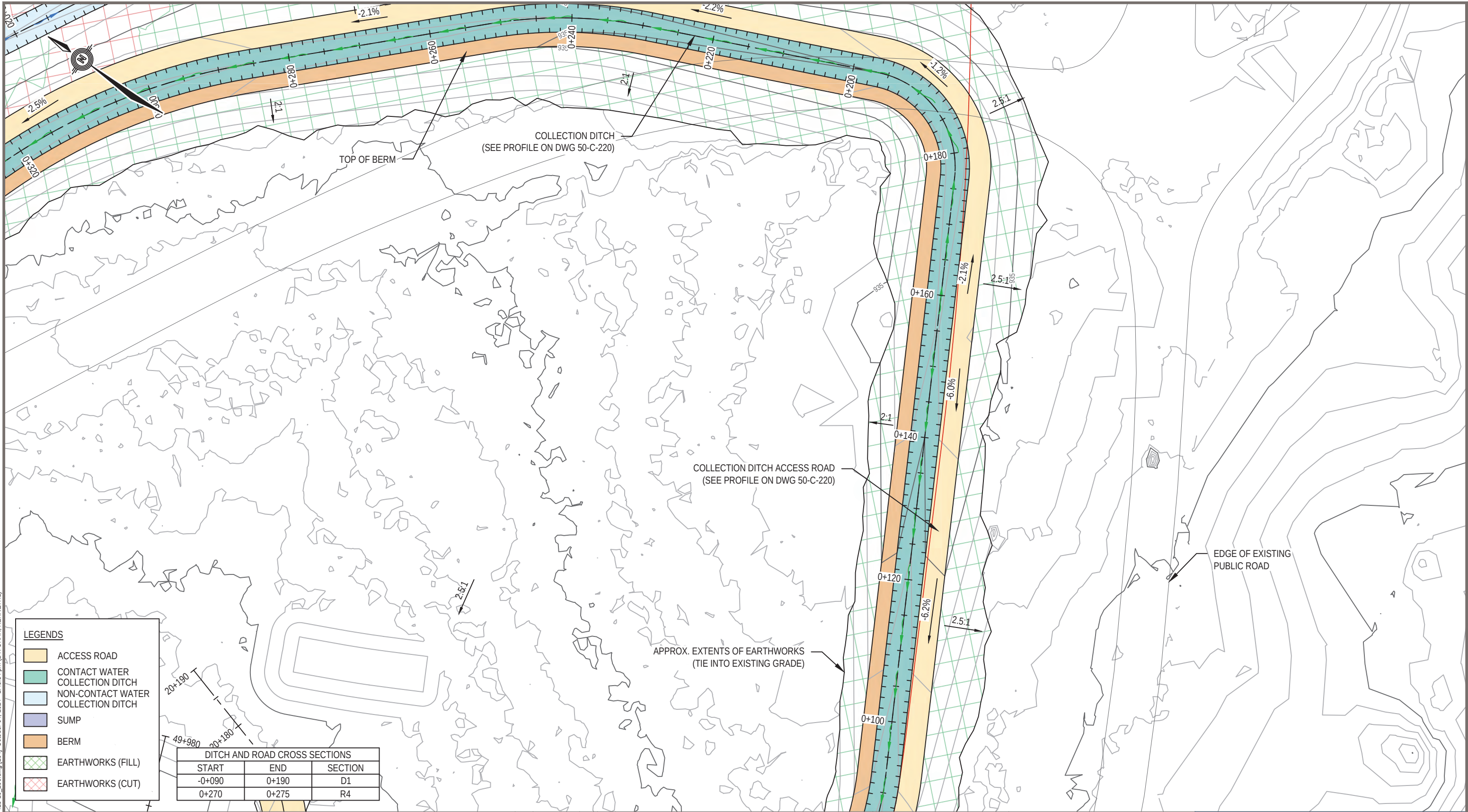
DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

COLLECTION DITCH AND ACCESS ROADS
PLAN 1 OF 4

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	1	50-C-203

DATE	SHEET No. of	DWN	APP	STATUS
October 4, 2024		KC	DNM	IFC

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LEGENDS

- ACCESS ROAD
- CONTACT WATER
- COLLECTION DITCH
- NON-CONTACT WATER
- COLLECTION DITCH
- SUMP
- BERM
- EARTHWORKS (FILL)
- EARTHWORKS (CUT)

DITCH AND ROAD CROSS SECTIONS		
START	END	SECTION
-0+090	0+190	D1
0+270	0+275	R4

NOTES:

- FOR TYPICAL ROAD AND DITCH SECTIONS, SEE DWG 50-C-222.



PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

NUM	DATE	DWN	CKD	APR	DESCRIPTION
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION



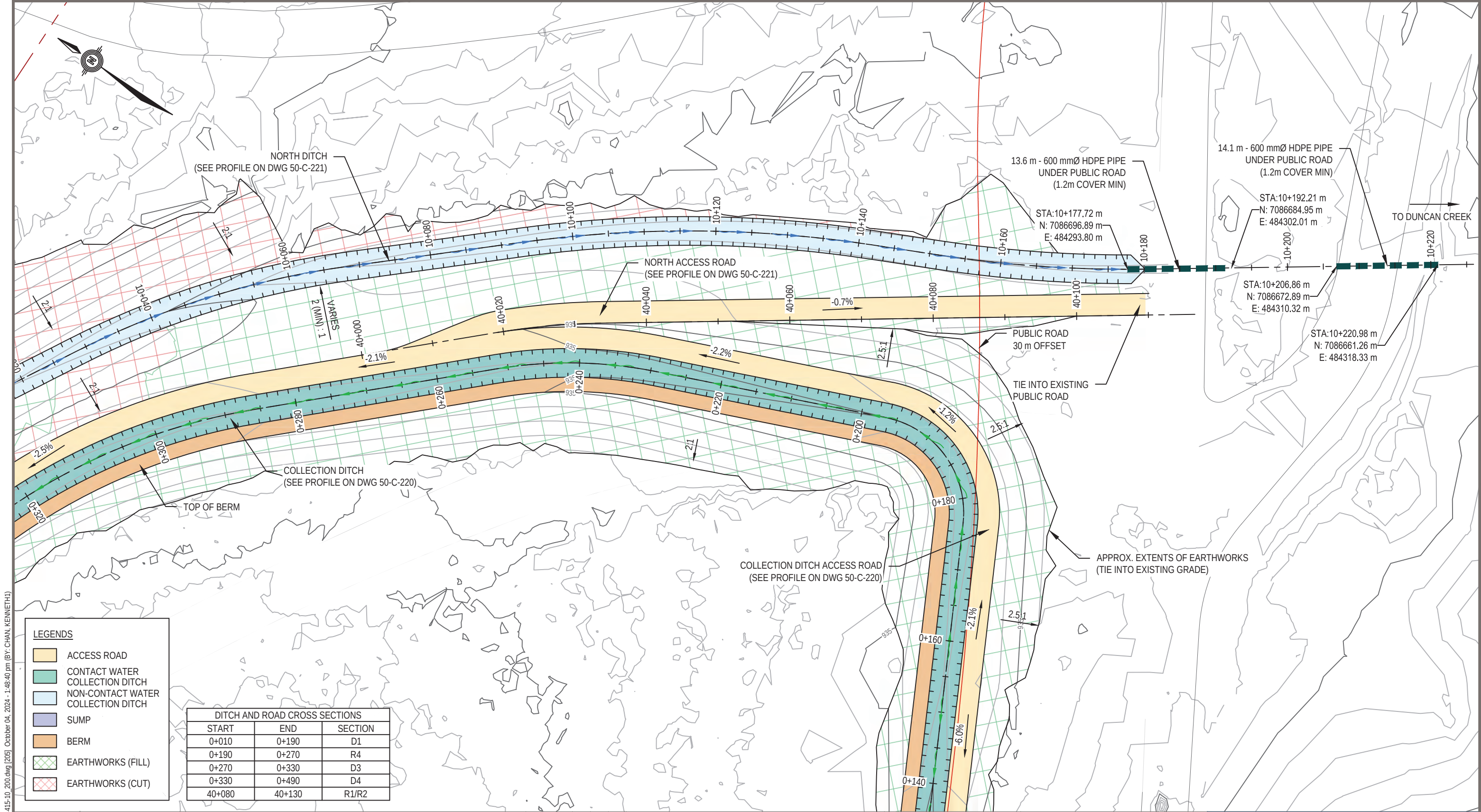
CLIENT



DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

COLLECTION DITCH AND ACCESS ROADS
PLAN 2 OF 4

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	1	50-C-204
DATE	SHEET No. of	DWN	APP	STATUS	
October 4, 2024		KC	DNM	IFC	



C:\pwworking\can_infra\m29134\ENG\WARC04415-10_200.dwg [205] October 04, 2024 - 1:48:40 pm (BY: CHAN, KENNETH)

LEGENDS

- ACCESS ROAD
- CONTACT WATER
- COLLECTION DITCH
- NON-CONTACT WATER
- COLLECTION DITCH
- SUMP
- BERM
- EARTHWORKS (FILL)
- EARTHWORKS (CUT)

DITCH AND ROAD CROSS SECTIONS		
START	END	SECTION
0+010	0+190	D1
0+190	0+270	R4
0+270	0+330	D3
0+330	0+490	D4
40+080	40+130	R1/R2

NOTES:

1. FOR TYPICAL ROAD AND DITCH SECTIONS, SEE DWG 50-C-222.



PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional
Engineers of Yukon

NUM	DATE	DWN	CKD	APR	DESCRIPTION
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION
REVISIONS					



CLIENT

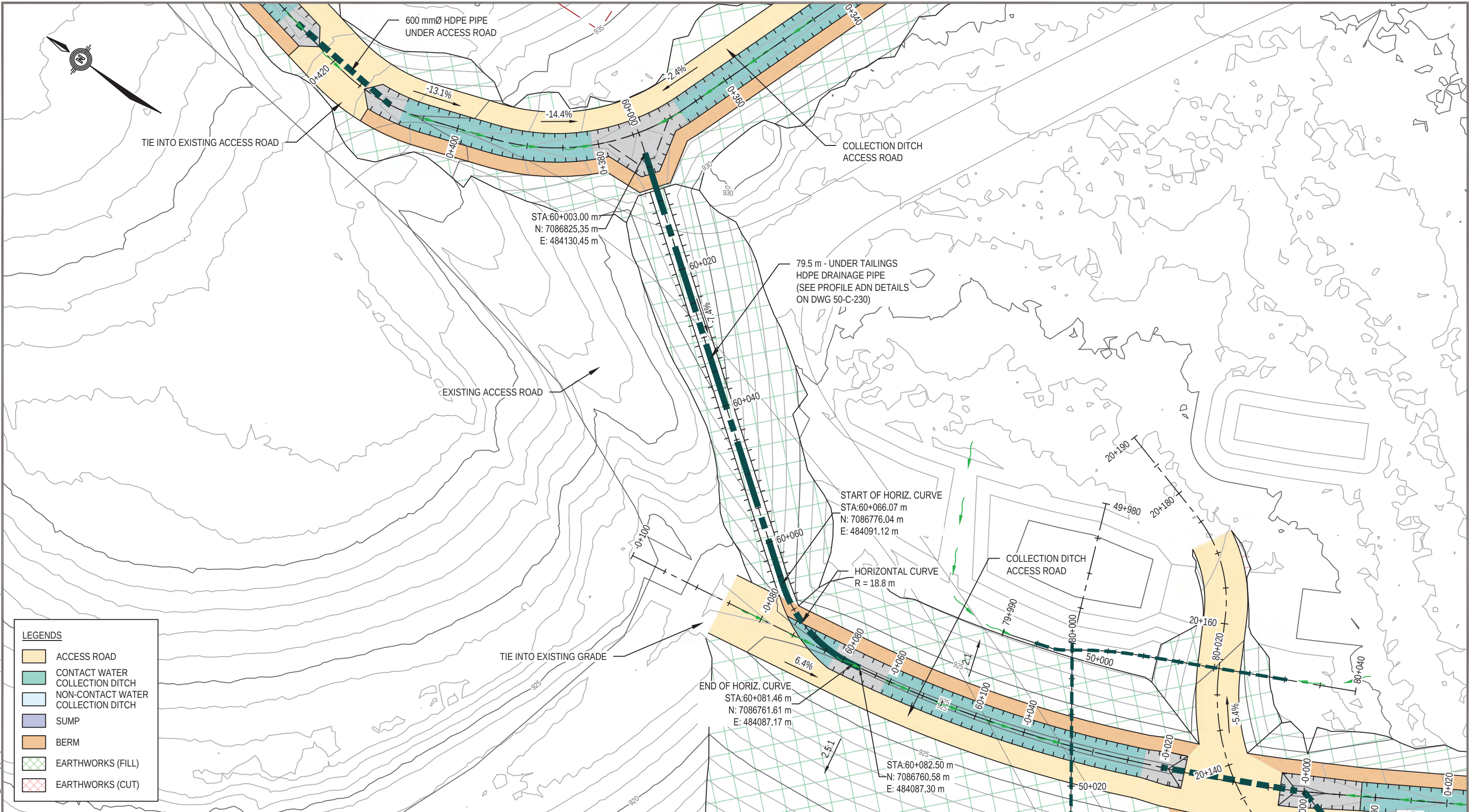


DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

COLLECTION DITCH AND ACCESS ROADS
PLAN 3 OF 4

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	1	50-C-205
DATE	SHEET No. of	DWN	APP	STATUS	
October 4, 2024		KC	DNM	IFC	

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LEGENDS	
	ACCESS ROAD
	CONTACT WATER
	COLLECTION DITCH
	NON-CONTACT WATER
	SUMP
	BERM
	EARTHWORKS (FILL)
	EARTHWORKS (CUT)



PERMIT TO PRACTICE

TETRA TECH CANADA INC.

SIGNATURE

Date 2024-10-08

PERMIT NUMBER PP003

Association of Professional Engineers of Yukon

NUM	DATE	DWN	CKD	APR	REVISIONS
1	04/10/24	KC	JY	DNM	RE-ISSUED FOR CONSTRUCTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION
					DESCRIPTION
					REVISIONS

PROFESSIONAL

2024-10-08

YUKON

DAVID N. MOSCHINI

TERRITORY

ENGINEER

PROFESSIONAL SEAL

CLIENT

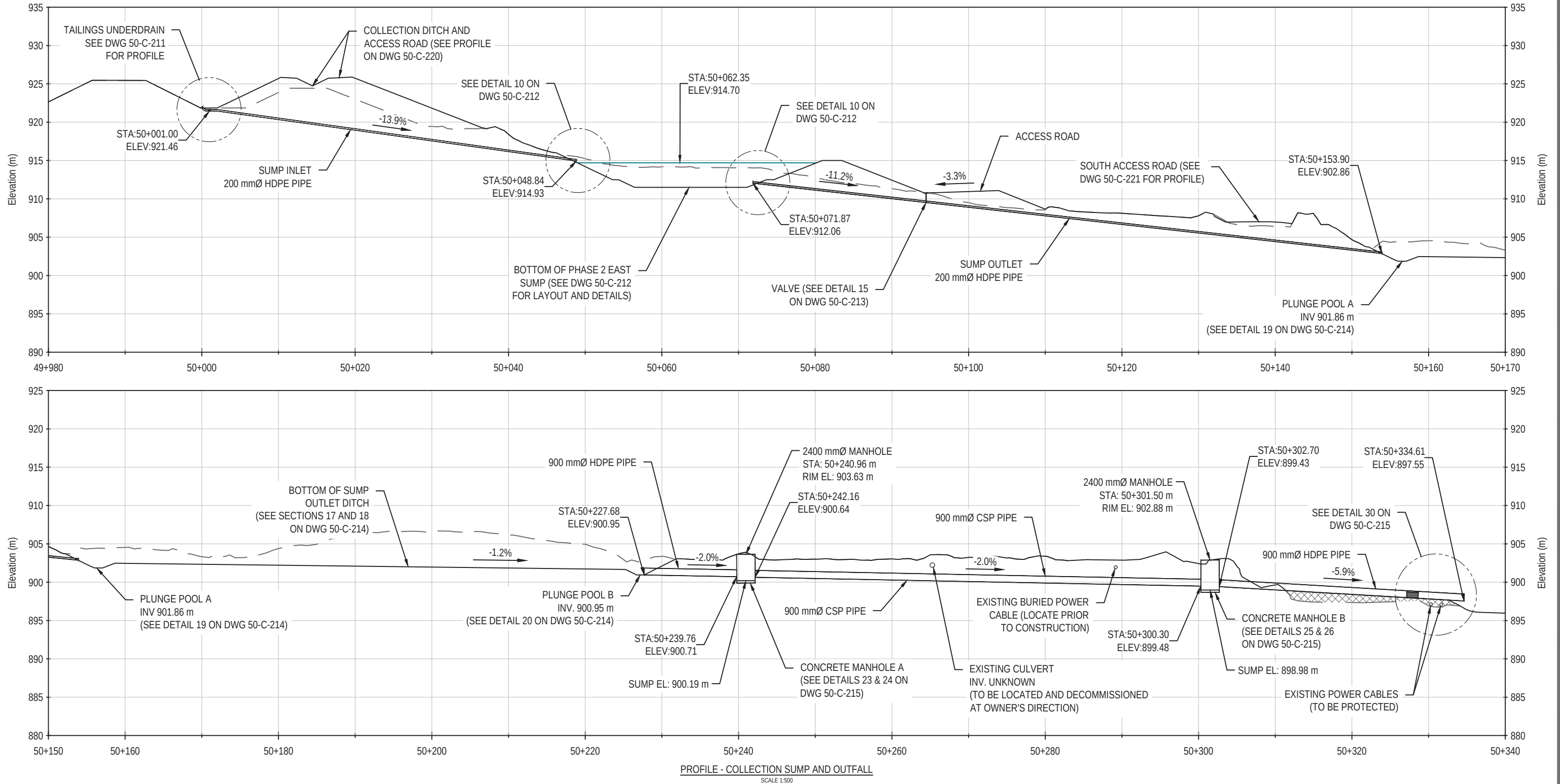
DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN

KENO HILL DISTRICT MILL SITE, YUKON

UNDER TAILINGS DRAINAGE PIPE PLAN

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	1	50-C-207
DATE	SHEET No.	DWN	APP	STATUS	
October 4, 2024	of	KC	DNM	IFC	

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NOTES:

- PIPE BEDDING NOT SHOWN FOR CLARITY. FOR PIPE BEDDING THICKNESSES AND DETAILING, SEE DETAILS 27-28 ON DWG 50-C-215.

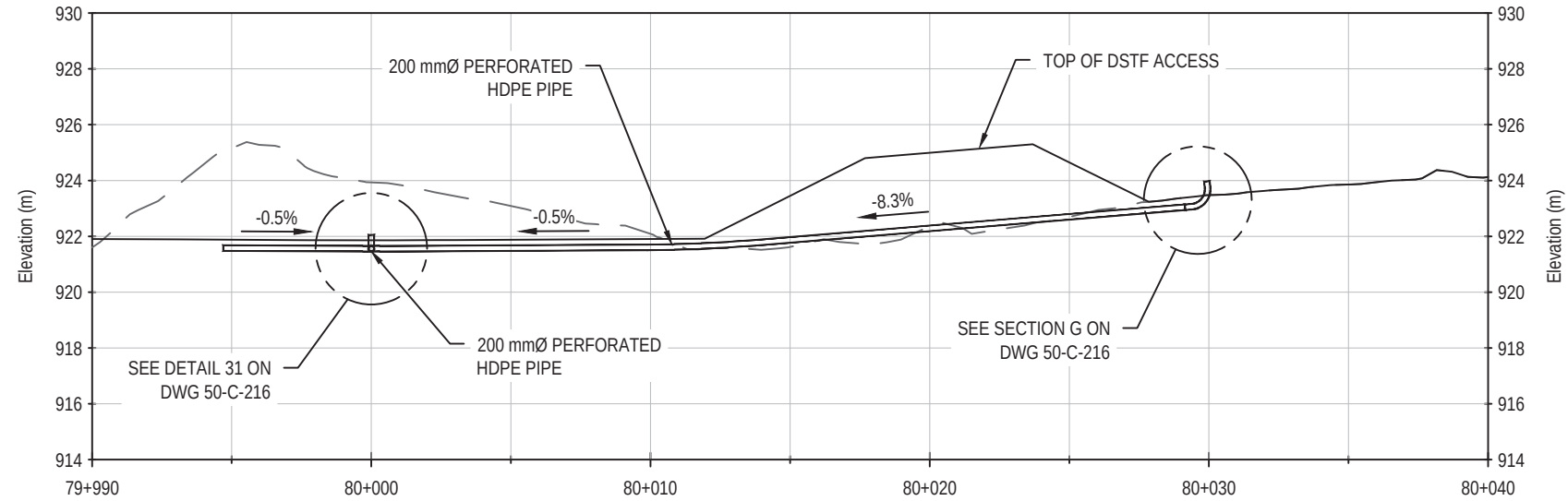


NUM	DATE	DWN	CKD	JY	DNM	ISSUED FOR CONSTRUCTION	DESCRIPTION
0	01/10/24	KC	JY	DNM	APR	ISSUED FOR CONSTRUCTION	
							REVISIONS

