Topic: HC-01: Assessment of Noise Impacts and Noise Complaint Resolution- DAR Vol. 2, Sec. 9.5.7.2; DAR Vol. 3, Sec. 13.0; DAR Vol. 4, Sec. 23.5.3; Response to DAR Review Comments AKDFN-11, HC-2, HC-3, HC-4, and HC-10

Reviewer Preamble:

The response to ADKFN-11 reports that Long-Term Community Annoyance "only applies to receptors within communities and therefore would not apply to other locations…". HC would like to clarify that percent highly annoyed (%HA) applies to all human receptors exposed to Project-related noise (construction and operation of the completed highway) that is of at least one year in duration at the receptor location. However, provided that R1 and R2 are the most affected receptor locations, evaluating long-term annoyance and sleep disturbance at these locations would be consistent with HC guidance.

Project noise from construction that is less than one year in duration at any given receptor should be assessed for potential sleep disturbance and complaints. Noise concerns from short-term exposures can be mitigated through best practices and HC acknowledges the mitigations described in the DAR (Volume 2, Section 9.5.7.2). For the construction of a highway that is this extensive, taking several years to complete, strong community consultation will be key to mitigating project-noise related concerns with individuals adversely impacted by project noise. Although HC does not have expertise in assessing noise impacts on wildlife, the community has expressed concerns in this area. These concerns may lead to heightened sensitivity toward project noise overall. In addition, public communication prior to elevated noise levels has been shown to be successful in reducing complaints.

Reviewer Request:

HC recommends:

Public communication prior to any particularly noisy activity.

Developing a noise complaint resolution plan that includes the following information:

- The method(s) for receiving complaints (e.g. website, telephone, etc.) and response time;
- The time of complaint and activities that were being undertaken at the time so that there is an understanding of what noise sources were considered problematic;
- Weather conditions as they can influence sound propagation and impact the validity of noise monitoring.

Topic: ECCC-22: Mitigation of Nitrogen Loading Due to Use of Explosives

Reviewer Preamble:

Both the Developer's Assessment Report (DAR) and Proponent responses propose a list of mitigation measures at quarries to reduce nitrogen compound loading from explosives residue in freshwater that includes: "To the extent possible, blasting activities will be completed during winter months to avoid freshet runoff."

It is not clear how this mitigation measure would be effective, since residue would remain on the rock and snow during the winter until it was washed out with freshet. Spring runoff would then potentially have higher concentrations of nitrogen compounds which would have to be monitored and managed appropriately.

Reviewer Request:

ECCC requests the Proponent explain how blasting in the winter months would reduce the extent to which residue rich in nitrogen compounds enters surface water during freshet.

Response from the Government of the Northwest Territories:

As described Section 16.4.2.2.4 of the Developer's Assessment Report, the use of Ammonia Nitrate Fuel Oil (ANFO) explosives is anticipated for the development of quarries and highway materials. The undetonated nitrogen component of the explosives, is highly water-soluble. The use of ANFO explosives may result in releases of nitrogen (which can be detected as nitrate, nitrite, and ammonia) from quarries and quarry materials to the aquatic environment.

Blasting-related nitrogen compounds can enter waterbodies through spillage (during the loading of blastholes or during transportation), by the movement of water through the blasthole, by the erosion of explosives from flowing water through the blasthole, and by leaching of undetonated explosive from the blast rubble and quarry materials.

Consistent with mitigation measures described in the Explosives Management Plan of the Inuvik to Tuktoyaktuk Highway Project (EGT Northwind, 2013), to the extent feasible, blasting activities will be completed during winter months prior to freshet runoff. The intent of this mitigation measure is to reduce the potential for moisture in the blastholes. This risk is reduced in the winter, when conditions are generally dry and/or frozen. Other proposed mitigation measures are to keep blastholes free of water, and to keep explosives sealed and dry to avoid incomplete detonation that can occur when blast holes contain water, or if ANFO becomes wet. Explosives management and mitigations will be addressed in detail in the site-specific Quarry Development Plans that are part of the Quarry License application process.

References

EGT Northwind. 2013. Inuvik to Tuktoyaktuk Explosives Management Plan. Developed for the Government of the Northwest Territorities by EGT Northwind Ltd., Tuktoyaktuk, NT.

Topic: ECCC-21: Surface Water Contamination at Material Sources

Reviewer Preamble:

The Surface Water and Sediment Quality Technical Data Report includes the statement "the potential for existing and future material sources to influence surface water quality in the [Regional Study Area] RSA is not well understood." Despite this poor comprehension, the Developer's Assessment Report (DAR) concludes "Cumulative effects on surface water and sediment quality are characterized as 'neutral' in direction and low magnitude." It is not clear how this conclusion was reached.