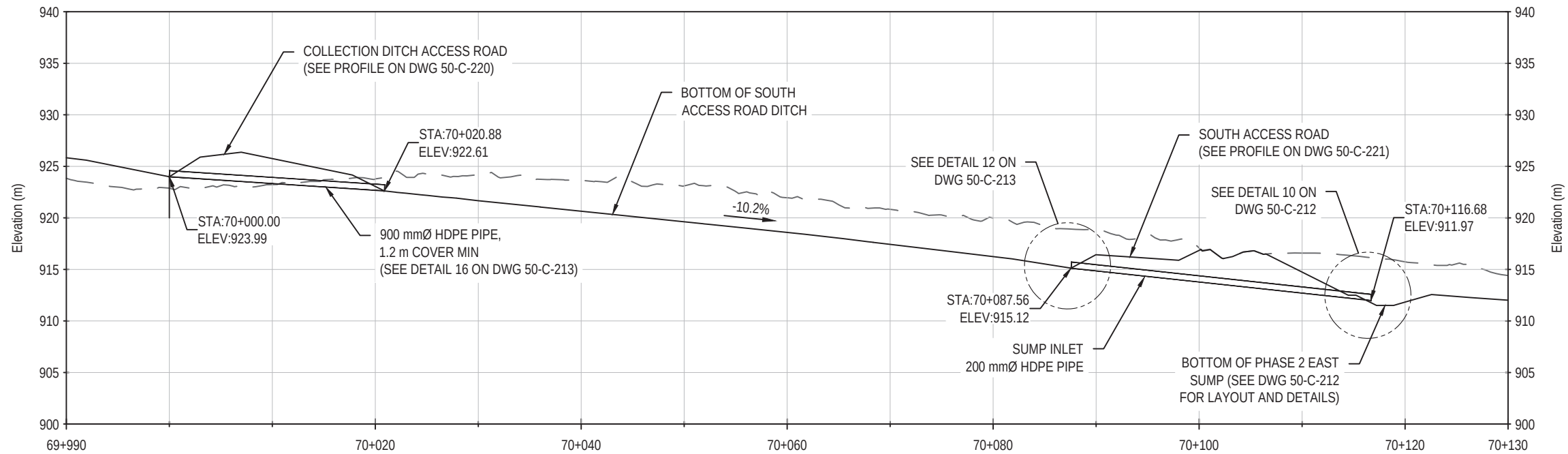


CLIENT		Hecla MINING COMPANY		DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON			
		TETRA TECH		COLLECTION SUMP & OUTFALL PROFILE			
PROJECT NO. WARC04415-10	OFFICE VANC	DES KC	CKD JY	REV 0	DRAWING 50-C-210		
DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC			

C:\pwworking\can_infra\m2913\ENGL\WARC04415-10_200.dwg [211] October 04, 2024 - 1:43:56 pm (BY: CHAN, KENNETHH)



PROFILE - TAILINGS UNDERDRAIN
SCALE 1:250



PROFILE - SOUTH ACCESS ROAD DITCH
SCALE 1:500

NOTES:

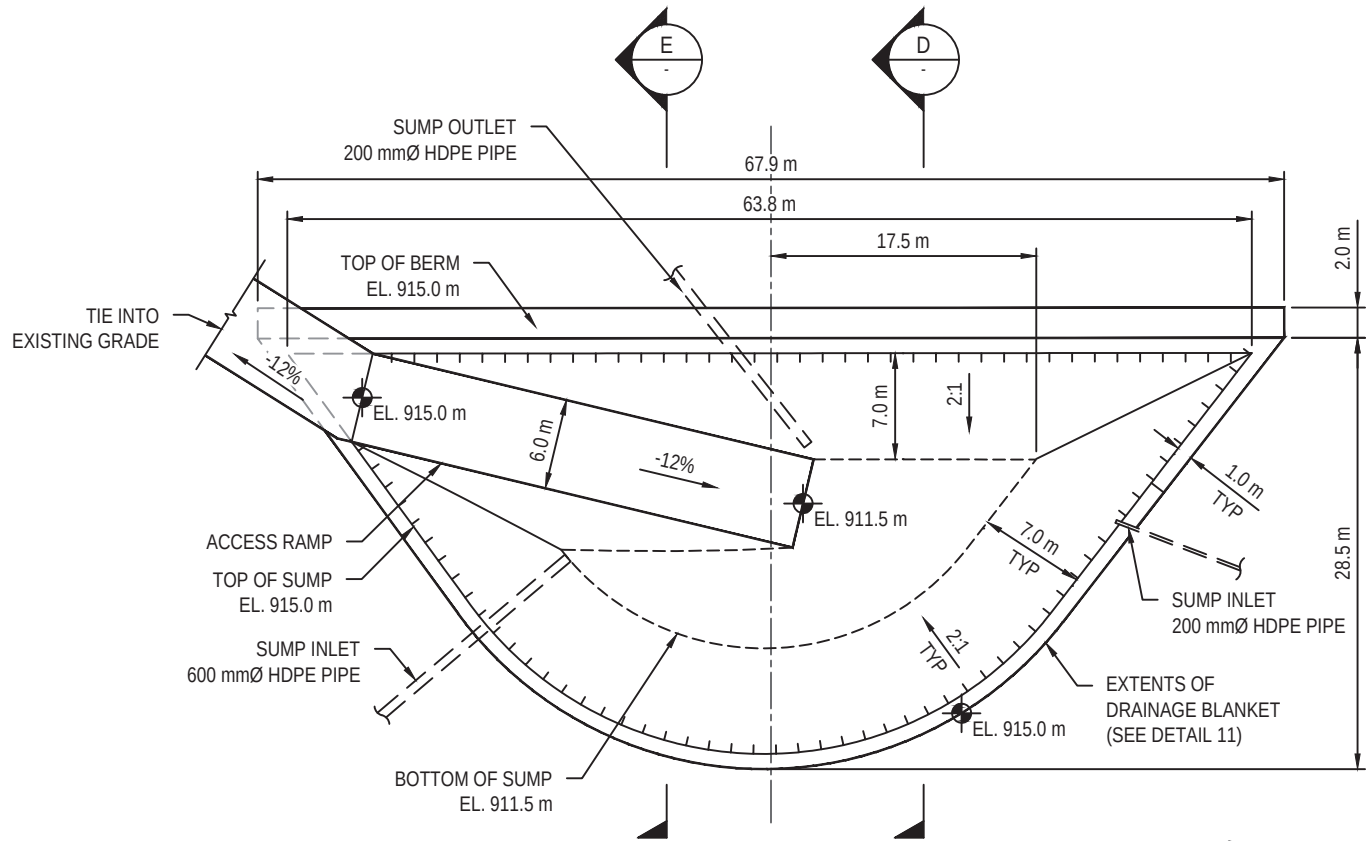
- PIPE BEDDING NOT SHOWN FOR CLARITY. FOR PIPE BEDDING THICKNESSES AND MATERIALS, SEE DETAILS 27-28 ON DWG 50-C-215.



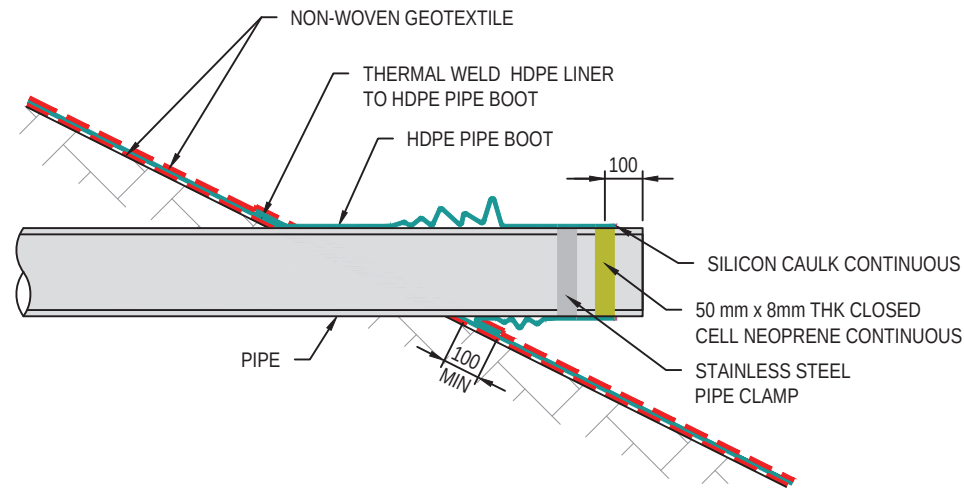
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION	
NUM	DATE	DWN	CKD	APR	DESCRIPTION	
REVISIONS						



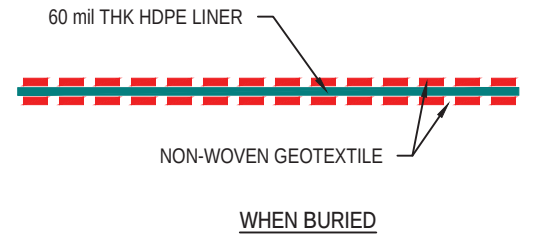
CLIENT		Hecla MINING COMPANY		DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON		
TETRA TECH		DRYSTACK DRAIN & SOUTH ACCESS ROAD DITCH PROFILES				
PROJECT NO. WARC04415-10	OFFICE VANC	DES KC	CKD JY	REV 0	DRAWING 50-C-211	
DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC		



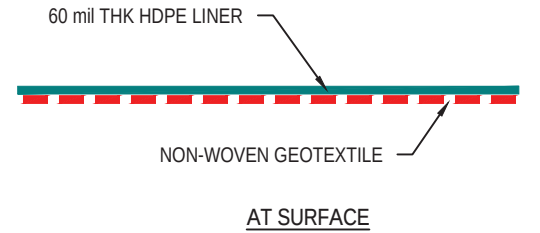
8 SUMP DETAIL
50-C-212 SCALE 1:500



10 TYPICAL LINER PENETRATION DETAILS
50-C-212 SCALE 1:20

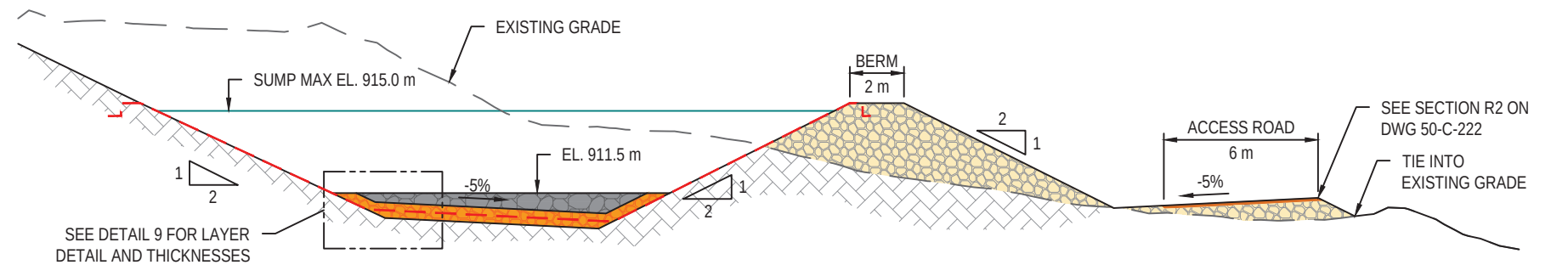


WHEN BURIED

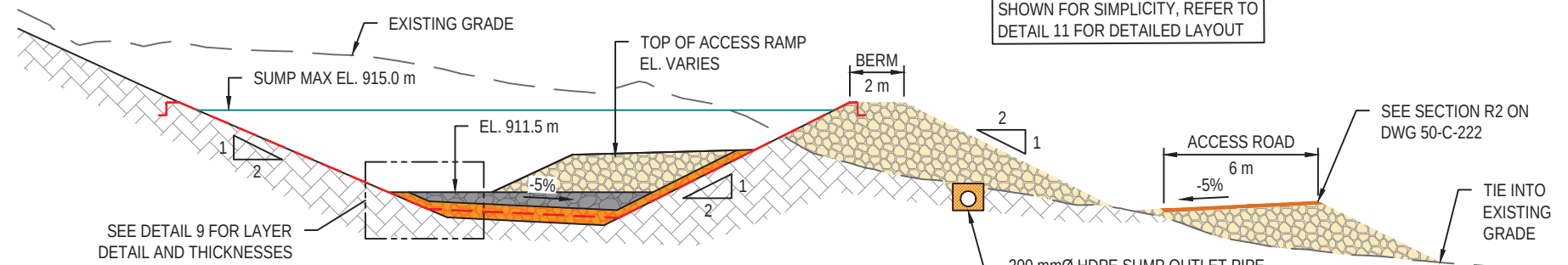


AT SURFACE

11 TYPICAL SUMP LINER DETAILS
50-C-212 SCALE 1:20



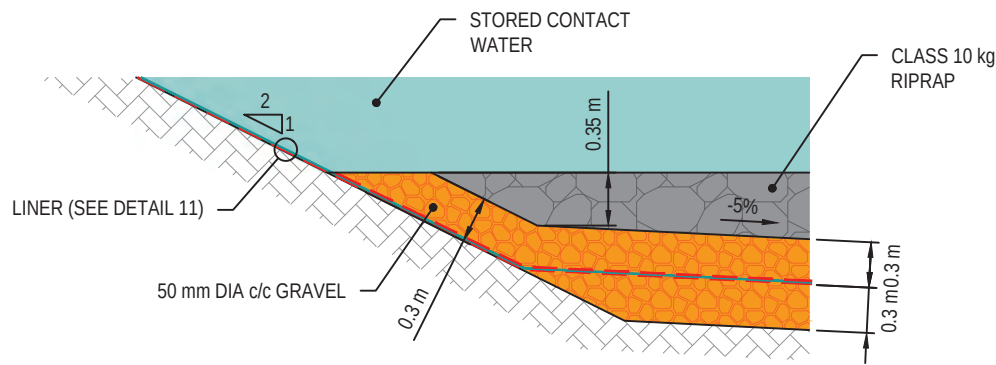
D SECTION
50-C-212 SCALE 1:250



E SECTION
50-C-212 SCALE 1:250

ONLY NON-WOVEN GEOTEXTILE IS SHOWN FOR SIMPLICITY, REFER TO DETAIL 11 FOR DETAILED LAYOUT

200 mm Ø HDPE SUMP OUTLET PIPE (SEE DETAIL 28 ON DWG 50-C-215)



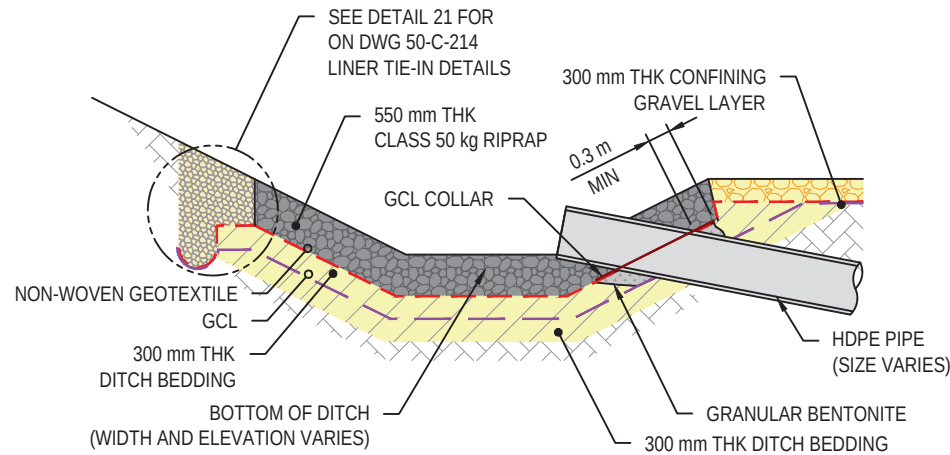
9 TYPICAL SUMP LAYER DETAILS
50-C-212 SCALE 1:50

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

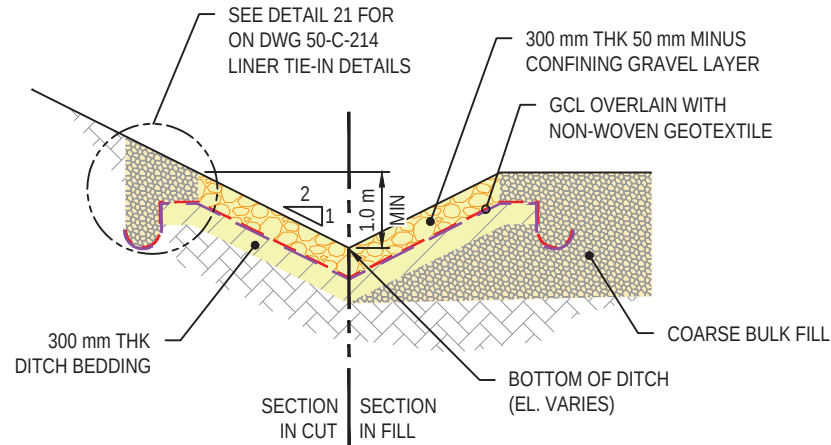
NUM	DATE	DWN	CKD	APR	ISSUED FOR CONSTRUCTION	DESCRIPTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION	
REVISIONS						



DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON						
COLLECTION SUMP SECTIONS AND DETAILS						
PROJECT NO. WARC04415-10	OFFICE VANC	DES KC	CKD JY	REV 0	DRAWING 50-C-212	
DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC		

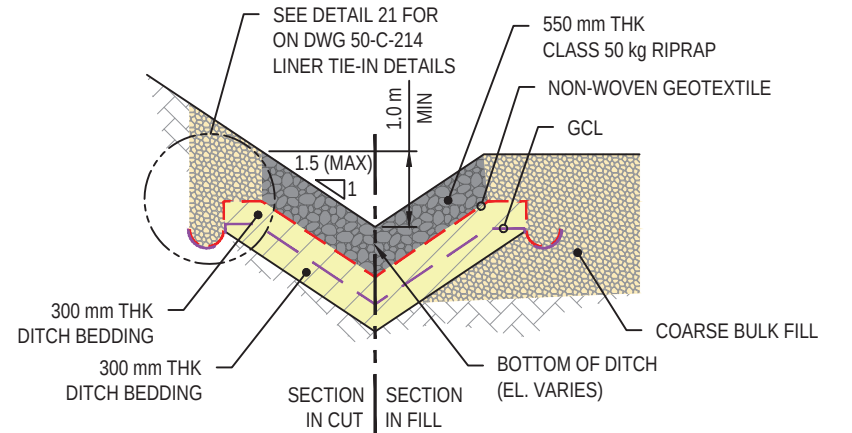


12 TYPICAL PIPE INLET DETAIL
50-C-213 SCALE 1:100



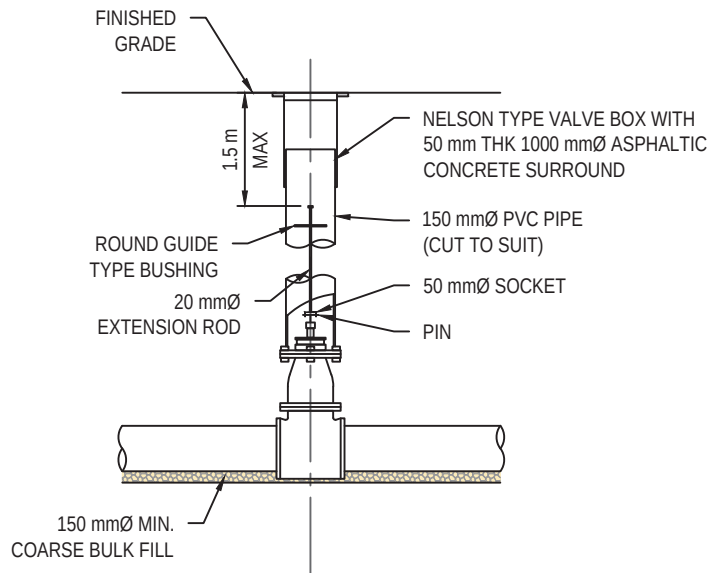
13 TYPICAL COLLECTION DITCH DETAIL
50-C-213 SCALE 1:100

FOR DITCH PROFILE SLOPES $\leq 2\%$

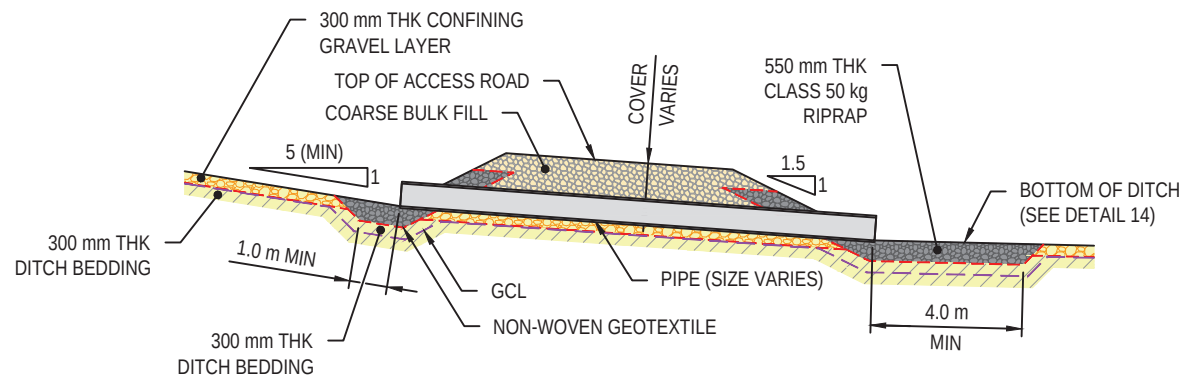


14 TYPICAL ARMoured COLLECTION DITCH DETAIL
50-C-213 SCALE 1:100

FOR DITCH PROFILE SLOPES $> 2\%$



15 TYPICAL VALVE DETAILS
50-C-213 SCALE 1:100



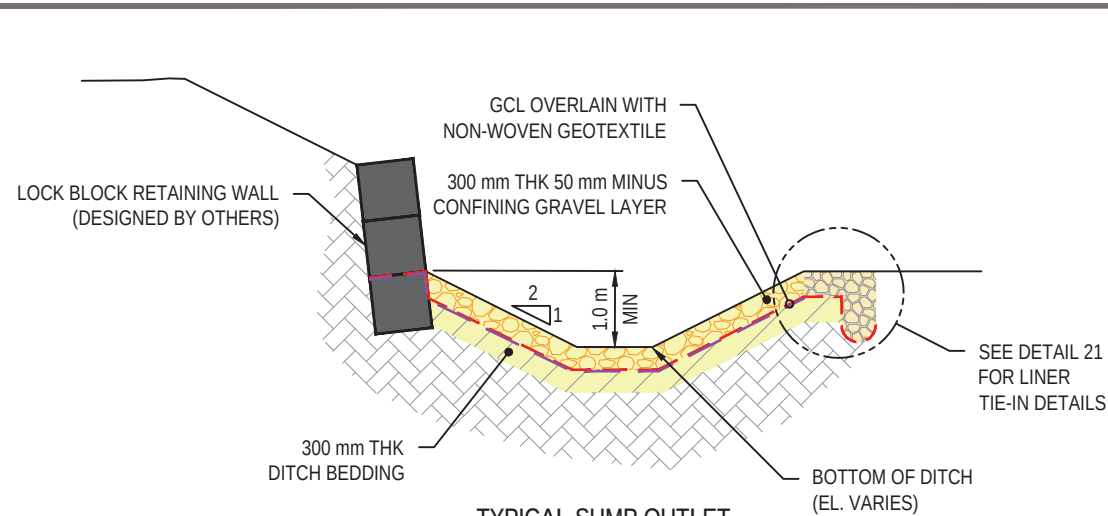
16 TYPICAL ROAD CROSSING DETAILS
50-C-213 SCALE 1:200

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

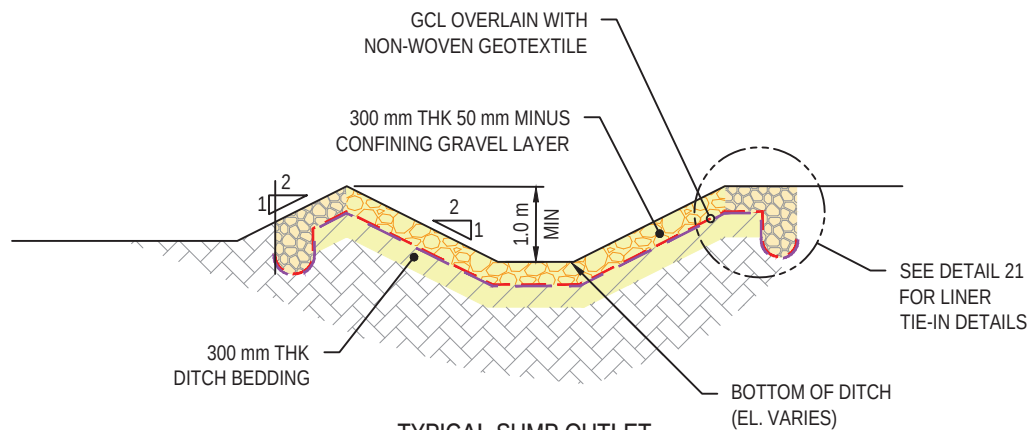
NUM	DATE	DWN	CKD	JY	DNM	ISSUED FOR CONSTRUCTION	DESCRIPTION
0	01/10/24	KC	JY	DNM	APR	ISSUED FOR CONSTRUCTION	
REVISIONS							

PROFESSIONAL
2024-10-08
YUKON
DAVID N. MOSCHINI
TERRITORY
ENGINEER

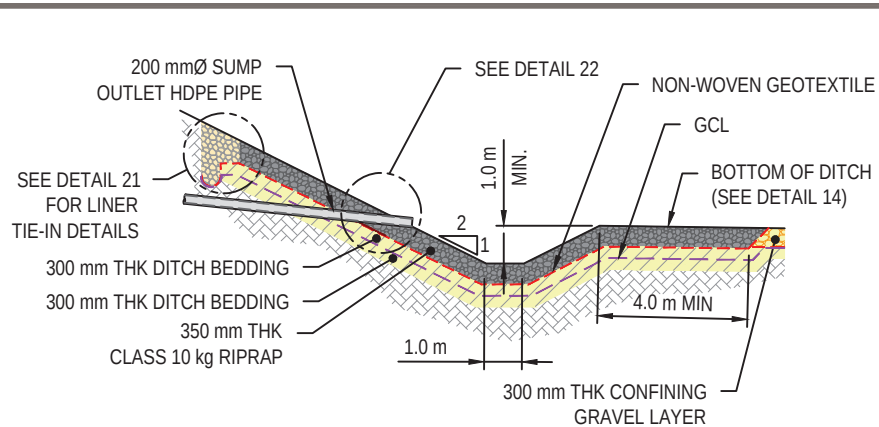
CLIENT		Hecla MINING COMPANY		DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON			
				DITCH, VAVLE & PIPE ROAD CROSSING TYPICAL DETAILS			
PROJECT NO. WARC04415-10	OFFICE VANC	DES KC	CKD JY	REV 0	DRAWING 50-C-213		
DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC			



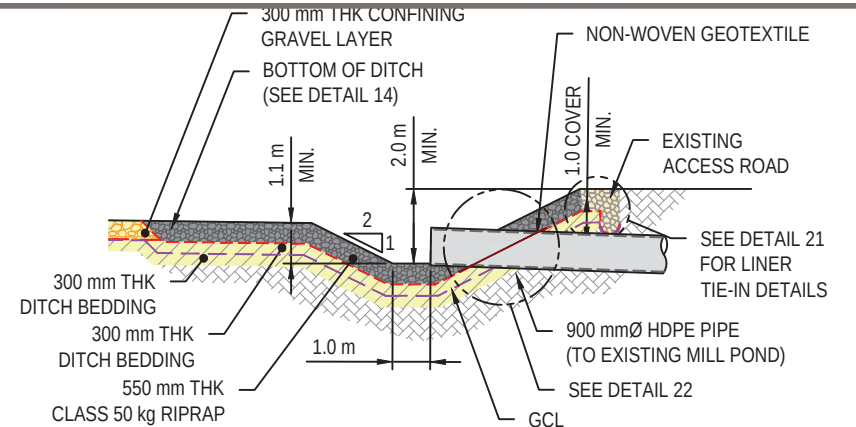
17 TYPICAL SUMP OUTLET DITCH SECTION (IN CUT)
50-C-214 SCALE 1:100



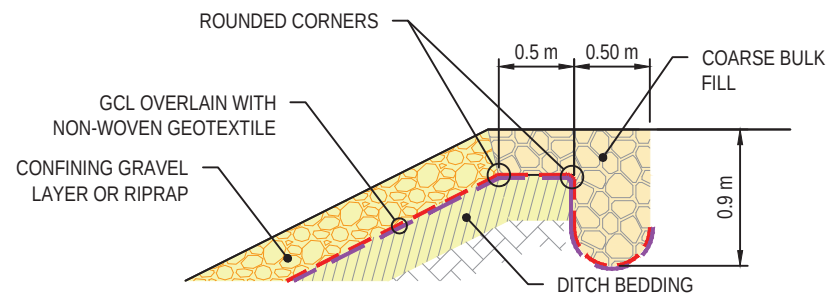
18 TYPICAL SUMP OUTLET DITCH SECTION (IN FILL)
50-C-214 SCALE 1:100



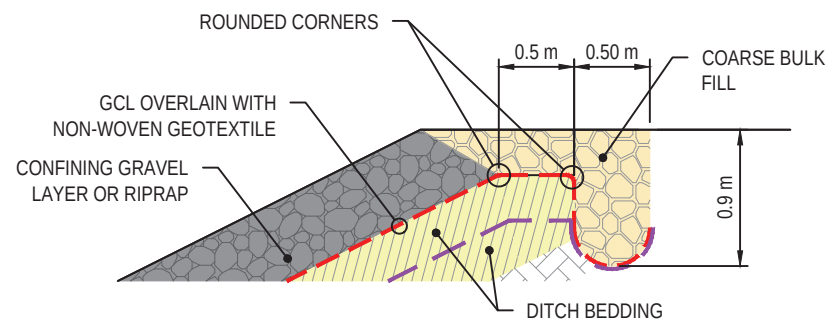
19 PLUNGE POOL A DETAILS
50-C-214 SCALE 1:200



20 PLUNGE POOL B DETAILS
50-C-214 SCALE 1:200

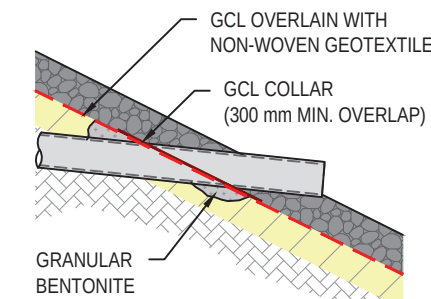


FOR TYPICAL DITCHES



FOR ARMoured DITCHES

21 TYPICAL LINER TIE-IN DETAILS
50-C-214 SCALE 1:50



22 TYPICAL GCL LINER PENETRATION DETAILS
50-C-214 SCALE 1:50

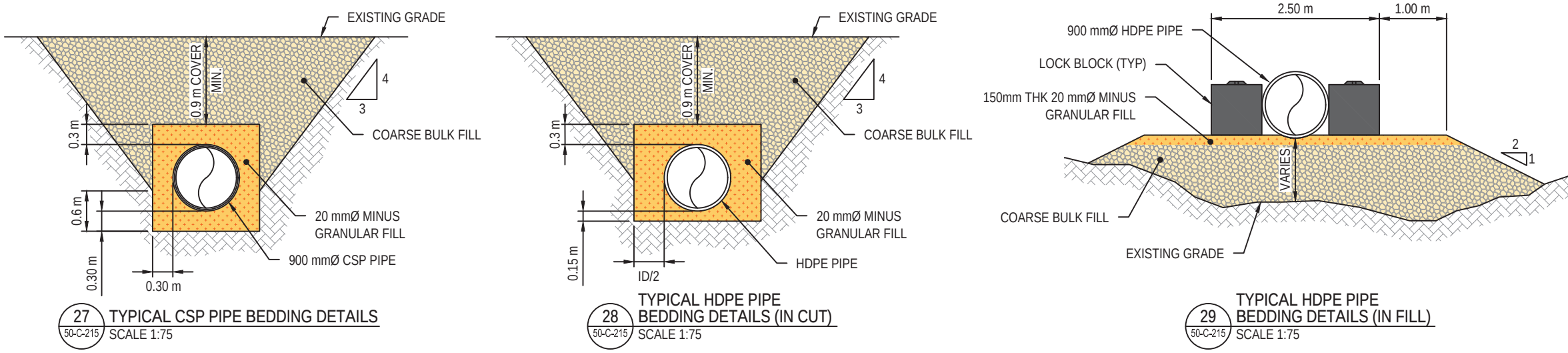
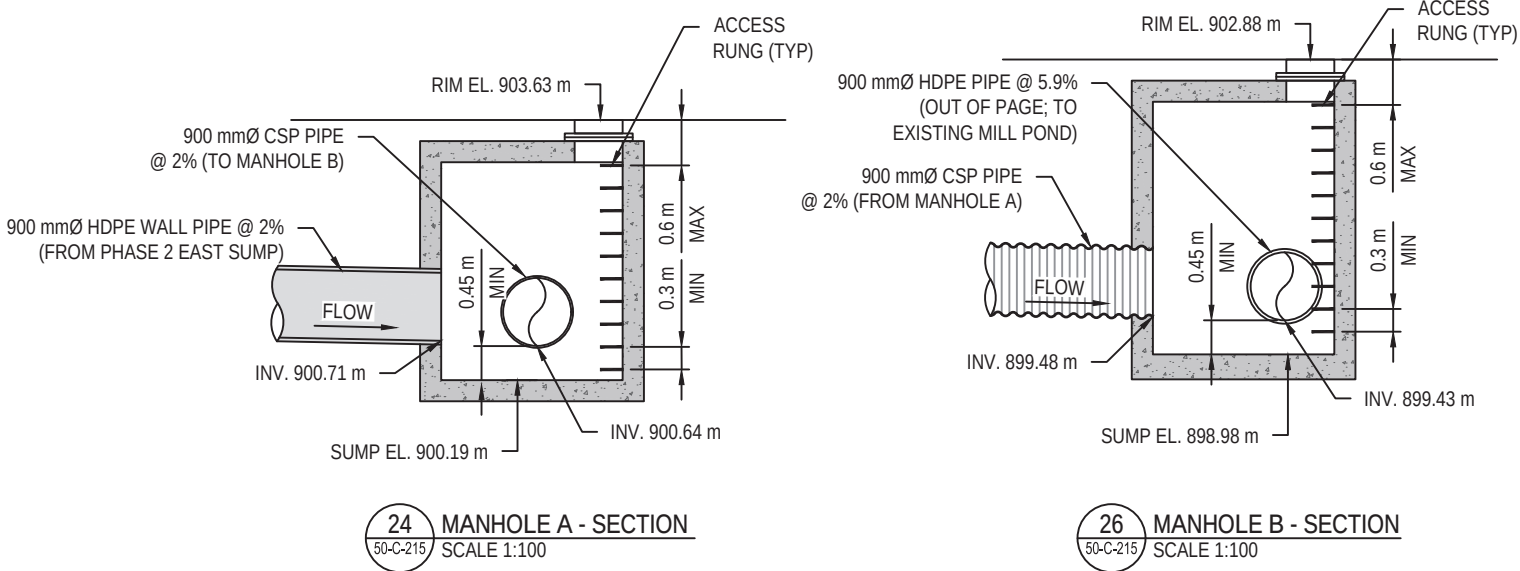
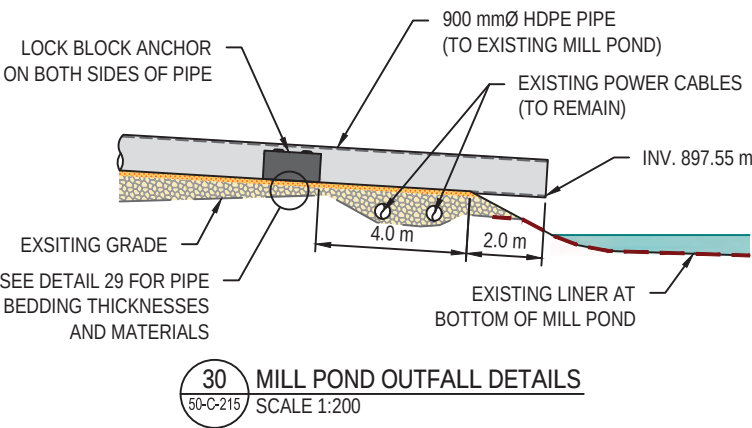
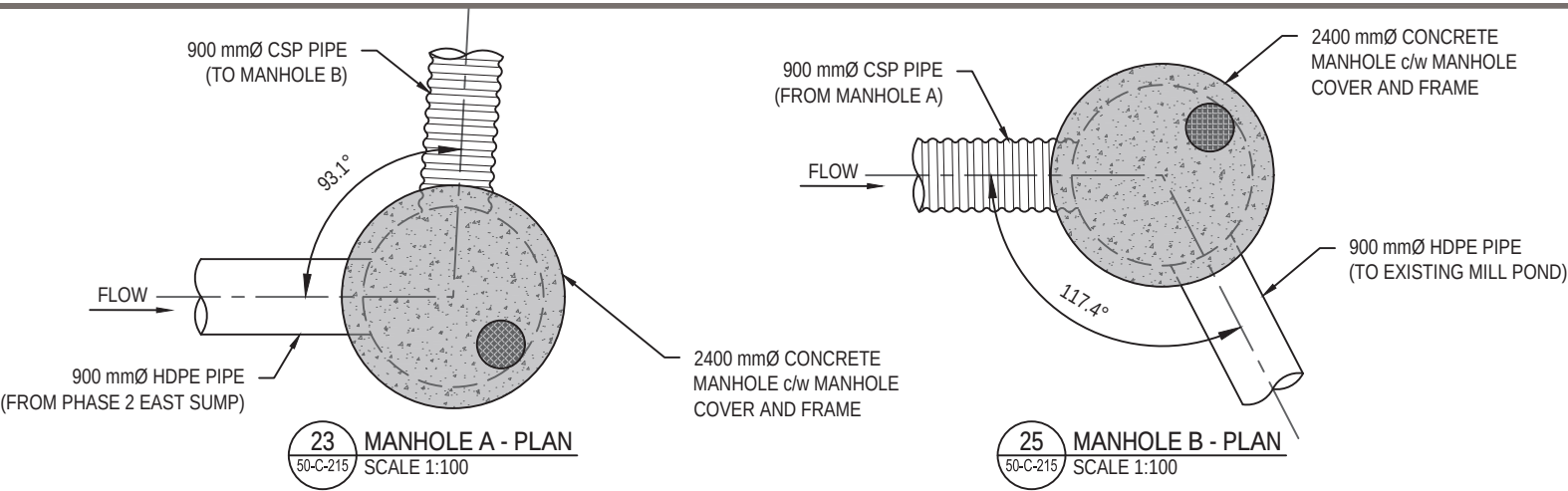
PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE *[Signature]*
Date 2024-10-08
PERMIT NUMBER PP003
Association of Professional
Engineers of Yukon

NUM	DATE	DWN	CKD	APR	ISSUED FOR CONSTRUCTION	DESCRIPTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION	
REVISIONS						



CLIENT		Hecla MINING COMPANY		DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON			
TETRA TECH		PROJECT NO. WARC04415-10		OFFICE VANC		DES KC	
		DATE October 4, 2024		SHEET No. of		CKD JY	
						REV 0	
						STATUS IFC	
						DRAWING	
						50-C-214	

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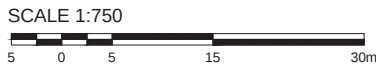
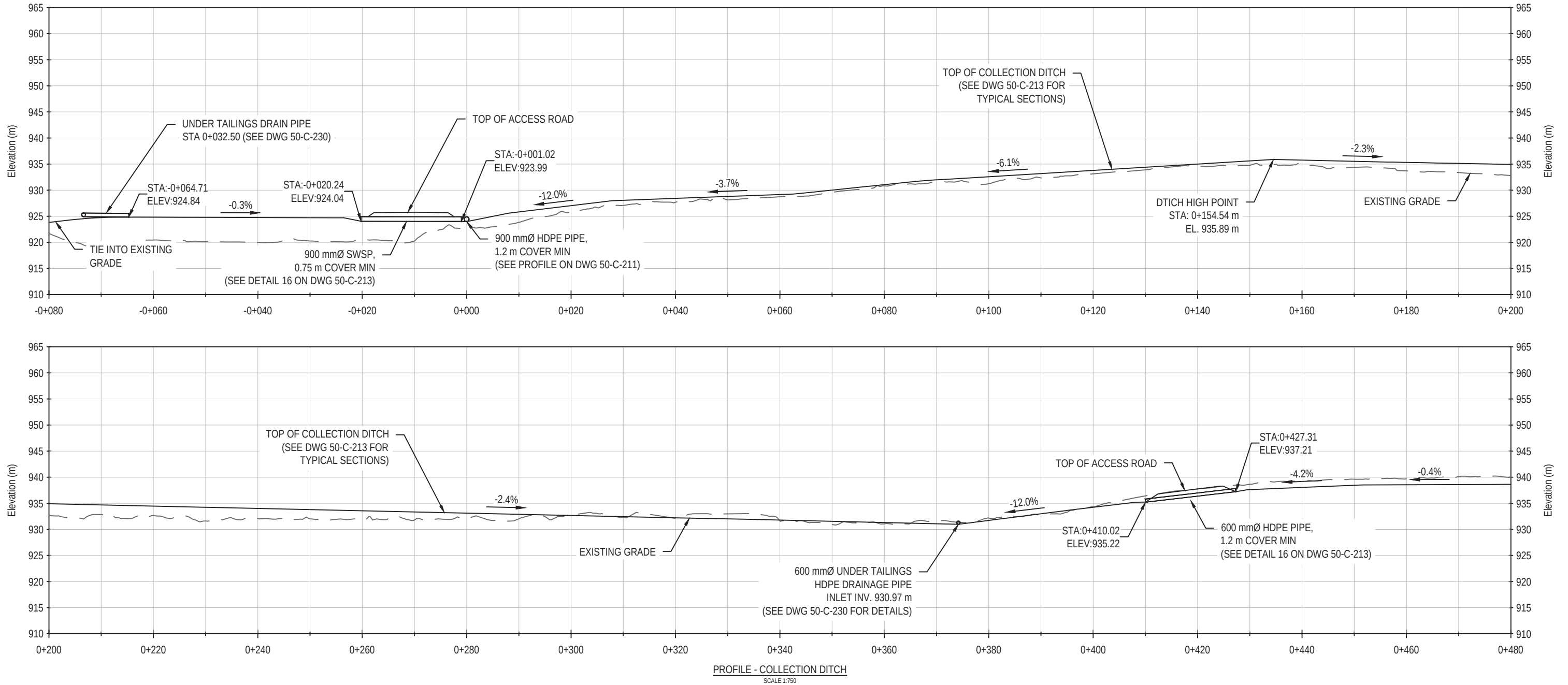
- NOTES:
- EXCAVATIONS GREATER THAN 1.2m SHALL BE SLOPED IN ACCORDANCE WITH YUKON WCB GUIDELINES.
 - MAXIMUM VERTICAL CUT OF 0.6 m.
 - SIDESOPES SHALL BE INSPECTED BY THE GEOTECHNICAL ENGINEER PRIOR TO ENTRY.