There is potential for material sources to impact the aquatic environment, including through increased sedimentation and leaching of nitrogen compounds from blast residue. It is necessary to understand influences of material sources to surface water quality to evaluate effectiveness of proposed mitigation measures. This must be done before it is possible to assess residual and cumulative effects.

Reviewer Request:

ECCC requests the Proponent:

- Describe which aspects the potential for material sources to impact surface water are not well understood, and what is proposed to reduce the uncertainty in this area.
- Justify how the conclusion of neutral and low magnitude cumulative effects was reached, given the uncertainty.

Response from the Government of the Northwest Territories:

The potential for material sources (e.g., borrow sources and quarries) to impact surface water are not well understood because there may not be a pathway of effects between the quarries and surface water. That is, the hydraulic connectivity between the material sources and watercourses has not been established at each individual borrow source or quarry. However, for the purpose of assessing potential effects, the Developer's Assessment Report's (DAR) effects assessment (and associated mitigations) assumed that the effect pathway will exist (i.e., that hydraulic connectivity will exist between quarries and watercourses). Therefore, the characterization of residual and cumulative effects (which were assessed as being neutral in direction and low magnitude effects) accounts for this effect pathway.

The above uncertainty with respect to hydraulic connectivity will be addressed in the Quarry Development Plans (QDPs) that are part of the Quarry License application process. The QDP for each material source will include details concerning the quarry layout, the drainage pathway(s), the phasing of the quarry's development, the locations of stockpiles, water management approaches, closure approach, Erosion and Sedimentation Control Plan, Explosives Management Plan, and Spill Contingency Plan. The QDPs will also include specific mitigations and best management approaches for the protection of freshwater sources.

The Government of Northwest Territories (GNWT) agrees that there is potential for material sources to impact the aquatic environment, including through increased sedimentation and potential leaching of nitrogen compounds from blast residue (due to incomplete combustion of explosives during quarry development). In addition to the mitigations and best management approaches outlined in the DAR to reduce or eliminate Project-related effects to surface water and sediment quality (including from streambank erosion and potential leaching of nitrogen compounds from material sources, etc.), a limited surface water and sediment quality monitoring program will be considered for culturally important waterbodies and drinking water locations along the highway and/or quarry sites. The potential monitoring locations and monitoring objectives will be identified as part of the GNWT's engagement program with Indigenous Governments, Indigenous Organizations, and other affected parties.

Topic: ECCC-20: Collecting Baseline Data for Water and Sediment Quality

Reviewer Preamble:

There is a shortage of data necessary to establish existing conditions of water and sediment quality. The Proponent argues that it is not necessary to collect additional baseline data because: they could not model effects on the aquatic environment from a non-point source such as the highway, they are proposing the use of mitigation measures that are well known to be effective, and water quality monitoring for turbidity would occur during construction activities.

The Developer's Assessment Report (DAR) states "Project-related effect pathways relevant to surface water and sediment quality are directly associated with the development of the Project and will not persist into operation."

ECCC does not agree with this conclusion because effects to the aquatic environment next to the road might occur beyond the construction period, including:

- from dust lifted by highway traffic
- increased runoff from the road, and;
- dust suppressants like calcium chloride

While it is unfeasible to sample and make measurements of every creek along the highway alignment, it would be relevant to characterize baseline water and sediment quality at water crossings in sensitive areas (such as near wetlands) and those that are of cultural importance. This data will be necessary to confirm if mitigation measures are effectively preventing impacts to the aquatic environment.

Water quality data available for sites in the region from the Canadian Aquatic Biomonitoring Network were not included in the list of water quality data sources discussed in Technical Data Report Surface Water and Sediment Quality. Given the paucity of data on water quality presented as baseline data, this data source should be considered unless there are factors which render it unusable.

Reviewer Request:

ECCC requests the Proponent:

- Describe how they will collect baseline water and sediment quality data at water crossings in sensitive areas and areas of cultural importance.
- Consider including Canadian Aquatic Biomonitoring Network water quality data available for sites in the area in their baseline data.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) is interested in discussing with Indigenous Governments and Indigenous Organizations, and other potentially affected parties the implementation of a surface water and sediment quality monitoring program for culturally important waterbodies and drinking water locations along the highway and/or quarry sites during the operations and maintenance phase. Potential monitoring locations and monitoring objectives would be identified as part of the GNWT's ongoing engagement program. Locations within the regional and local assessment areas (RAA and LAA) that were previously identified to be relevant drinking water sources (Table 16.4 of the Developer's Assessment Report) will help inform the selection of monitoring sites.

Following the identification of potential monitoring sites and monitoring objectives, the GNWT would prepare a monitoring plan which would include information regarding the scope and objectives of the monitoring program, the parameters of interest, sample collection methods, protocols for quality assurance and quality control (QA/QC), data analysis, and the reporting of results. The monitoring plan would be provided to relevant stakeholders for review and feedback.