NUM	DATE	DWN	CKD	APR	ISSUED FOR CONSTRUCTION	DESCRIPTION
0	01/10/24	KC	JY	DNM	ISSUED FOR CONSTRUCTION	
REVISIONS						



DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON						
MANHOLE, PIPE OUTFALL, AND PIPE BEDDING TYPICAL SECTIONS AND DETAILS						
PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING	
WARC04415-10	VANC	KC	JY	0	50-C-215	
DATE	SHEET No.	DWN	APP	STATUS		
October 4, 2024	of	KC	DNM	IFC		

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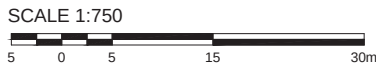
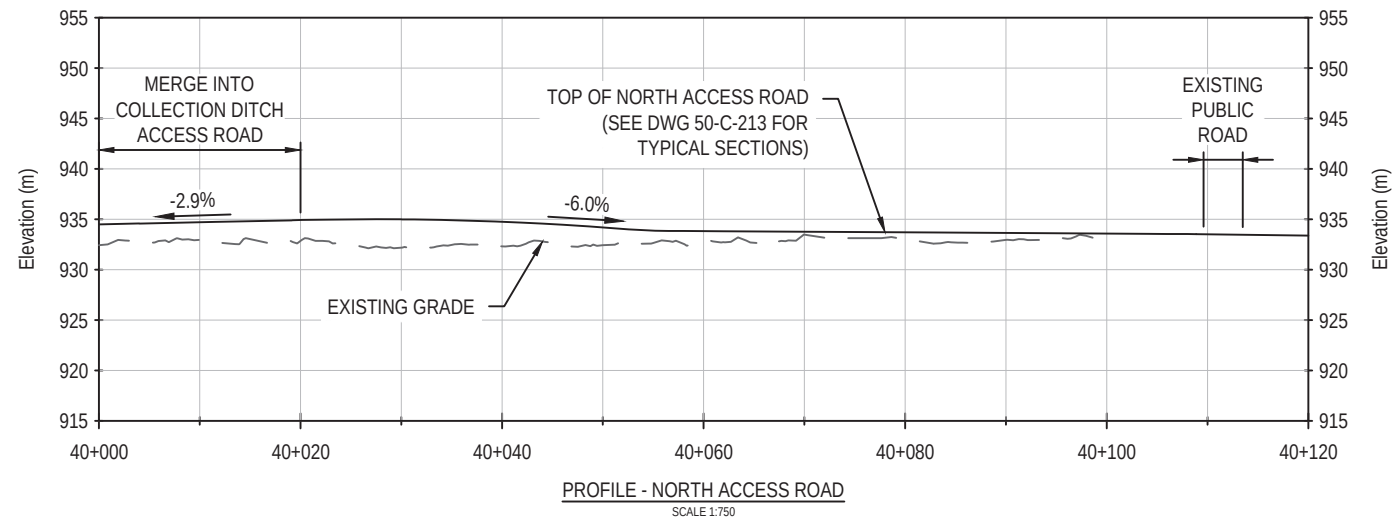
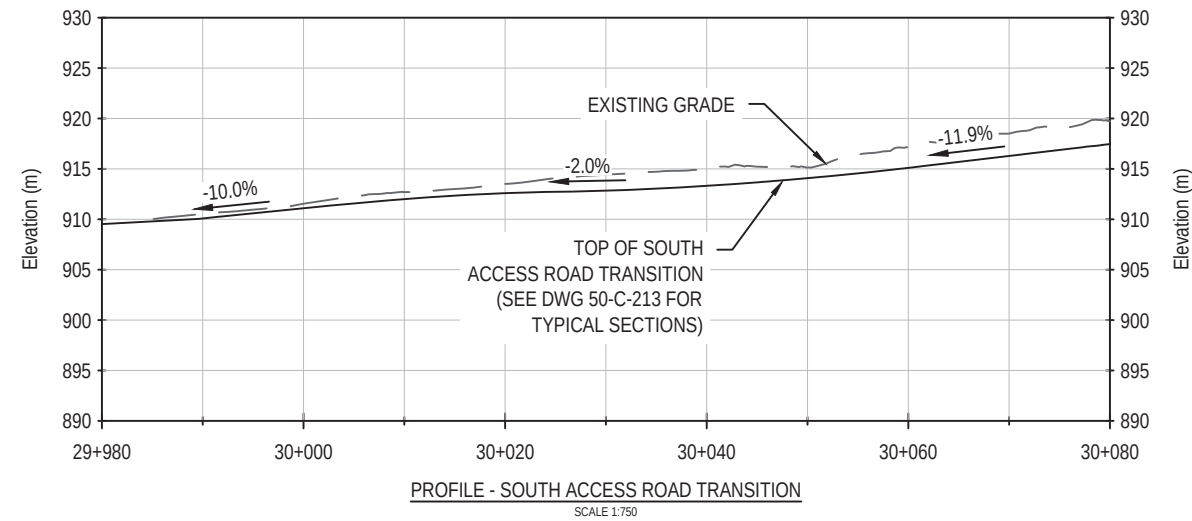
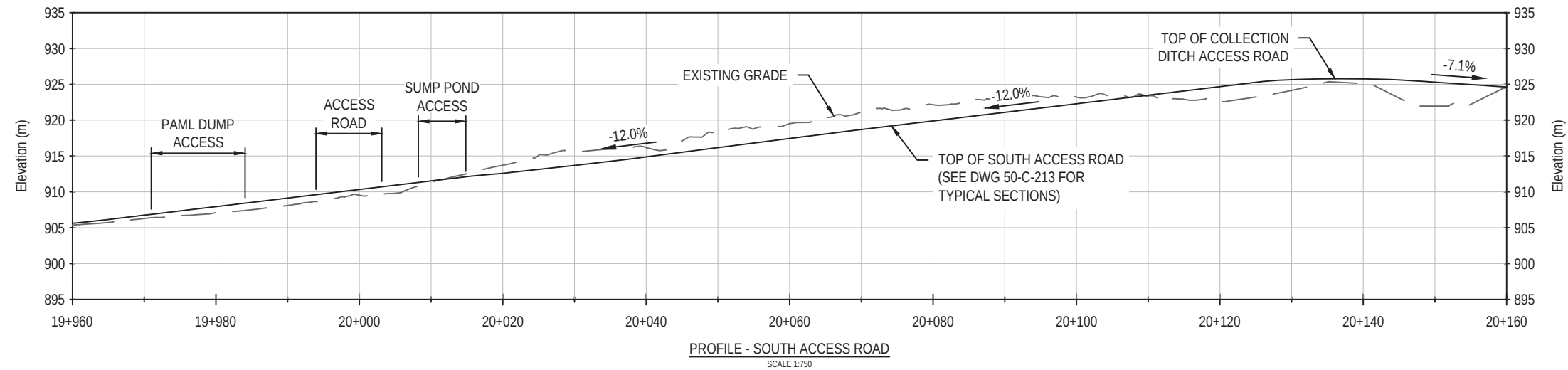
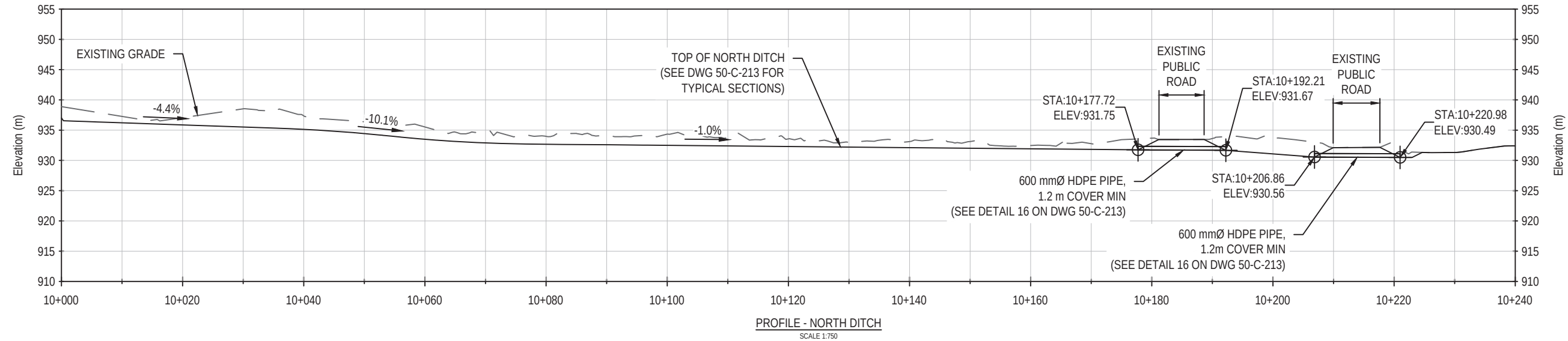
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Engineers of Yukon

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0	01/10/24	KC	JY	DNM		ISSUED FOR CONSTRUCTION
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		TETRA TECH		COLLECTION DITCH PROFILE			
PROJECT NO.	WARC04415-10	OFFICE	VANC	DES	KC	CKD	JY
DATE	October 4, 2024	SHEET No.	of	DWN	KC	APP	DNM
				REV	0	STATUS	IFC
				50-C-220			

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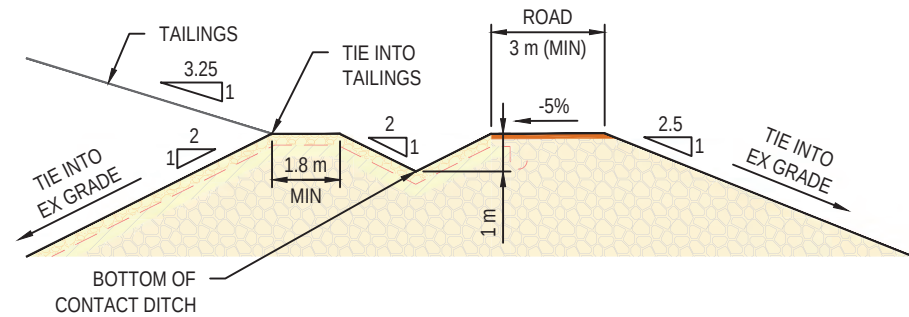
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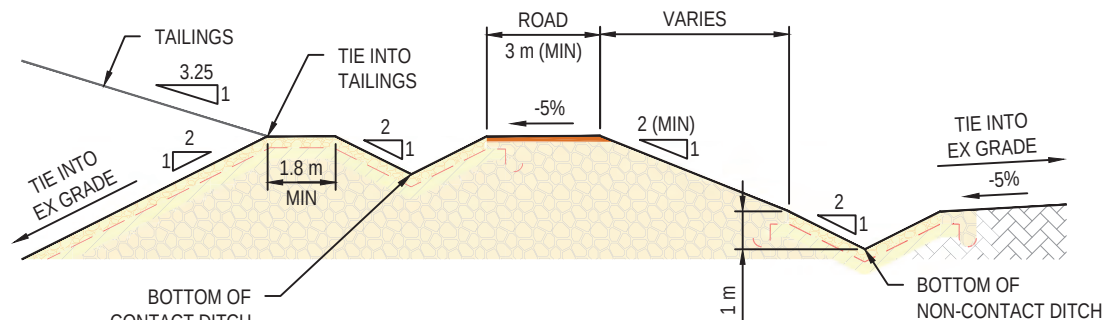


DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON						
ACCESS ROADS AND DITCH PROFILES						
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DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC		

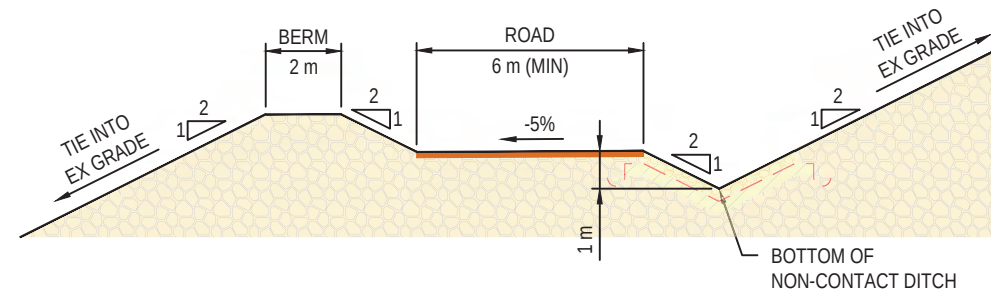
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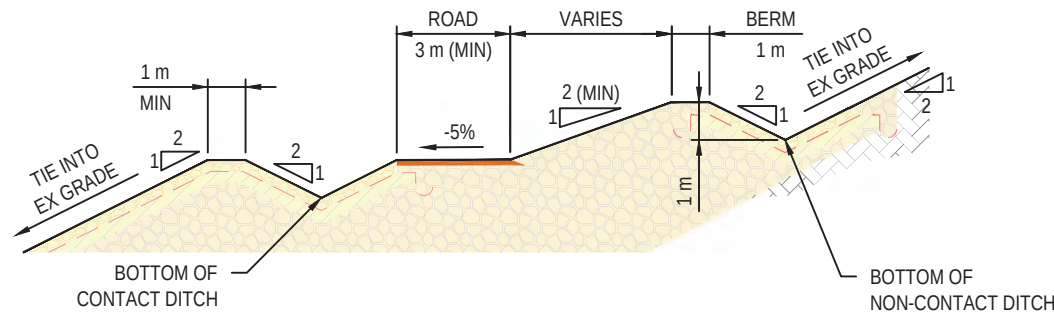
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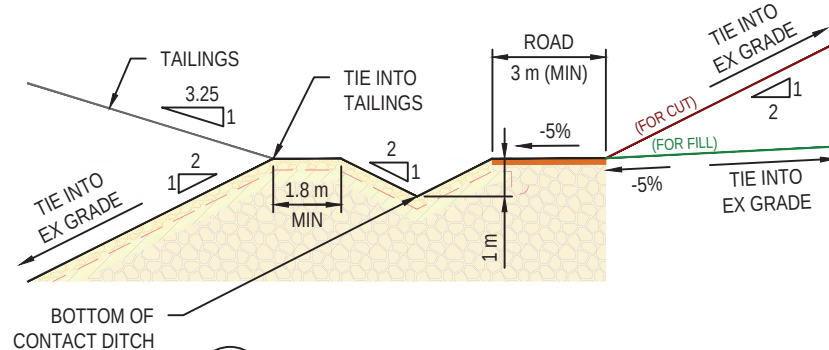
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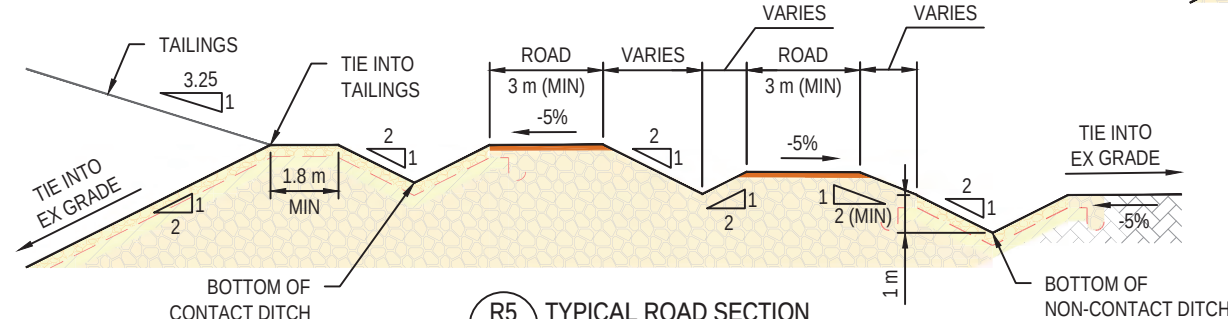
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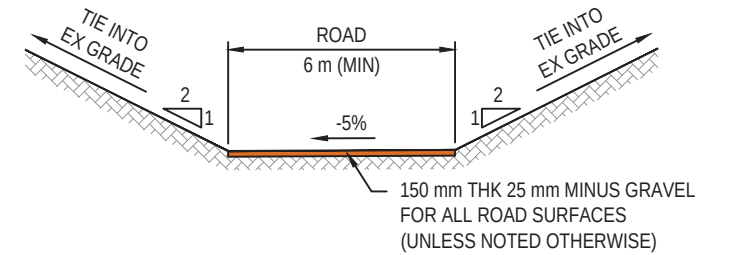
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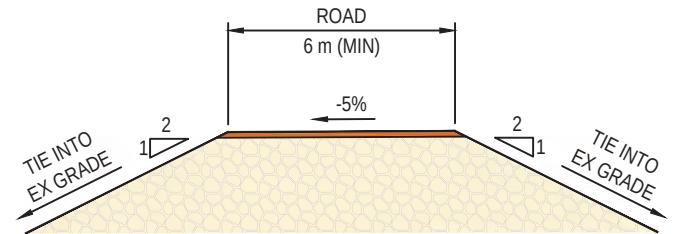
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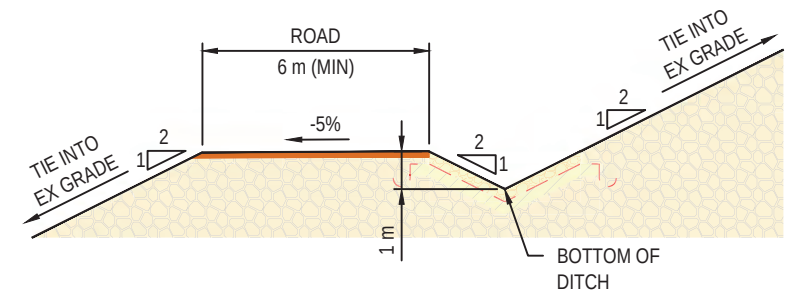
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50-C-223 SCALE 1:200



R1 TYPICAL ROAD SECTION (IN CUT)
50-C-223 SCALE 1:200



R2 TYPICAL ROAD SECTION (IN FILL)
50-C-223 SCALE 1:200



R3 TYPICAL ROAD SECTION
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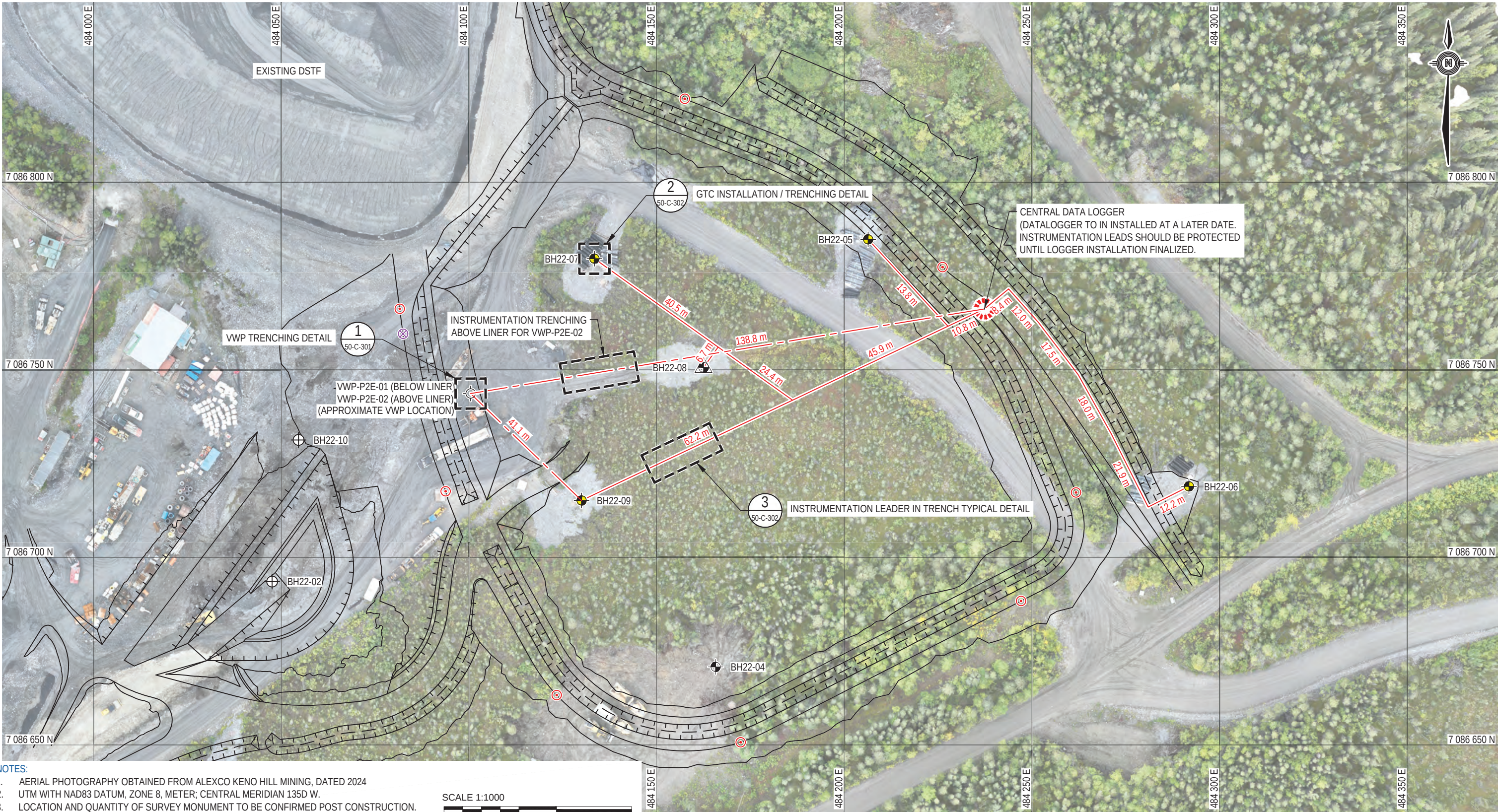
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CLIENT		Hecla MINING COMPANY		DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON		
TETRA TECH		COLLECTION DITCH AND ACCESS ROADS TYPICAL SECTIONS		PROJECT NO. WARC04415-10		
DATE October 4, 2024		SHEET No. of		OFFICE VANC		
				DES KC		
				CKD JY		
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NOTES:

1. AERIAL PHOTOGRAPHY OBTAINED FROM ALEXCO KENO HILL MINING, DATED 2024
2. UTM WITH NAD83 DATUM, ZONE 8, METER; CENTRAL MERIDIAN 135D W.
3. LOCATION AND QUANTITY OF SURVEY MONUMENT TO BE CONFIRMED POST CONSTRUCTION.
4. INSTRUMENTATION AND EXTENSIONS WILL BE PROVIDED BY THE ENGINEER OR OWNER.

LEGEND

- APPROXIMATE LOCATION OF CABLE EXTENSION TRENCHES
- VIBRATING WIRE PIEZOMETER
- GTC- TT CABLE, 16 CHANNEL AMPHENOL
- GTC-BEADED STREAM - DIGITAL WITH LOGGER
- VIBRATING WIRE PIEZOMETER TO BE INSTALLED (LOCATION TO BE CONFIRMED DURING CONSTRUCTION)
- SURVEY MONUMENT³
- SLOPE INCLINOMETER

NUM	DATE	DWN	EL	IM	GK	APR	ISSUED FOR CONSTRUCTION	DESCRIPTION
0	23-SEP-24							
REVISIONS								



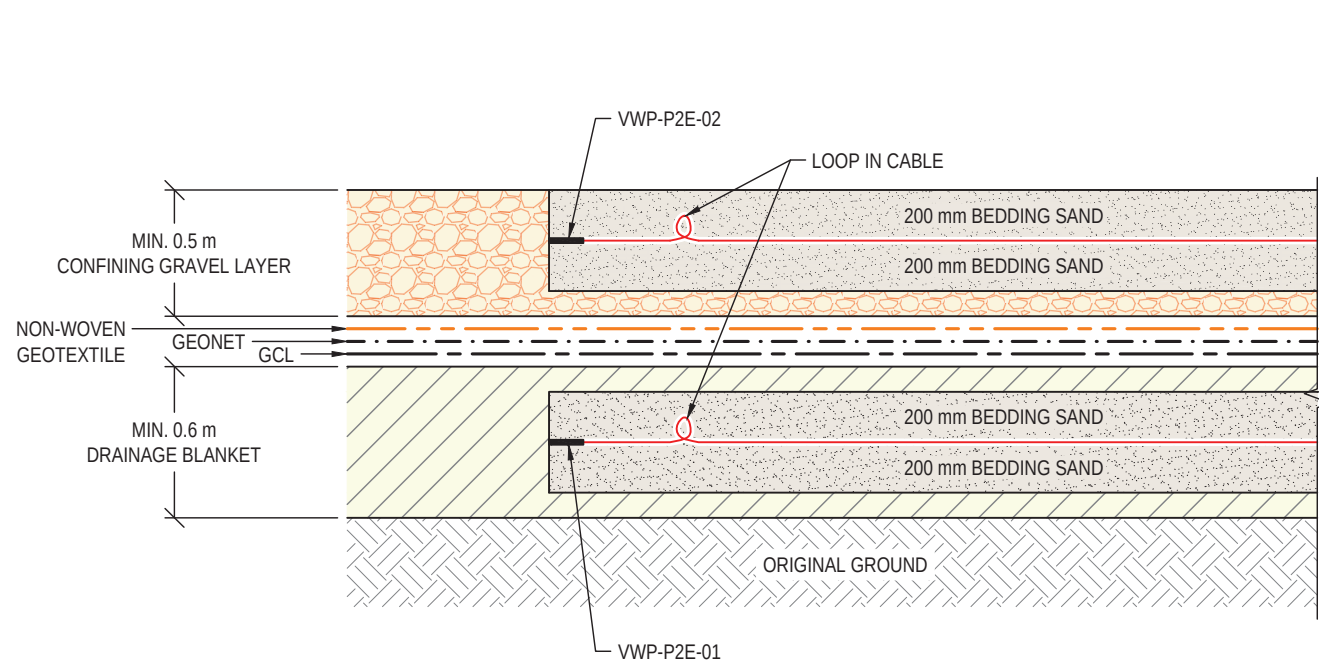
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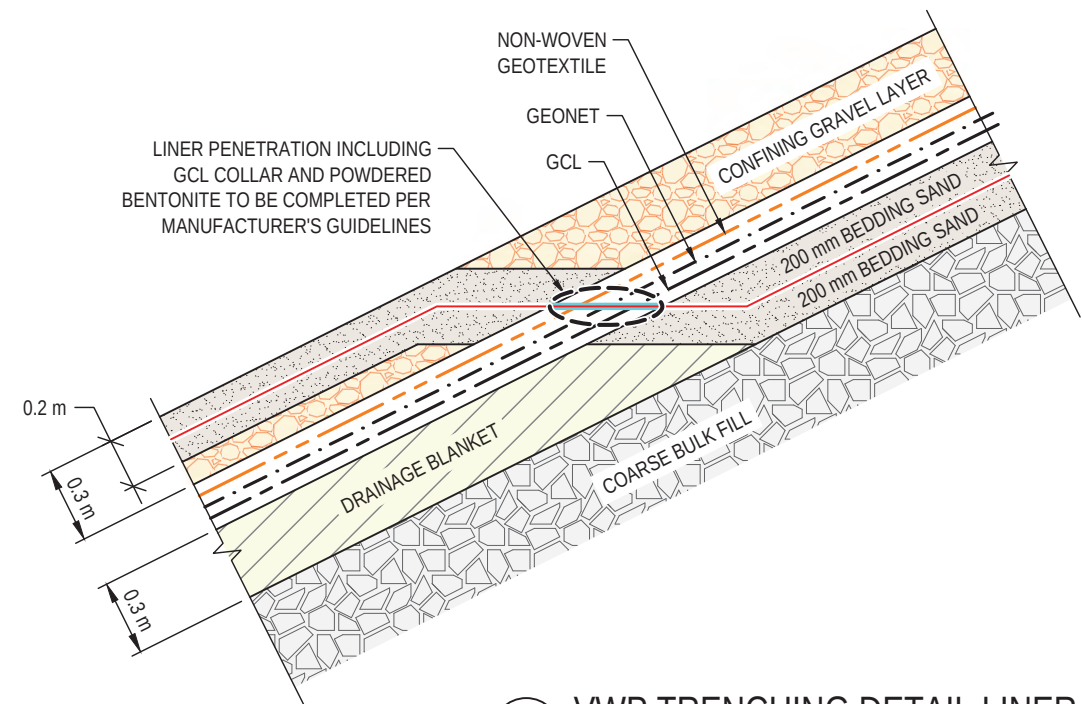
DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

INSTRUMENTATION
PLAN VIEW

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	EDM	YQ	IM	0	50-C-300
DATE	SHEET No.	DWN	APP	STATUS	
September 23, 2024	30 of 32	EL	GK	IFC	



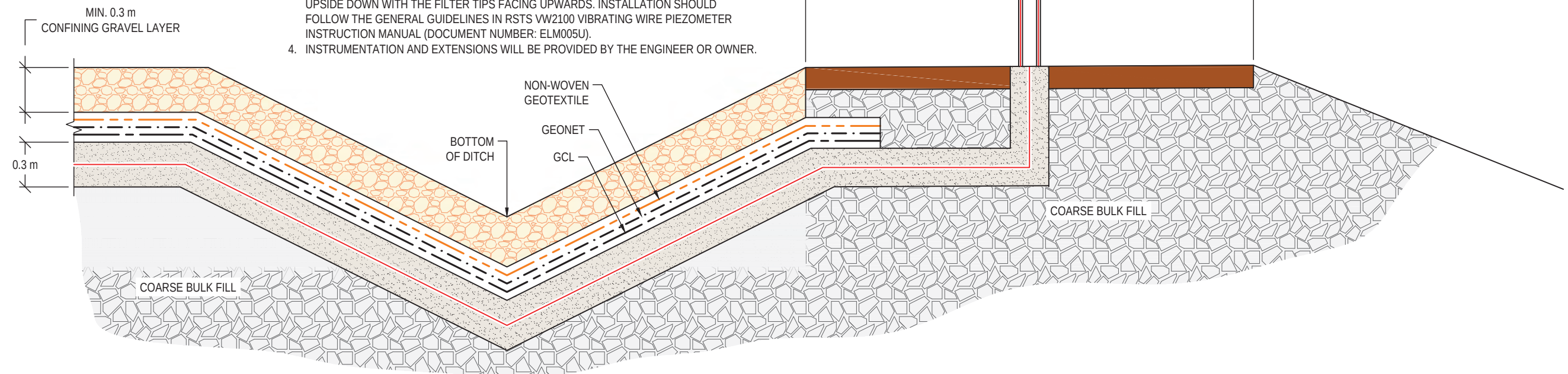
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SCALE: N.T.S.



1 VWP TRENCHING DETAIL LINER PENETRATION
SCALE: N.T.S.

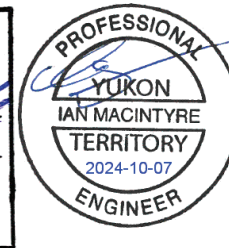
NOTE:

1. VWP-P2E-01 WILL CONNECT AND RUN IN THE SAME TRENCH AS GTC IN BH22-09.
2. WHERE MULTIPLE CABLES ARE IN THE SAME TRENCH, CABLES SHOULD BE SPACED BY 50 mm WITH SAND COVER BETWEEN THEM.
3. IF VWP MODEL #VW2100 ARE USED IN PLACE OF MODEL #VW2191, A SMALL VERTICAL HOLE WILL NEED TO BE EXCAVATED TO ALLOW THE VWP TO BE INSTALLED VERTICALLY UPSIDE DOWN WITH THE FILTER TIPS FACING UPWARDS. INSTALLATION SHOULD FOLLOW THE GENERAL GUIDELINES IN RSTS VW2100 VIBRATING WIRE PIEZOMETER INSTRUCTION MANUAL (DOCUMENT NUMBER: ELM005U).
4. INSTRUMENTATION AND EXTENSIONS WILL BE PROVIDED BY THE ENGINEER OR OWNER.



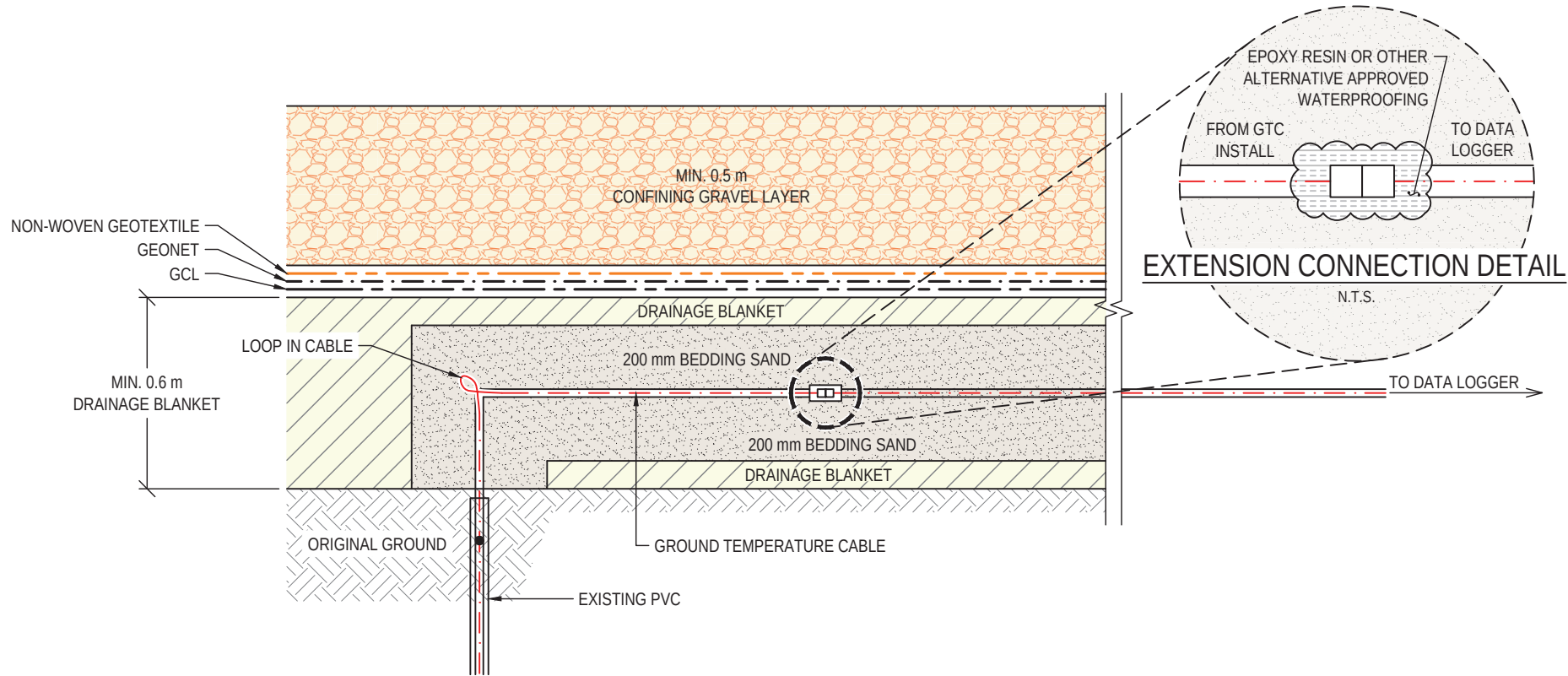
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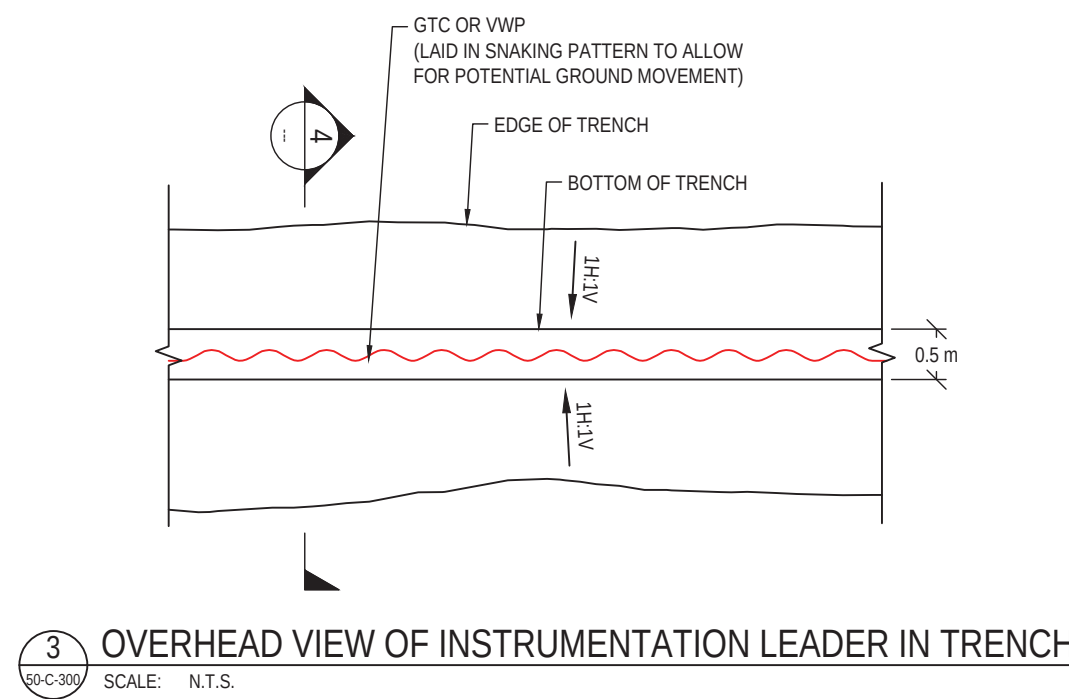


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DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON					
INSTRUMENTATAION DETAILS (1 of 2)					
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DATE September 23, 2024	SHEET No. 31 of 32	DWN EL	APP GK	STATUS IFR	

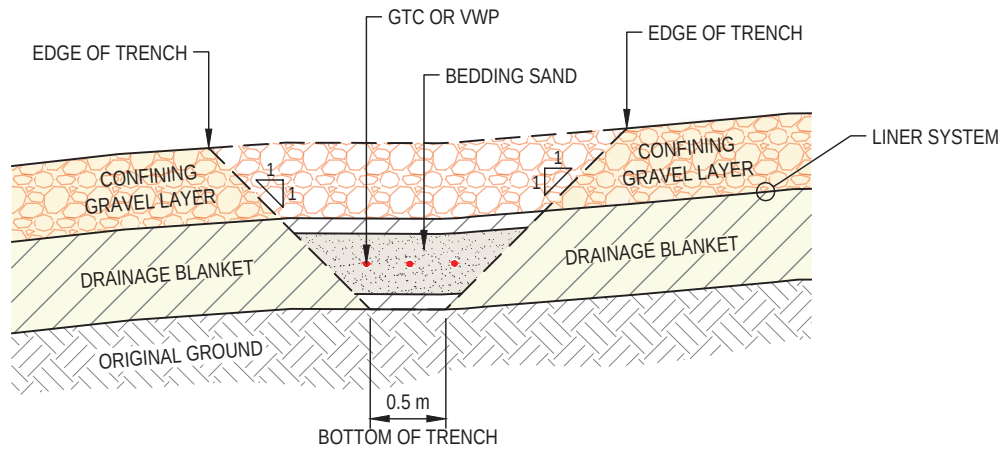
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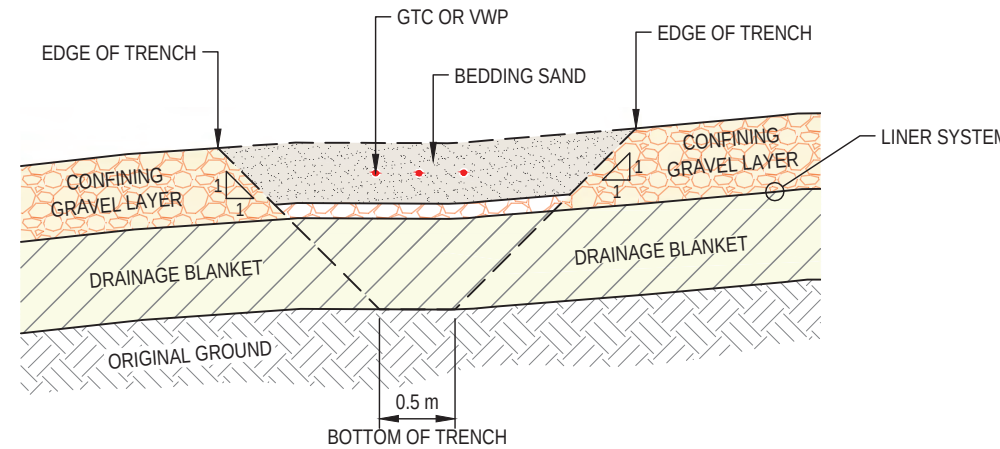
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3 OVERHEAD VIEW OF INSTRUMENTATION LEADER IN TRENCH
50-C-300 SCALE: N.T.S.



4 TYPICAL TRENCH DETAIL - INSTRUMENTATION UNDER LINER
50-C-300 SCALE: N.T.S.

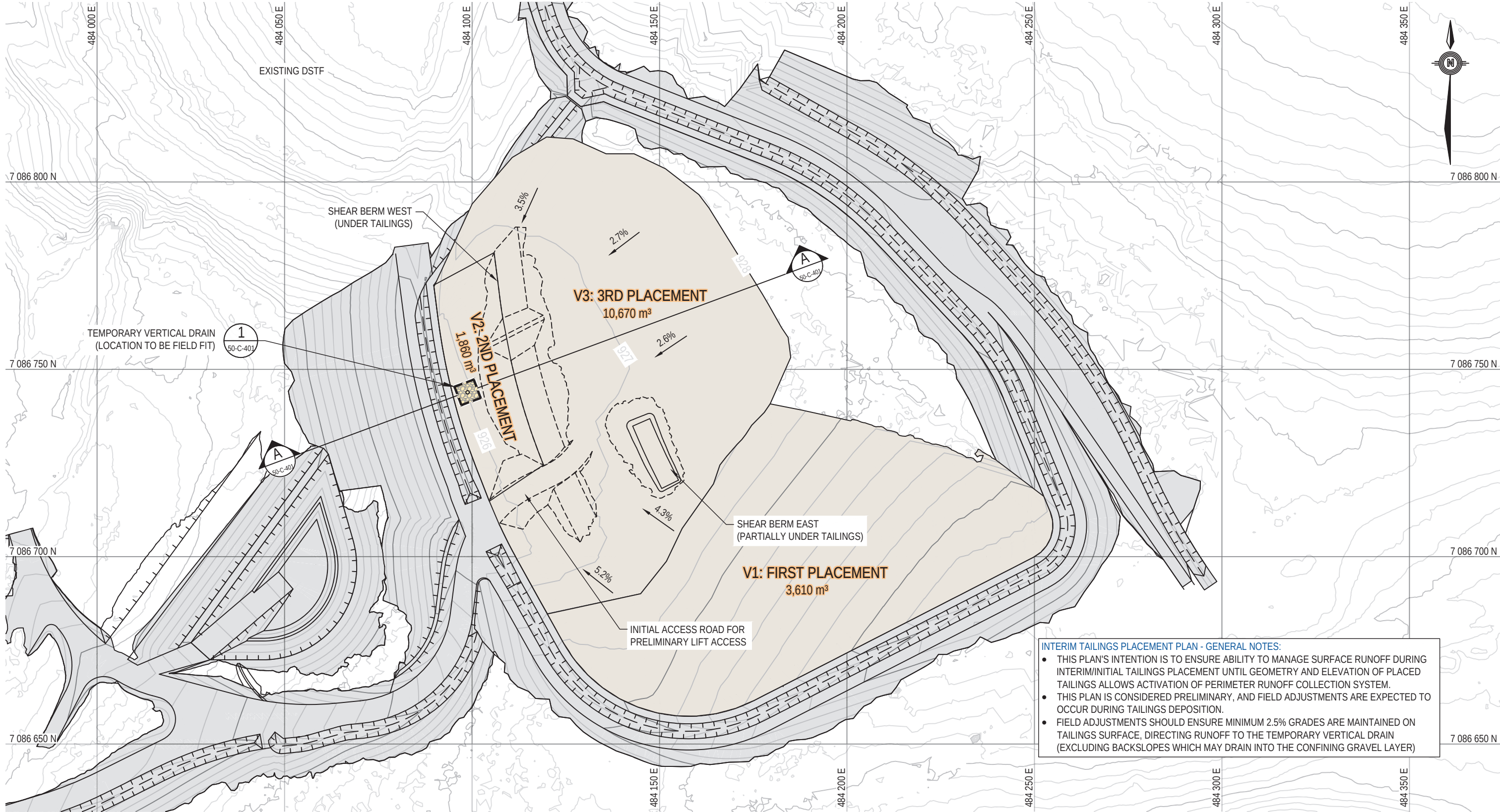


4 TYPICAL TRENCH DETAIL - INSTRUMENTATION ABOVE LINER
50-C-300 SCALE: N.T.S.

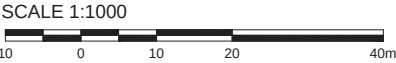
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CLIENT		DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN KENO HILL DISTRICT MILL SITE, YUKON					
		INSTRUMENTATAION DETAILS (2 of 2)					
 TETRA TECH		PROJECT NO. WARC04415-10	OFFICE EDM	DES YQ	CKD IM	REV 0	DRAWING 50-C-302
		DATE September 23, 2024	SHEET No. 32 of 32	DWN EL	APP GK	STATUS IFR	



NOTES:
1. UTM WITH NAD83 DATUM, ZONE 8, METER; CENTRAL MERIDIAN 135D W.



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NUM	DATE	DWN	CKD	APR	DESCRIPTION	
						REVISIONS

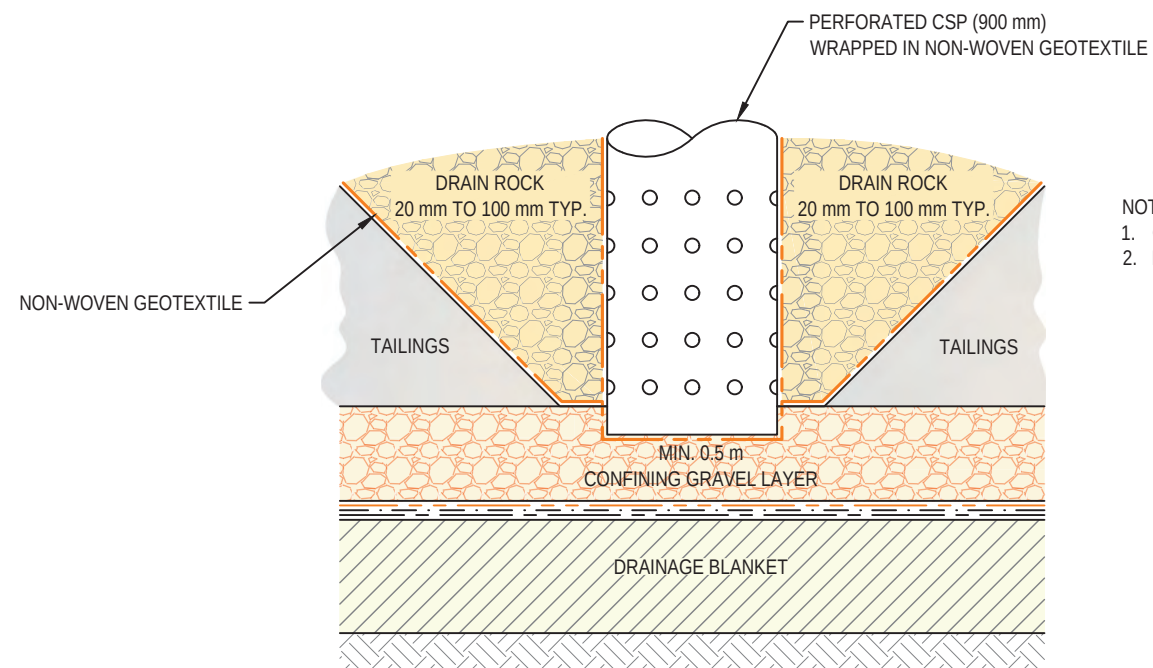
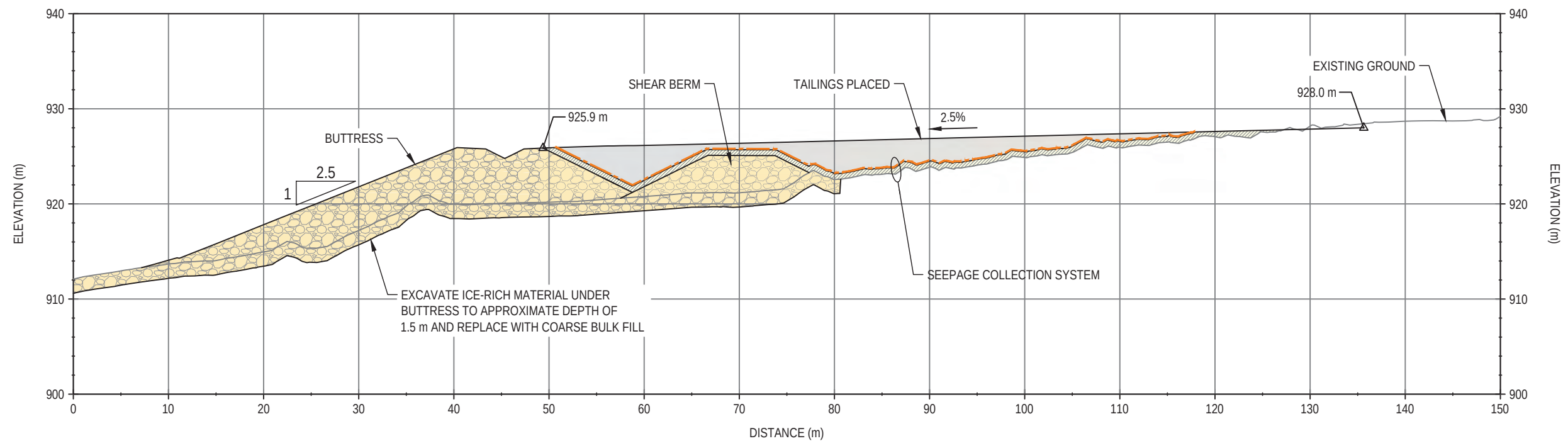
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Association of Professional
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DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON
INITIAL TAILINGS DEPOSITION PLAN

PROJECT NO. WARC04415-10	OFFICE EDM	DES YQ	CKD IM	REV 0	DRAWING 50-C-400
DATE September 23, 2024	SHEET No. 30 of 31	DWN EL	APP GK	STATUS IFC	



NOTE:

1. CSP INSERTED INTO GRAVEL LAYER MINIMUM OF 100 mm.
2. INTERIM TAILINGS SLOPE OF 1H:1V SURROUNDING PIPE.

NUM	DATE	DWN	CKD	APR	REVISIONS	DESCRIPTION
0	23-SEP-24	EL	IM	GK	ISSUED FOR CONSTRUCTION	

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Date 2024-10-08

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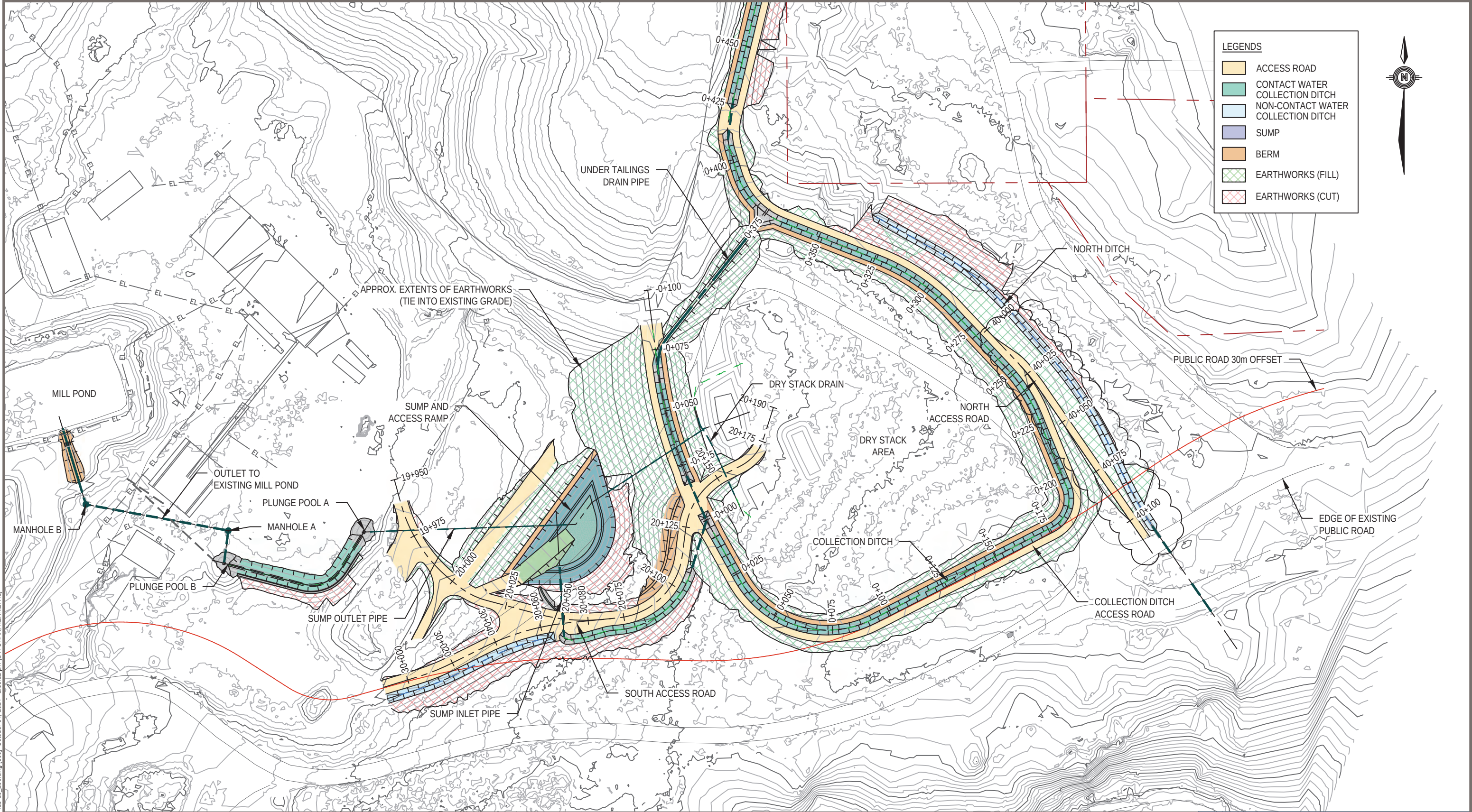
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DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

INITIAL TAILINGS DEPOSITION CROSS-SECTION AND TYPICAL DETAIL

PROJECT NO. WARC04415-10	OFFICE EDM	DES YQ	CKD IM	REV 0	DRAWING 50-C-401
DATE September 23, 2024	SHEET No. 30 of 31	DWN EL	APP GK	STATUS IFC	



- NOTES:
1. ALL REFERENCES TO HDPE PIPES SHALL REFER TO DR17 HDPE PIPE.
 2. ALL SPIRAL WOUND STEEL PIPES (SWSP) SHALL BE 12.5 mm IN GAUGE.



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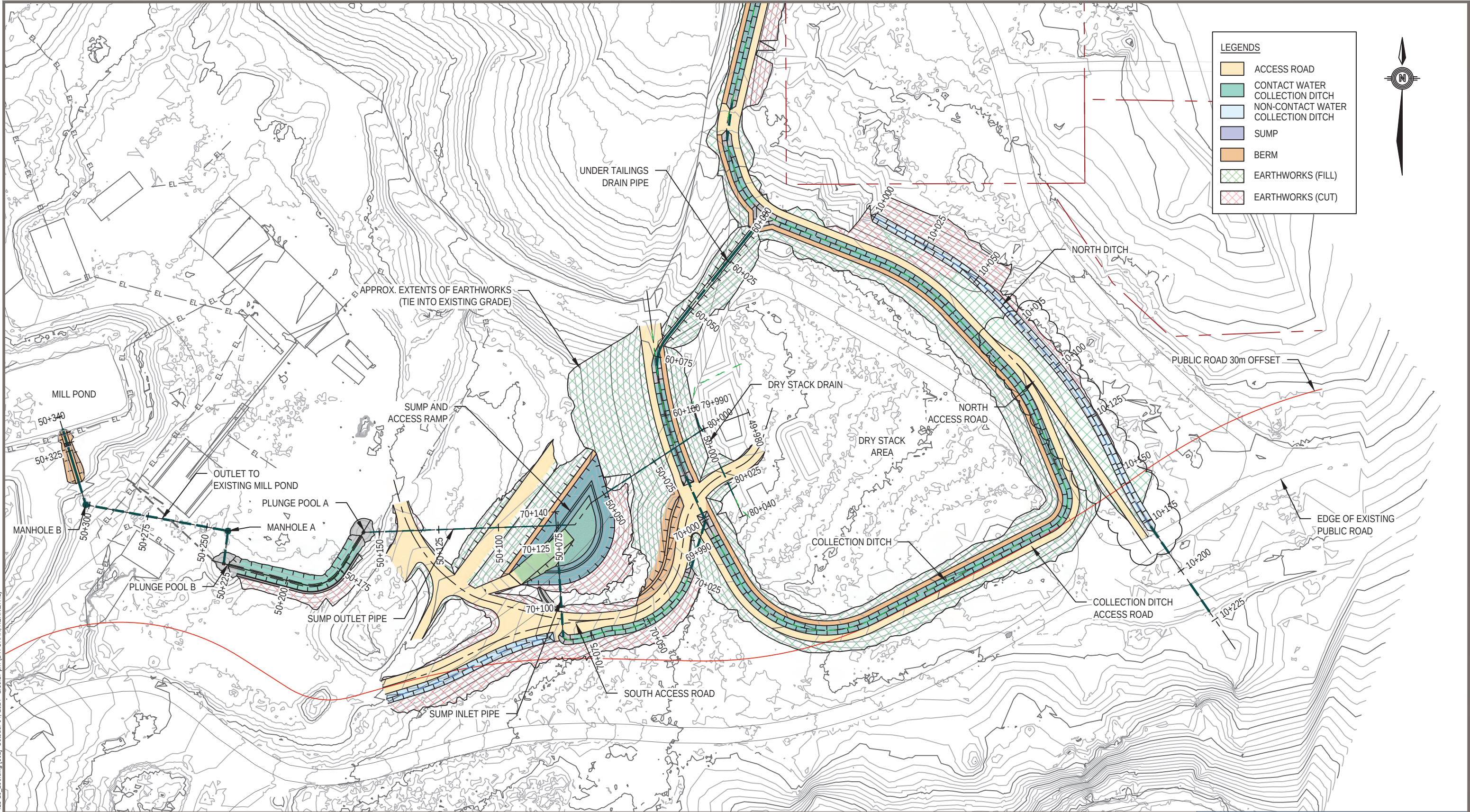
Hecla MINING COMPANY

TETRA TECH

DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

PLAN VIEW SHOWING STATIONING
BUTTRESS AND ROADS

PROJECT NO. WARC04415-10	OFFICE VANC	DES KC	CKD JY	REV 0	DRAWING 50-C-500
DATE October 4, 2024	SHEET No. of	DWN KC	APP DNM	STATUS IFC	



- NOTES:
1. ALL REFERENCES TO HDPE PIPES SHALL REFER TO DR17 HDPE PIPE.
 2. ALL SPIRAL WOUND STEEL PIPES (SWSP) SHALL BE 12.5 mm IN GAUGE.



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0	04/10/24	KC	JY	DNM	APR	ISSUED FOR CONSTRUCTION	
							REVISIONS



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DRY STACKED TAILINGS FACILITY PHASE 2 DESIGN
KENO HILL DISTRICT MILL SITE, YUKON

PLAN VIEW SHOWING STATIONING
DITCHES AND CONVEYANCE

PROJECT NO.	OFFICE	DES	CKD	REV	DRAWING
WARC04415-10	VANC	KC	JY	0	50-C-501
DATE	SHEET No. of	DWN	APP	STATUS	
October 4, 2024		KC	DNM	IFC	

Appendix D – DSTF Phase 2 East Construction Specifications

Construction Specifications Dry Stack Tailings Facility – Phase II East Keno Hill Mine, YT



PRESENTED TO
Alexco Keno Hill Mining Corp.

2024-09-23T00:00:00
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TETRA TECH FILE: 704-WARC04415-10

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Revision History

Revision Number	Description	Date
0	Issued for Use	September 24, 2024

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LIMITATIONS OF REPORT

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1.0 DEFINITIONS AND ACRONYMS

1.1 General

- .1 Definitions of terms, common acronyms, and standard units of measure used throughout the Construction Specifications are presented in this Section.

1.2 Definitions

Contract	The legal and binding agreement between the Contractor and AKHM regarding the construction of the Keno Hill Mine DSTF P2E
Contractor	The general contractor responsible for constructing the Keno Hill Mine DSTF P2E
Construction Drawings	The drawings, as issued for construction, Phase II East (P2E) Dry Stack Tailings Facility (DSTF)
Construction Monitor	Tetra Tech's on-site geotechnical representative during construction or related activities
Construction Specifications	This document
Construction Supervisor	AKHM representative overseeing daily construction activities
Engineer	Tetra Tech design engineer(s) providing direction on design related issues and design modifications and reviewing QA/QC results
Liner System	A composite structure that comprises a liner, bedding material, and/or geotextile.
Owner	Alexco Keno Hill Mining Corp. (AKHM)
Project Manager	AKHM representative providing project oversight and coordination of construction activities
Site	The area in which construction of the DSTF P2E or related activity is occurring
Unsuitable	Not meeting the requirements stated herein or not receiving the Engineer's approval

1.3 Acronyms

AKHM	Alexco Keno Hill Mining
ASTM	American Society for Testing and Materials
CBR	California Bearing Ratio
CQMP	Construction Quality Management Plan
CSA	Canadian Standards Association
DSTF	Dry-stack Tailings Facility
GCL	Geosynthetic Clay Liner
HDPE	High-density Polyethylene
P2E	Phase II East
PVC	Polyvinyl Chloride
ROM	Run-of-Mine
SI	International System of Units
SOW	Scope of Work
UV	Ultraviolet

VWP
YT

Vibrating Wire Piezometer Yukon Territory

1.4 Units of Measure

km	Kilometre
cm	Centimetre
cm/s	Centimetre per second
g	Gram
g/m ²	Gram per square metre
kg	Kilogram
kNm/m ³	Kilonewton-metre per cubic metre
kPa	Kilopascal
L	Litre
l/min/m ²	Litre per minute per square metre
m	Metre
m ²	Square metre
m ² /s	Square metre per second
m ³	Cubic metres
min	Minute
mL	Millilitre
mm	Millimetre
N	Newton
N/mm	Newton per millimetre
s	Second

END OF SECTION

2.0 GENERAL

2.1 General

- .1 This specification has been prepared for construction of the Phase II East (P2E) Dry Stack Tailings Facility (DSTF) Keno Hill Mill Site located in Yukon Territory (YT) and for the exclusive use of the Owner, Alexco Keno Hill Mining Company.
- .2 This document follows the International System of Units (SI).

2.2 Project Description

The P2E DSTF is a GCL lined containment facility for the deposition and storage of filter pressed tailings. It comprises a lined, earthworks embankment to contain tailings and surface water and seepage collection systems to manage contact water. Key components of the P2E DSTF include:

- Granular perimeter berm to provide containment, stability and manage surface runoff. Perimeter ditching directs surface runoff to an exterior sump.
- Interior shear berms to provide geotechnical stability.
- A granular drainage blanket to collect seepage or meltwater from under the DSTF and direct it to an underdrain at the northwest corner of the DSTF.
- An interior liner system, overlying the drainage blanket, to provide containment and prevent seepage into the underlying foundation. The liner system comprises:
 - Geosynthetic Clay Liner (GCL): The GCL is the primary water barrier and will prevent seepage water from leaving the DSTF.
 - Geonet: Geosynthetic above GCL to allow for drainage of the placed tailings material.
 - Non-woven Geotextile: Non-woven geotextile placed above the geonet to prevent angular material in the tailings deposit from damaging the GCL below.
- Liner system cover material comprises a 50 mm minus granular fill (same as drainage blanket material).
- An HDPE lined sump located to the west of the DSTF to collect surface runoff or seepage from the facility. Contact water from the sump is conveyed to the Mill Pond via a series of ditches and culverts. Culverts are connected by manholes at select locations.

2.3 Scope of Work

- .1 Load, haul, and place the following:
 - .a Coarse bulk fill for shear berms, exterior berms, road subgrade and other locations
 - .b 50 mm minus granular fill for drainage blanket and GCL cover
 - .c 20 mm minus granular fill for culvert bedding and backfill, and road surfacing

- .2 Excavate and dispose of unsuitable ice-rich material underlying the embankment and sump foundations
- .3 Clear trees larger than 50 mm from within DSTF footprint
- .4 Construct geotextile wrapped underdrains to transport meltwater from under the liner system
- .5 Install liner system comprising GCL, geonet and geotextile within the DSTF footprint and extending over the surface ditching
- .6 Construct temporary contact water sump and install HDPE and geotextile
- .7 Install HDPE pipe to provide conveyance at several locations
- .8 Construct lined conveyance to direct water from sump to Mill Pond
 - .a Line ditch with GCL and geotextile
 - .b Install manholes at junction points in conveyance
 - .c Install culvert conveyance under existing mine infrastructure
- .9 Construct non-contact water perimeter ditching
- .10 Construct site access roads and tie into existing road network
- .11 Protect and complete extension of existing instrumentation, and install new instrumentation as shown in the Construction Drawings.

2.4 Construction Methods

- .1 The Contractor shall comply with all local, territorial and federal laws that are pertinent to this work.
- .2 The elevations and dimensions shown on the Construction Drawings are for the purpose of construction and measurement. The Contractor shall ensure that all grades, elevations, and dimensions are adhered to.
- .3 The Contractor is responsible for all construction surveys and documentation to verify quantities.
- .4 Layout points and design surfaces will be provided to the Contractor in digital format.

2.5 Drawing Discrepancies

- .1 Any discrepancies found on the Construction Drawings shall be brought to the immediate attention of the Engineer. No deviations shall be permitted from the Construction Drawings without written approval from the Construction Supervisor.
- .2 The Contractor shall immediately submit in writing to the Engineer any conflicts discovered within this document or between this document, the purchase order, the accompanying data sheets, drawings, and any other supplemental information or specifications. The Engineer will then make a ruling and clarify the matter in writing.

2.6 Utility Locates

- .1 The Contractor will confirm location of all utilities prior to starting work. This will include but is not limited to alignment of conveyance pipe(s) and buried electrical cables. Excavations will not be permitted to start until such time all utilities in the work area have been identified.

END OF SECTION

3.0 SITE PREPARATION AND CLEANUP

3.1 General

- .1 This section describes the construction and general site housekeeping during the construction Keno Hill DSTF Phase II East Civil Works.
- .2 All material placed on the existing topography shall be removed prior to the completion of the project. Care should therefore be taken during construction to minimize the amount of material placed on undeveloped grounds.

3.2 Site Access

- .1 No equipment or vehicles shall operate on the undeveloped ground surrounding the site.
- .2 No equipment or vehicles shall operate within 50 m of streams or rivers.

3.3 Clearing

- .1 The contractor shall cut all trees larger than 50 mm in diameter.
- .2 Tree debris shall be placed at the timber storage locations shown on the Construction Drawings or as directed by AKHM.
- .3 Tree debris may not be burned or buried.
- .4 Foundation preparation shall consist of hand cutting and removal of all trees and vegetation larger than 50 mm in diameter with minimal disturbance to the organic surface.
- .5 Trees and vegetation smaller than 50 mm in diameter should be left in place and or mulched.
- .6 Care should be taken to minimize the disturbance to the organic surface.
- .7 Vegetation shall be removed such that stumps are lowered to be flush with the surrounding organic mat. In areas where there is no surrounding organic mat, vegetation shall be lowered to be flush with the surrounding ground.

3.4 Granular Fill Removal

- .1 The Contractor shall excavate and remove all previously placed roads, pads, accesses or other granular material within the DSTF P2E footprint
- .2 Granular material shall be disposed of as directed by the Construction Supervisor.
- .3 The exposed ground surface shall be inspected by the Construction Monitoring following excavation to confirm the presence of ice-rich permafrost.
- .4 Ice-rich permafrost underlying the exposed ground surface shall be excavated, as directed by the Construction Monitor and replaced with Coarse Bulk Fill in accordance with Section 6 – Fill Materials. Coarse Bulk Fill shall be placed and compacted in accordance with Section 7 – Fill Placement.

3.5 Site Clean Up

- .1 The site and surrounding area shall be kept clean and tidy, and any safety hazards shall be removed or dealt with promptly.
- .2 The Contractor shall not store any products that, under uncontrolled release, may have a negative impact on the surrounding environment.
- .3 The Contractor shall remove all temporary storage structures and shall clean up the construction areas, borrow areas, and stockpile areas.
- .4 Surplus material generated during construction shall be loaded, hauled, and disposed of as directed by the Construction Supervisor.
- .5 Prior to construction completion, all debris, waste material, or any other foreign material shall be removed from the site.

END OF SECTION

4.0 WATER, SNOW AND ICE CONTROL

4.1 General

- .1 This section describes water, snow, and ice control during the construction of the Keno Hill DSTF P2E.
- .2 Water, snow, and ice control and construction-related dewatering is the responsibility of the Contractor.

4.2 Water and Snow Control

- .1 All fill, geotextile, and geomembranes shall be placed in a dry environment.
- .2 Snow shall be removed prior to all fill, geotextile, and geomembrane placement during the winter.
- .3 The Contractor shall employ all measures necessary to control inflow into the excavations during construction. This may include the construction of temporary water control structures, such as berms, or excavation of interceptor trenches.
- .4 Construction, maintenance, and operation of any temporary water control works shall be the responsibility of the Contractor but shall be approved by the Construction Supervisor before construction.
- .5 Water collected during construction shall be discharged as directed by the Owner.
- .6 Following completion of the work, all temporary water control works shall be removed, and the affected areas graded to provide drainage towards the Keno Hill DSTF Phase II Collection Sump.
- .7 All temporary sumps, if required, shall be backfilled with Coarse Bulk Fill material in accordance with **Error! Reference source not found.** – Fill Material. Backfill shall be placed in accordance with Section 7 – Fill Placement.

END OF SECTION

5.0 EXCAVATION AND FOUNDATION PREPARATION

5.1 General

- .1 This section describes excavation and foundation preparation for the Keno Hill DSTF P2E.
- .2 The Contractor is advised that variable ground conditions may be encountered during excavation, which could include glacial till, lacustrine and alluvial deposits, other ice-rich soil or ice lenses, and bedrock in both frozen and unfrozen conditions.
- .3 The Contractor shall be prepared to excavate in variable ground conditions to facilitate construction of the Keno Hill DSTF P2E as shown on the Construction Drawings. The Contractor is advised that mechanical fracturing of frozen soil may be required.

5.2 Excavation

- .1 The Contractor shall undertake the P2E sump, perimeter ditching, culverts, and all other excavations to the dimensions and alignments indicated on the Construction Drawings.
- .2 All excavations shall be completed in compliance with Yukon Workers' Safety and Compensation Board requirements.
- .3 Excavation beyond the limits shown on the Construction Drawings shall not be undertaken without the Construction Supervisor's prior approval.
- .4 Over-excavation affecting the DSTF P2E ditch alignment or other component of the DSTF shall be backfilled as directed by the Construction Supervisor. Backfill shall be placed in accordance with Section 7 – Fill Placement.
- .5 All excavations shall be maintained free of water, snow, ice, or deleterious materials.
- .6 Disturbed areas surrounding the excavations shall be graded following construction to promote drainage toward the DSTF Phase II Collection Ditch.
- .7 All excavations and prepared foundations shall be inspected and approved by the Engineer or the Construction Monitor as their representative prior to fill placement in accordance with Section 7 – Fill Placement.

5.3 Foundations

- .1 Following excavation, the base and side slopes shall be inspected by the Construction Supervisor and Construction Monitor and approved by the Engineer prior to fill placement. The Contractor shall give not less than 24 hours' notice prior to the required inspection.
- .2 The subgrade shall be free from soft and/or loosened areas, snow, and ice. Removal of soft/loose soil, snow, or ice to expose competent soil and/or bedrock may be required at the discretion of the Construction Supervisor and/or Monitor.
- .3 Ice-rich permafrost underlying embankments, berms, or sumps shall be excavated as directed by the Engineer and replaced with Coarse Bulk Fill in accordance with Section 6 – Fill Materials and Section 7 – Fill Placement.

- .a Typical depth of excavation is estimated to be 1.5 m based on known ground conditions.
 - .b Final excavation depth shall be confirmed by Construction Monitor during excavation.
 - .c The excavated surface, including base and embankment slopes, shall be free of snow, ice, or other debris prior to fill placement.
- .4 If other unsuitable foundation soils are found in the subgrade, the Contractor shall excavate below the design subgrade elevation and backfill as directed by the Construction Supervisor. The material shall be placed and compacted in accordance with Section 7 – Fill Placement.
- .a The depth and extent of excavation below subgrade elevation, if required, shall be determined by the Construction Monitor.
 - .b The excavated surface, including base and embankment slopes, shall be free of snow, ice, or other debris prior to fill placement.

END OF SECTION

6.0 FILL MATERIALS

6.1 General

- .1 This section describes the fill material requirements for the construction of the Keno Hill DSTF P2E.

6.2 Reference Standards

- .1 ASTM D 4791-19R23, Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.
- .2 ASTM C 117-23, Standard Test Method for Material Finer than 0.075 mm (No.200) Sieve in Mineral Aggregates by Washing.
- .3 ASTM C 136M-19, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
- .4 ASTM C 131/C 131M-20, Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

6.3 Material Sources

- .1 No material of any type shall be borrowed or excavated without the Owner's prior approval.
- .2 Pits and quarries shall be maintained and managed in accordance with the requirements of the Owner's Land Use and Quarry Permits.
- .3 Fill materials shall be processed from material obtained from sources approved by the Owner, provided the final product meets the requirements specified herein. Processing will be required to achieve the specified gradation.
- .4 The parent rock from which all fill materials are derived shall consist of sound, hard, durable, non-acid generating material free from soft, thin, elongated, or laminated particles.
- .5 All materials shall be free from roots, frozen material, organics, and other deleterious material and foreign substances.

6.4 Material Specifications

6.4.1 Coarse Bulk Fill

- .1 Coarse bulk fill is select material sourced from excavations or other sources, approved by the Owner, consisting of pit run granular material in an unfrozen state, free from boulders larger than 500 mm in diameter and having less than 15 percent (by mass) smaller than 0.08 mm.
- .2 Coarse Bulk Fill is generally used for:
 - .a Embankment construction
 - .b Shear berms
 - .c Backfilling sub excavations

- .d Road subgrade
- .e General fill
- .3 Coarse Bulk Fill shall consist of hard durable particles, be free of roots, topsoil and other deleterious material, as approved by the Construction Supervisor.

6.4.2 50 mm Minus Granular Fill

- .1 50 mm Minus Granular Fill is select material obtained from excavations or other sources accepted by the Owner that generally consists of screened or crushed stone, gravel, or sand in an unfrozen state and free from particles larger than 50 mm in diameter.
- .2 50 mm Minus Granular Fill is used for:
 - .a Drainage blanket material
 - .b Confining gravel layer
- .3 50 mm Minus Granular Fill shall consist of hard durable particles, be free of roots, topsoil and other deleterious material, as approved by the Construction Supervisor.
- .4 The material shall have a particle size distribution as presented in Table 6-1.

Table 6-1: 50 mm Minus Granular Fill Particle Size Distribution

Particle Size (mm)	% Passing By Mass
50	100
20	87-100
10	55-100
5	20-90
2.5	10-70
1.25	5-30
0.63	2-10
0.08	0-5

6.4.3 20 mm Minus Granular Fill

- .1 20 mm Minus Granular Fill is select material obtained from excavations or other sources accepted by the Owner that generally consists of crushed stone, gravel, or sand in an unfrozen state and free from particles larger than 20 mm in diameter.
- .2 20 mm Minus Granular Fill is used for:
 - .a Culvert bedding and Backfill
 - .b Road Surfacing

- .3 20 mm Minus Granular Fill shall consist of hard, durable particles, be free of roots, topsoil, and other deleterious materials, as approved by the Construction Supervisor.
- .4 20 mm Minus Granular Fill shall have a particle size distribution as presented in Table 6-2.

Table 6-2: 20 mm Minus Granular Fill Particle Size Distribution

Particle Size (mm)	% Passing By Mass
20	100
12.5	65-100
5	45-70
0.63	15-35
0.08	4-10

6.5 Drain Rock

- .1 Drain Rock is select material sourced from excavations or other sources approved by the Owner, consisting of open graded granular material in an unfrozen state with a maximum particle size of 100 mm and no particles smaller than 25 mm.
- .2 Drain Rock is used for:
 - .a French drain under liner system
- .3 Drain Rock shall consist of hard durable particles, be free of roots, topsoil and other deleterious material, as approved by the Construction Supervisor.

6.6 10 kg Riprap

- .1 10 kg Riprap is select material obtained from excavations or other sources accepted by the Owner generally consisting of angular screened pit run or quarry stone, an unfrozen state.
- .2 10 kg Riprap is used for:
 - .a Erosion protection in sumps and ditches at velocity discharge locations
- .3 10 kg Riprap shall consist of hard, durable particles, be free of roots, topsoil, and other deleterious materials, as approved by the Construction Supervisor
- .4 10 kg Riprap shall have a particle size distribution as presented in Table 6-3.

Table 6-3: 10 kg Riprap Particle Size Distribution

Particle Size (mm)	% Passing By Mass
325	100
200	50-80
175	30-50
100	0

END OF SECTION

7.0 FILL PLACEMENT

7.1 General

- .1 This section describes the fill placement methods for construction of the Keno Hill DSTF P2E.
- .2 Construction shall be performed in accordance with the best modern practice and with equipment best adapted to the work being performed. Materials shall be placed so that each zone is homogenous, free of stratifications, ice chunks, snow, lenses, pockets, ruts, and layers of material of different textures and grading not conforming to the requirements specified in Section 6 – Fill Materials. The Contractor shall remove and dispose of these materials in an area approved by the Owner.
- .3 No fill material shall be placed until the area has been prepared as specified in Section 5 – Excavation and Foundation Preparation and approved by the Construction Supervisor. Placement of material shall conform to the lines, grades and elevations shown on the Construction Drawings or as otherwise specified by the Engineer.
- .4 Fill placement shall not proceed when the work cannot be performed in accordance with the requirements of Section 6 – Fill Materials.
- .5 Any part of the fill placement which has been damaged by the action of rain and snow, or any other cause, shall be removed and replaced with material conforming to the requirements specified in Section 6 – Fill Materials before continuing with construction.
- .6 Stockpiling, loading, transporting, placing, and spreading of all materials shall be carried out in such a manner so as to avoid segregation. Segregated materials shall be removed and replaced with materials meeting the requirements stated in Section 6 – Fill Materials.
- .7 Construction beyond the limits shown on the Construction Drawings shall not be undertaken without prior approval of the Construction Supervisor.
- .8 Disturbed areas surrounding construction work areas shall be graded to promote positive drainage immediately following construction.

7.2 Reference Standard

- .1 ASTM D 698 – 07 e1, Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (600 kN-m/m³).
- .2 ASTM D 2922-01, Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

7.3 Coarse Bulk Fill

- .1 Coarse bulk fill shall be placed on the prepared subgrade surface as approved by the Construction Supervisor. The subgrade surface shall be free of snow, debris or other deleterious materials.
- .2 Coarse bulk fill shall be placed in lifts not exceeding 500 mm.
- .3 The lifts will be compacted with a smooth-drum vibratory packer weighing at least 10,000 kg with a minimum of eight (8) full (forward and backward) passes.
- .4 Compaction adequacy shall be monitored by the Construction Monitor during fill placement.

7.4 Drainage Blanket and Confining Gravel (50 mm Minus Granular Fill)

- .1 The drainage blanket underlying the liner system and confining gravel overlying the liner shall comprise 50 mm Minus Granular Fill.
- .2 Drainage Blanket and Confining Gravel shall be placed in a single lift. The material shall be placed to avoid segregation.
- .3 Drainage Blanket material shall be placed as follows:
 - .a Drainage blanket shall be placed over the existing organic cover. Care should be taken to minimize disturbance of the surface to limit degradation of permafrost.
 - .b Drainage blanket material shall be placed in one lift using a “pad-out” construction method to prevent equipment from travelling directly on the organic surface.
 - .c Drainage blanket shall be “track packed” using the spreading equipment and compacted using a smooth drum roller
 - .d Placement surface should be free of snow, debris, or other deleterious materials.
 - .e The final Drainage Blanket surface should be smooth, free of debris or other deleterious material, with no ruts or protrusions greater than 25 mm.
- .4 Confining Gravel material shall be placed as follows:
 - .a Confining Gravel shall be placed over the deployed liner system. Care should be taken to not damage the liner system during placement.
 - .b Confining gravel shall be placed in a “pad-out” construction method to prevent equipment from travelling directly on the liner surface
 - .c No vehicles or equipment shall travel directly on the liner surface
 - .d Confining gravel shall be “track packed” using the spreading equipment and compacted using a smooth drum roller
 - .e Placement surface should be free of snow, debris, or other deleterious materials.
- .5 Construction of the Drainage Blanket and Confining Gravel shall be completed to the dimensions indicated on the Construction Drawings, unless otherwise approved by the Construction Supervisor.

7.5 50 mm Minus Granular Fill

- .1 50 mm Minus Granular fill, not used for drainage blanket or confining gravel, shall be placed in lifts not exceeding 300 mm.
- .2 The material shall be moisture conditioned and compacted to at least 95 percent of standard Proctor maximum dry density (SPMDD) (ASTM D 698) at optimum moisture content ± 2 percent.

7.6 20 mm Minus Granular Fill

- .1 20 mm Minus Granular fill shall be placed in lifts not exceeding 150 mm.
- .2 The material shall be moisture conditioned and compacted to at least 95 percent of standard Proctor maximum dry density (SPMDD) (ASTM D 698) at optimum moisture content ± 2 percent.

7.7 Drain Rock

- .1 Drain Rock shall be placed in a single lift to the lines and dimensions shown on the Construction Drawings.

7.8 10 kg Riprap

- .1 10 kg Riprap shall be placed to the lines and dimensions shown on the Construction Drawings.
- .2 10 kg Riprap shall be placed so that particles are well nested, and no large voids are present.
- .3 The finished surface shall be reasonably uniform and free from bumps or depressions.

END OF SECTION

8.0 NON-WOVEN GEOTEXTILE

8.1 General

- .1 This section includes product and installation specifications for the non-woven geotextile for the Keno Hill DSTF P2E.
- .2 The non-woven geotextile shall be provided by the Owner and installed by the Contractor.

8.2 Reference Standards

- .1 American Society for Testing Materials – Geotextile Standards
 - .a ASTM D 4632, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
 - .b ASTM D 4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
 - .c ASTM D 4833, Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
 - .d ASTM D 5261, Standard Test Method for Measuring Mass per Unit Area of Geotextiles.
 - .e ASTM D 5199, Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
 - .f ASTM D 4491, Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
 - .g ASTM D 4751, Standard Test Methods for Determining Apparent Opening Size of a Geotextile.
 - .h ASTM D 6241, Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe.

8.3 Shipping and Storage

- .1 Any visible damage to the shipment of the geotextile shall be noted on the freight receipt and project records.
- .2 Storage of geotextile rolls on site shall be in a secure location that will minimize exposure to the elements and physical damage.

8.4 Non-Woven Geotextile Properties

- .1 Non-woven geotextile shall comprise needle punch polypropylene fabric made of 100 percent polypropylene staple fibers conforming to the properties in Table 8-1.
- .2 All non-woven geotextile shall have a weight of at least 270 g/m².
- .3 The manufacturer shall, prior to shipment of materials, provide to the Engineer a signed manufacturing certification that materials to be shipped to site have test values that meet or exceed the requirements listed in Table 8-1.

Table 8-1: Minimum Geotextile Properties

Material Property	ASTM Test Method (Or Approved Equal)	Material Specifications
Fabric Weight - MARV	ASTM D 5261	270 g/m ² (8 oz/yd ²)
Grab Tensile	ASTM D 4632	1001 N (225 lb)
Grab Elongation	ASTM D 4632	50 %
Trapezoidal Tear	ASTM D 4533	400 N (90 lb)
CBR Puncture	ASTM D 6241	2670 N (600 lb)
Water Flow	ASTM D 4491	4075 l/min/m ² (100 gpm/ft ²)
Permittivity	ASTM D 4491	1.26 s ⁻¹
Permeability	ASTM D 4491	0.30 m/s
Apparent Opening Size (AOS)	ASTM D 4751	0.180 mm (80 US Sieve)

8.5 Installation Methods

- .1 The area to be covered by the Geotextile shall be smooth and free of sharp objects that could puncture the geotextile and damage the overlying geomembrane liner.
- .2 The Contractor shall ensure that the integrity of the non-woven geotextile is not compromised during installation. Precautions the Contractor may take to avoid damaging the non-woven geotextile may include, but not limited to, avoiding turning tracked vehicles on the material above the non-woven geotextile, providing light plants in the work area to improve operator visibility, or using pylons to mark the edge of lift/liner system interface or any other sensitive areas.
- .3 Geotextile placement shall not be conducted during periods of high wind.
- .4 The Geotextile shall be placed with a minimum overlap of 150 mm and connected at the seam by heat bonding. Horizontal seams should be kept to a minimum on the side slopes.
- .5 Sufficient temporary anchorage shall be used to hold the Geotextile in place during placement of the other elements of the liner system.
- .6 Any damage to the Geotextile shall be immediately reported to the Engineer. Repair work shall commence as soon as possible.

8.6 Repair Procedures

- .1 The Construction Supervisor shall record all areas requiring repair due to damage during shipping, handling, deploying, or manufacturing flaws. The Construction Supervisor shall prescribe the method of repair to be used.
- .2 Any tears or holes made in the Geotextile should be repaired by placing a patch of geotextile on the defect and fastening it by heat bonding.
- .3 All repairs made by the placement of a patch of the same material over the damage shall extend at least 500 mm beyond the flaw or damage in every direction.

END OF SECTION

9.0 GEOSYNTHETIC CLAY LINER (GCL)

9.1 General

- .1 This section describes the material specifications of the GCL component of the foundation for the Keno Hill DSTF P2E.

9.2 Reference Standards

- .1 American Society for Testing Materials – Geomembrane/Geotextile Standards
 - .a ASTM D 5993 – 99 (2009) Standard Test Method for Measuring Mass Per Unit of Geosynthetic Clay Liners
 - .b ASTM D 4632 - 08 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
 - .c ASTM D 5887 - 09 Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter
 - .d ASTM D 5321 - 08 Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
 - .e ASTM D 5261 - 10 Standard Test Method for Measuring Mass per Unit Area of Geotextiles
 - .f ASTM D 5890 - 06 Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
 - .g ASTM D 4643 - 08 Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating
 - .h ASTM D 5891 - 02(2009) Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
 - .i ASTM D 1505 - 03 Standard Test Method for Density of Plastics by the Density-Gradient Technique
 - .j ASTM D 5199 - 01(2006) Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
 - .k ASTM D 5035 – 06 (2008)e1 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)
 - .l ASTM D 4716 - 08 Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
 - .m ASTM D 4833 - 07 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
 - .n ASTM D 4491 – 99 a(2009) Standard Test Methods for Water Permeability of Geotextiles by Permittivity
 - .o ASTM D 4751 - 04 Standard Test Method for Determining Apparent Opening Size of a Geotextile
 - .p ASTM D 6243, Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method.
 - .q ASTM D 6496, Standard Test Method for Determining Average Bonding Peel Strength Between Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners.
 - .r ASTM D 6768, Standard Test Method for Tensile Strength of Geosynthetic Clay Liners.

9.3 Materials

- .1 The GCL shall consist of sodium bentonite between two geotextiles that are bonded by needle punching. The GCL shall conform to the physical, mechanical and hydraulic properties in Table 9-1.

Table 9-1: Recommended GCL Property Specifications and Limits

Material Property	ASTM Test Method (Or Approved Equal)	Required Values
Bentonite Swell Index	ASTM D 5890	24 ml/2g min
Bentonite Fluid Loss	ASTM D 5891	18 ml max
Bentonite Mass/Area	ASTM D 5993	3.6 kg/m ² (0.75 lb/ft ²) min
GCL Grab Strength	ASTM D 6768	53 N/cm (30 lbs/in) MARV
GCL Peel Strength	ASTM D 6496	6.1 N/cm (3.5 lbs/in) min
GCL Index Flux	ASTM D 5887	1 x 10 ⁻⁸ m ³ /m ² s max
GCL Hydraulic Conductivity	ASTM D 5887	5 x 10 ⁻⁹ cm/s max
GCL Hydrated Internal Shear Strength	ASTM D 5321 ASTM D 6243	500 psf (24kPa) typ @ 200 psf

- .2 Storage of GCL rolls on site shall be in a secure location that will minimize exposure to the elements or any other physical damage per the manufacturer's requirements. Exposure to water during storage will compromise the quality of materials.

9.4 Installation

- .1 Installation of the GCL shall be completed to the dimensions and alignments indicated on the Construction Drawings.
- .2 The area to be covered by the GCL shall be smooth and free of sharp objects that could puncture or tear the GCL.
- .3 The GCL panels shall be unrolled downslope on the DSTF.
- .4 The GCL shall have a minimum overlap of 600 mm, and seams shall be treated with powdered bentonite. The bentonite shall be applied at a minimum rate of 0.4 kg/m of the seam. Alterations to the minimum overlap and minimum bentonite application rate must be reviewed and approved by the Construction Supervisor.
- .5 All joints shall be placed such that higher gradient panels overlap lower gradient panels.
- .6 The GCL is not resistant to UV light and thus cannot be left exposed for extended periods of time. The schedule of placement of GCL and subsequent tailings layer must be reviewed and approved by the Construction Supervisor.
- .7 The liner materials shall be installed on the underlying Drainage Blanket material at grades no steeper than 4H:1V, unless otherwise approved by the Construction Supervisor.
- .8 GCL shall be covered with confining gravel during the same shift as GCL deployment or immediately during the follow shift.

- .9 GCL that is exposed to rain or adverse environmental conditions shall be inspected by the Construction Supervisor for unconfined swelling of the GCL. Damaged GCL shall be replaced or repaired in accordance with Section 9.6.

9.5 GCL Penetrations

- .1 Where instrumentation or penetrations will intercept the liner surface, the geosynthetic materials should be cut cleanly to allow the instrument or penetration to pass through. The cut will be treated with 0.4 kg/m of granular bentonite, and a secondary GCL collar be placed, per manufacturer guidelines and details.

9.6 GCL Damage

- .1 The Construction Monitor shall record all areas requiring repair or replacement due to damage from manufacturing error, shipping, or placement.
- .2 All GCL repairs shall use patches of the same material to be repaired.
- .3 The patch shall be placed with a minimum overlap of 600 mm in all directions.
- .4 Powdered bentonite shall be applied at a minimum rate of 0.4k g/m of patch perimeter.

END OF SECTION

10.0 GEONET

10.1 General

- .1 This section describes the material specifications of the Geonet Drain component for the Keno Hill DSTF P2E.

10.2 Reference Standards

- .1 American Society for Testing Materials – Geocomposite Standards
 - .a ASTM D 1505 – 03, Standard Test Method for Density of Plastics by the Density-Gradient Technique.
 - .b ASTM D 5199 - 01(2006), Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
 - .c ASTM D 7179 – 18, Standard Test Method for Determining Geonet Breaking Force.
 - .d ASTM D 4716 – 08, Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head.
 - .e ASTM D 4751 – 04, Standard Test Method for Determining Apparent Opening Size of a Geotextile.
 - .f ASTM D 5261 – 10, Standard Test Method for Measuring Mass per Unit Area of Geotextiles.

10.3 Materials

- .1 The geonet shall conform to the physical, mechanical and hydraulic properties in Table 10-1.

Table 10-1: Minimum Geonet Drain Properties

Material Property	ASTM Test Method (Or Approved Equal)	Material Specifications
Thickness	ASTM D 5199	200 mil (5.08 mm)
Tensile Strength	ASTM D 7179	7.87 N/mm
Density	ASTM D 1505	0.94 g/cm ³
Transmissivity	ASTM D 4716	2 x 10 ⁻³ m ² /s

- .2 Storage of geocomposite drain material on site shall be in a secure location that will minimize exposure to the elements or any other physical damage.

10.4 Installation

- .1 Installation of the geonet shall be completed to the dimensions and alignments indicated on the Construction Drawings.
- .2 All joints shall be placed such that higher gradient panels overlap lower gradient panels.

10.5 Geonet Drain Damage

- .1 The Construction Supervisor shall record all areas requiring repair or replacement due to damage during manufacture, shipping, handling, or placement. The Construction Supervisor shall prescribe the method of repair to be used on a case-by-case basis.

END OF SECTION

11.0 HIGH DENSITY POLYETHYLENE (HDPE) LINER

11.1 General

- .1 This section describes the material specifications of the HDPE liner for the Collection Sump for the Keno Hill DSTF P2E.
- .2 The work includes the installation of the liner, anchor, trench, connections, field welds, and supply and inspection of the geomembrane.
- .3 The Owner shall supply the geomembrane material.

11.2 References

- .1 Where material properties are specified, the following standards are applicable:
- .2 American Society for Testing and Materials (ASTM):
 - .a ASTM D 413, Standard Test Methods for Rubber Property—Adhesion to Flexible Substrate.
 - .b ASTM D 638, Standard Test Method for Tensile Properties of Plastics.
 - .c ASTM D 746, Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.
 - .d ASTM D 751, Standard Test Methods for Coated Fabrics.
 - .e ASTM D 792, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
 - .f ASTM D 1004, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
 - .g ASTM D 1204, Standard Test Method for Linear Dimensional Changes of Non Rigid Thermoplastic Sheeting or Film at Elevated Temperature.
 - .h ASTM D 1238, Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
 - .i ASTM D 1505, Standard Test Method for Density of Plastics by Density-Gradient Technique.
 - .j ASTM D 1603, Standard Test Method for Carbon Black in Olefin Plastics.
 - .k ASTM D 3895, Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis.
 - .l ASTM D 4218, Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
 - .m ASTM D 4437, Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
 - .n ASTM D 4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
 - .o ASTM D 5199, Standard Test Method for Measuring Nominal Thickness of Smooth Geomembranes.
 - .p ASTM D 5397, Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefins using Notched Constant Tensile Load Test.
 - .q ASTM D 5596, Standard Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds.

- .r ASTM D 5641, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
- .s ASTM D 5820, Test Method for Air Testing.
- .t ASTM D 5820-95, Pressurized Air Channel Test for Dual Seamed Geomembranes.
- .u ASTM D 5994, Standard Test Method for Measuring Nominal Thickness of Textured Geomembranes.
- .v ASTM D 6365, Standard Practice for the Nondestructive Testing of Geomembrane Seams using The Spark Test.
- .w ASTM D 6392, Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo Fusion Methods.
- .x ASTM D 6693, Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
- .3 Geosynthetic Research Institute (GRI):
 - .a GRI GM 9 Cold Weather Seaming of Geomembranes.
 - .b GRI GM 10 The Stress Crack Resistance of HDPE Geomembrane Sheet.
 - .c GRI GM 12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage.
 - .d GRI GM 13 Test Properties, Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.
 - .e GRI GM 14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes.
 - .f GRI GM 19 Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

11.3 Special Requirements

- .1 Experience of Contractor
 - .a The Contractor shall have demonstrated an ability to perform this work by having previously successfully installed a minimum of 100,000 square metres of similar type flexible liners.
 - .b The onsite liner supervisor assigned full time to this work shall have directed the installation of a minimum of 50,000 square metres of similar type flexible liner.

11.4 Material

- .1 General
 - .a The liner material produced shall be free of blisters, holes, undispersed raw materials, or any sign of contamination by foreign matter. Any such defect shall be repaired using welding techniques in accordance with manufacturer's recommendations. Excessive defects, as determined by the Construction Supervisor, may be grounds for rejection of entire roll of liner.
- .2 Material Property
 - .a The material supplied under these Specifications shall be new, first quality products.
 - .b The liner material shall be a high density polyethylene (HDPE) geomembrane, and have the minimum property values indicated in Table 11-1.

Table 111-1: Minimum HDPE Geomembrane Properties

Test Parameter	ASTM Test Method (Or Approved Equal)	Required Specifications
Minimum Average Thickness (mm / mil)	ASTM D 5994	1.5 / 60
Density	ASTM D 792	.94
Stress @ Yield (kN/m / psi)	ASTM D 6693	22 / 126
Stress @ Break (kN/m / psi)		16 / 90
Strain @ Yield (%)		12
Strain @ Break (%)		100
Tear Resistance (N / lbs)	ASTM D 1004	187 / 42
Low Temperature (°C / °F)	ASTM D 746 Procedure B	-60 / -76
Dimensional Stability (%)	ASTM D 1204	+/-2.0
Puncture Resistance (N / lbs)	ASTM D 4833	400 / 90
Carbon Black (min)	ASTM D 1603	2
Carbon Black Dispersion	ASTM D 5596	Category 1 or 2

- .c Extrusion resin used for extrusion joining of sheets and for repairs shall be HDPE from the same resin as the sheet resin. Physical properties shall be the same as the liner sheets.

11.5 Installation

.1 General

- .a During installation of the liner, the Construction Supervisor shall have complete authority to order a stop work due to inclement weather, the use of improper installation procedures, or for any reason that in his sole opinion may result in a defective liner.
- .b Geomembrane shall be free of holes, pinholes, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges.
- .c The geomembrane liners shall be installed in accordance with a panel layout plan approved by the Construction Supervisor.
- .d Horizontal seams on slopes shall not be permitted, unless no other option is available and only as approved by the Engineer.
- .e Tie-in seam shall be a minimum of 1.5 m beyond the toe of slope on the base of the facility.

.2 Material Transportation and Storage

- .a Storage: The on-site storage location for the geomembrane material should be level, smooth, elevated, and dry. The Contractor shall provide a suitable storage site which will protect the geomembrane from punctures, abrasions, excessive moisture, and dirt.
- .b Handling: The materials are to be handled so as to prevent damage. Use equipment that does not contact the material itself when handling. Slings or other lifting devices shall provide adequate

support without damaging the material. Instructions for moving geomembrane rolls shall be provided by the Manufacturer upon request.

.3 Liner Deployment

- .a Deploy materials to minimize handling, damage, and contamination during installation.
- .b Sufficient protection should be placed between the soil surface of the berm and the geomembrane to protect the underside of the geomembrane from damage during deployment.
- .c Ensure that the sheet is not folded at any time during manufacturing, shipping, or installation.
- .d Provide sufficient anchorage against uplift due to wind. Sandbags are preferred.
- .e Adequate thermal slack will be incorporated in all layers of geomembrane.
- .f Information to be documented on the liner throughout the installation, shall be clearly visible to such point that the material is covered or construction is complete and will include:
 - On each panel, the panel number, material roll number, and date deployed. A panel number will be a simple and logical identifying code. The coding system shall be subject to approval and shall be determined at the job site.
 - All repairs shall be given an identification number, the welder, welder operator, and date shall be recorded with the identification number.
 - All destructive sample locations will be identified by an identifying number and date removed.
 - All non-destructive test data and date of test.
- .g Key liner system (geomembrane liner and geotextile) completely down along the side and to the back of the anchor trench, as shown on the Construction Drawings.
- .h Do not allow heavy vehicular traffic directly on geomembrane or geotextile.

11.6 Seams and Joints

- .1 Joints between liner sheets shall be field welded using the manufacturer's recommended procedures and equipment. Only repairs shall be extrusion welded.
 - .a Seaming shall be performed using either the extrusion of double wedge automatic fusion welding equipment and techniques, as recommended by the manufacturer of the liner membrane. Extrusion welding shall be used where double wedge fusion welding is not possible such as for patches and repairs.
 - .b The weld area shall be free of all dirt, dust, moisture, or other foreign material. Surfaces to be welded shall be wiped with oil free rags when required to remove any contamination by oil, grease, or excessive dirt.
 - .c If necessary, grinding of the liner material prior to welding shall be per the manufacturer's recommendations. The weld shall be made immediately after preparation and cleaning is complete. The temperature of the welding apparatus shall be checked a minimum of once every hour during welding.
 - .d The liner panels shall be welded together through the anchor trench.

- .2 An overlap line, a minimum of 150 mm from the edge of the underlying sheet, will be clearly identified on the underlying panel of every fusion seam.
- .3 The overlap shall be sufficient to leave a loose flap of geomembrane at least 25 mm wide adjacent to both sides of the seam.
- .4 Cross and toe seams shall be staggered a minimum of 1 m.
- .5 Completed seams and joints shall have a minimum bonded seam strength as follows:
 - .a Completed seams shall have a minimum strength in shear of at least 21 N/mm (85 percent of the specified parent material tensile strength) at yield when tested in accordance with ASTM D 4437, or approved equal.
 - .b Completed seams shall have a minimum strength in peel of at least 14 N/mm (60 percent of the specified parent material tensile strength) at yield, and break as a film tear bond or a minimum of 10 percent adhesion break when tested in accordance with ASTM D 4437, or approved equal.
- .6 Seaming shall not proceed when ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation. Installer shall demonstrate that acceptable seaming can be performed by completing acceptable trial welds.
- .7 Defects and Repairs
 - .a Examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter.
 - .b Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations which have been repaired until test results with passing values are available.
- .8 Seaming and repairs will not be completed without the presence of the Engineer.

11.7 Welding

- .1 All welds will be completed according to the contractor's appropriate welding procedure.
 - .a Deviation from the written weld procedures in any manner may be cause for rejection of the affected welds by the Owner's representative.
 - .b Any welds that have been rejected shall be remedied to the satisfaction of the Construction Supervisor, at no additional cost to the Owner.
- .2 Welding equipment and accessories shall meet the following requirements.
 - .a Gauges showing temperatures in apparatus extrusion welders (preheat and barrel) or wedge welders (wedge temperature; travel speed) shall be operational and clearly visible.
 - .b An adequate number of welding apparatus shall be available to avoid delaying work. There should at all times be an additional wedge welder and extrusion welder not in use, in the case of malfunction of those in use.
 - .c Power source capable of providing constant voltage under combined line load shall be used.
- .3 Qualification of Welders
 - .a Perform trial, or qualification welds, in the presence of the Construction Monitor, on geomembrane samples to verify welding equipment is operating properly.

- .b No welding equipment or welder shall be allowed to perform production welds until equipment and welders have successfully completed a trial weld.
 - .c Trial welds shall be performed prior to use and at a minimum 4-hour frequency throughout each operating day, or as the origin (existing or new) of the liner panels to be seamed changes.
 - .d If any welder settings are changed, or maintenance is required other than routine cleaning, the welder will have to be prequalified.
- .4 Trial Welds
- .a Make trial welds under the same surface and environmental conditions as the production welds, (i.e. in contact with subgrade and at similar ambient temperature).
 - .b Trial welds of existing material from representative locations, to new material will be required as directed by the Owner's representative.
 - .c Each trial weld shall be a minimum of 1.5 m in length.
 - .d Cut five, 25 mm wide by 150 mm long test strips from the trial weld. Quantitatively test four specimens for peel adhesion, and then one for bonded seam strength (shear).
 - .e Repeat the trial weld, in its entirety, when any of the trial weld samples fail in either peel or shear.
- .5 Extrusion Welding
- .a Hot-air bond adjacent pieces together using procedures that do not damage the geomembrane, or underlying material.
 - .b Purge welding apparatus of heat-degraded extrudate before welding.
 - .c Extrudate tails shall not be discarded on any geosynthetic surface while still hot, and shall not be left discarded on or below the liner.
 - .d Clean geomembrane surfaces according to the appropriate manufacturer approved procedures before welding, and weld shortly after.
- .6 Wedge Welding
- .a Welding apparatus shall be a self-propelled device equipped with an electronic controller which displays applicable temperatures.
 - .b Protect against moisture build-up between sheets.
 - .c Continuously clean seam area of dust, mud, moisture, and debris immediately ahead of the hot wedge welder.

11.8 Repair Procedures

- .1 Any liner area showing injury due to excessive scuffing, puncture, or distress from any cause, shall, as directed by the Construction Supervisor, be replaced or repaired with an additional piece of HDPE liner welded over the defective area. All patches shall extend a minimum of 150 mm from the affected area.
- .2 Remove damaged geomembrane and replace with acceptable geomembrane materials if damage cannot be satisfactorily repaired.
- .3 All repairs shall be completed within 24 hours from when they are identified, except by approval of the Construction Supervisor.
- .4 Repair any portion of unsatisfactory geomembrane or seam area failing a destructive or non destructive test. Installer shall be responsible for repair of damaged or defective areas. Agreement upon the

appropriate repair method shall be decided between the Construction Supervisor and the Installer. Procedures available include the following:

- .a Patching: Used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.
 - .b Abrading and Re-welding: Used to repair small seam sections.
 - .c Spot Welding: Used to repair pinholes or other minor, localized flaws or where geomembrane thickness has been reduced.
 - .d Capping: Used to repair large lengths of failed seams.
 - .e Flap Welding: Used to extrusion weld the flap (excess outer portion) of a fusion weld in lieu of a full cap.
 - .f Removing the unacceptable seam and replace with new material.
- .5 Repair Verification
- .a Number and log each patch repair.
 - .b Non-destructively test each repair using methods identified in this Specification.

11.9 Contractor Construction Quality Control

- .1 A visual inspection of the liner panels and joints shall be made as the installation progresses and again upon completion of the liner. Defective and questionable areas shall be clearly marked and repaired. All areas identified shall be repaired to the satisfaction of the Construction Supervisor.
- .2 The Contractor shall further test all joints and repairs in the HDPE liner by vacuum testing or pressurized dual seams testing (for double hot wedge welds only). All testing shall be done in the presence of or with knowledge of the Construction Supervisor. All defective areas detected shall be repaired to the satisfaction of the Construction Supervisor.
- .3 The Contractor shall perform a vacuum test on all extrusion welded seams and repairs, in the following manner:
 - .a The area to be tested shall be cleaned of all dirt, debris, and other foreign matter and then a soap and water solution shall be applied.
 - .b A gasket vacuum box (American Parts and Service Company, Alhambra, California, Series #A100 or approved equal) assembly consisting of a rigid housing, a clean transparent viewing window, and a vacuum gauge shall be immediately placed, in a manner as to ensure a seal over the area of the liner to be tested.
 - .c A vacuum of 35 kPa shall be induced and held for a minimum of 5 seconds or long enough for the area to be thoroughly examined.
 - .d Examine the geomembrane through the viewing window for the presence of soap bubbling, all areas where leaks are identified shall be marked and repaired.
 - .e Any portion of an extrusion seam or repair that cannot be vacuum tested, must be pick tested.
 - .f The Contractor shall perform pressurized testing of all double wedge weld seams, regardless of length, in the following manner.
- .4 Both ends of the seam to be tested shall be sealed.
 - .a A needle with pressure gage, or other approved pressure feed device equipped with a pressure gauge, shall then be inserted into the channel produced in the middle of the double wedge weld.

- .b The channel shall be pressurized to 200 kPa to allow the seam to stretch and stabilize before beginning the test.
- .c If the loss of pressure exceeds 28 kPa during the testing period or does not stabilize, then the seam will either be repaired entirely or the faulty area will be located and marked for repair.
- .d If blockage is present, locate and test seam on both sides of blockage.
- .e Remove needle or other approved pressure feed device and seal all penetration holes by extrusion welding.
- .5 Destructive testing will be conducted by the Installer and witnessed by the Construction Monitor. The contractor will be responsible for cutting destructive samples as directed by the Construction Monitor, repairing and testing the repaired area.
 - .a Sampling procedures are to be performed as follows:
 - The installer shall cut samples at locations designated as the installation progresses in order to obtain laboratory test results before the geomembrane is covered.
 - The Construction Monitor will number each sample and mark sample number and location on the installation layout drawing.
 - The Installer shall repair all holes in the geomembrane resulting from destructive sampling. Repair and test the continuity of the repair in accordance with these Specifications.
 - Samples shall be 200 mm wide and a minimum length of 700 mm, with the seam centred lengthwise.
 - .b Location and frequency of testing of wedge welded seams.
 - One test per 150 m of welded seams.
 - Where possible the Construction Monitor and contractor shall coordinate destructive samples to be extracted from end of seams to be discarded and above the designed maximum fluid level.
 - Test locations will be determined after seaming.

11.10 Failed Seam Procedures

- .1 The following procedure shall be used when there is a destructive test failure.
 - .a The installer shall follow one of two options:
 - Reconstruct the seam, or seams between any two passed test locations.
 - Track the poor weld by extracting additional samples from either side of the failed sample. These samples must be taken a minimum of 3 m from the failed sample in both directions from the location of the failed test.
 - .b Check next seam welded using same welding device if required to obtain additional sample (i.e. if one side of the seam is fewer than 3 m long).
 - .c If any subsequent sample fails, the process shall be repeated to establish the zone in which the seam shall be reconstructed.
 - .d Acceptable seams shall be bounded by two locations from which samples have passed destructive tests.

11.11 Submissions

- .1 Identify the material selected for use.
- .2 With delivery of material, provide written certification from the manufacturer of the material properties for each lot of material supplied.
- .3 Additional Submittals (In-Progress and at Completion):
 - .a Manufacturer's warranty.
 - .b Geomembrane installation warranty.
 - .c Low-temperature seaming procedures.
 - .d Field seam non-destructive test results.
 - .e Field seam destructive test results.
 - .f Daily field installation reports.
 - .g Installation record drawing.

11.12 Liner Acceptance

- .1 The geomembrane liner will be accepted by the engineer when:
 - .a The entire installation is finished.
 - .b All documentation of installation is completed.
 - .c Verification of the adequacy of all field seams and repairs and associated testing is complete.

END OF SECTION

12.0 CULVERTS AND CONVEYANCE

12.1 General

- .1 This section summarizes the specifications for material and installation of culverts and piping within the Keno Hills DSTF P2E.
- .2 Conveyance structures shall include culverts, HDPE piping and manholes as shown on the Construction Drawings.

12.2 Materials

- .1 All culverts, piping, manholes and other conveyance structures shall be provided by the Owner for installation by the Contractor.

12.3 Installation

- .1 All excavations shall be undertaken in accordance with Section 5 – Excavation and Foundation Preparation.
- .2 Culverts and HPDE pipe shall be installed on the prepared base, true to the designed lines and grades shown on the Construction Drawings.
- .3 The Contractor shall use due care when installing the culvert to avoid damaging the material.
- .4 The Contractor shall backfill under the haunches using hand tools or other means to ensure no voids existing under the culvert or pipe.
- .5 Backfill and compaction layers shall be brought up simultaneously and evenly on both sides of the culvert or pipe, filling all corrugations and ensuring firm contact with the entire bottom surface of the pipe.
- .6 This compaction procedure shall be continued until the backfill reaches a minimum thickness of 0.3 m above the top of the pipe, or greater, as determined by the Engineer if necessary to carry the weight of construction equipment without damage to the culvert.
- .7 Backfilling of the remainder of the culvert excavation, beyond the immediate region of the culvert, shall be carried out in accordance with Section 7 – Fill Placement.

END OF SECTION

13.0 QUALITY ASSURANCE TESTING

13.1 General

- .1 This section describes the quality assurance testing that shall be carried out during the construction of the Keno Hill DSTF P2E.
- .2 The on-site testing shall be carried out by the Construction Monitor with results reviewed by the Engineer.
- .3 Additional details are included in the Construction Quality Management Plan (CQMP).

13.2 Reference Standards

- .1 The most recent copy of the following standards
 - .a ASTM C 136, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
 - .b ASTM D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.
 - .c ASTM D 2922, Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

13.3 Fill Testing Requirements

- .1 Particle Size Analysis
 - .a Particle size analyses shall be completed in accordance with ASTM C 136.
 - .b Particle size analysis testing shall be completed on representative samples obtained during excavation of fill material
 - .c Samples shall be collected and tested at the following frequencies:
 - (a) 50 mm Minus Granular Fill: one test per 500 cubic metres of material produced
 - (b) 20 mm Minus Granular Fill: one test per 500 cubic metres of material produced
- .2 Moisture-Density Testing
 - .a Moisture density testing shall be completed on the 50 mm Minus Granular Fill and 20 mm Minus Granular Fill frequency of one test per 5,000 cubic metres of material produced.
 - .b Moisture-density testing shall be completed in accordance with ASTM D 698.

13.4 Field Density Testing

- .1 For granular materials requiring density testing placed within DSTF footprint one (1) test will be completed per 500 square metres, per lift.
- .2 For linear infrastructure, field density testing shall be conducted on granular materials at a minimum frequency of two (2) tests per 100 linear metres, and a minimum of three (3) tests per lift.

END OF SECTION