Sources of historical surface water quality data from several monitoring programs within the Regional Study Area (RSA) area are referenced in the Technical Data Report ([TDR] Volume 4, Appendix 16A). These data are available from the following sources:

- GNWT Community-Based Monitoring Program (Mackenzie DataStream, 2024)
- Environment and Climate Change Canada (ECCC) National Long-term Water Quality Monitoring Data (ECCC, 2024; Mackenzie DataStream, 2024)
- Fisheries and Oceans Canada (DFO): Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data (Rempel and Gill (2011)
- Golder (2015): Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge
- Mackenzie Gas Project Environmental Impact Statement (EIS): Biophysical Baseline Report for Water Quality (EIS Volume 3, Section 6; IORVL, 2004)

Compiled water quality data sourced from Water Resources, Indigenous and Northern Affairs Canada (INAC) for the Mackenzie Valley Pipeline were also reviewed during the preparation of the TDR.

The Mackenzie DataStream website is an open access data hub that provides compiled surface water quality data from numerous monitoring programs in the Mackenzie Valley, including the GNWT Community-Based Monitoring Program, long-term ECCC monitoring, and others (Mackenzie DataStream, 2024). Historical GNWT Water Quality Monitoring Data from programs such as Transboundary Rivers, South Slave Regional Network, Yellowknife, Marian and Cameron Rivers Network are also available on Mackenzie DataStream (2024). DataStream may not include all monitoring data from these and other programs in the Mackenzie Valley, so data owners will be contacted to confirm the completeness of the datasets on DataStream, or to request the direct sharing of data.

If historical data from these sources, including previously-conducted Canadian Aquatic Biomonitoring Network (CABIN) monitoring results are available for the selected monitoring locations, these data will be considered for incorporation into the monitoring program based on confidence in the quality and relevance of the data.

References

ECCC (Environment and Climate Change Canada). 2024. National Long-term Water Quality Monitoring Data. Government of Canada. https://open.canada.ca/data/en/dataset/67b44816-9764-4609-ace1-68dc1764e9ea Accessed September 2024.

Golder. 2015. Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge. Report Number: 1401835 Final Report 1. May 21, 2015. Available at : https://www.nwt-esrf.org/sites/nesrf/files/2016-10/Central%20Mackenzie%20Water%20and%20Groundwater%20Baseline%20Assessment%20Report%201%20-%20Technical%20State%20of%20Knowledge.pdf Accessed September 2024.

IORVL (Imperial Oil Resources Ventures Limited). 2004. Environmental Impact Statement. Volume 3: Biophysical Impact Assessment. Section 6 Water Quality. Available at: https://apps.cer-rec.gc.ca/REGDOCS/Item/View/3892241 Accessed September 2024.

Mackenzie DataStream. 2024. Accessed online September 2024 at: https://mackenziedatastream.ca/en

Rempel, L.L. and G.J. Gill. 2011. Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data. Available at https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/344429.pdf Accessed September 2024.

Topic: ECCC-19: Carbon Sinks- Response to DAR Review Comment ECCC-5

Reviewer Preamble:

The methodology used for the calculation of the carbon sinks is missing information and details, and there are some inconsistencies with the carbon sink emission factor used. It is not clear how the carbon sinks emission factor was determined from the source listed (Kurz et al. 2013). The carbon accumulation rate for only forested areas was provided (non-forested ecosystems have not been included in the calculations), however the carbon accumulation for the wetland areas should also be considered. As per the Strategic Assessment of Climate Change (SACC), the carbon sinks evaluation should not be included in the calculation of net GHG emissions (only land-use change should be included in net GHG emissions, carbon sinks are considered separately). Due to the size of the Project area, site-specific or region-specific values should be used for the carbon sinks calculations.

Reviewer Request:

ECCC requests that the Proponent update the carbon sink assessment and provide:

- reference to the draft Technical Guide Related to the SACC: Guidance on quantification of net GHG emissions, impact on carbon sinks, mitigation measures, net-zero plan and upstream GHG assessment, section 4 for calculation methods for carbon sinks.
- forest age and class when calculating the carbon sink potential of the forest that overlaps with the Project footprint
- more site-specific land and vegetation data as per the SACC and the Technical Guide, by incorporating specific site or regional values (through a literature review or field measurements). regional values (through a literature review or field measurements).
- an outline of how the carbon sink emission factor was determined from the source provided. The carbon sink emission factor should be phrased in terms of carbon (C), not units of gas or CO2e, and on a per-year basis.
- application of carbon sink rates for other land-use change classes (such as wetlands) for non-forested areas.
- the method(s) used in the Technical Guide, where the carbon sink rate should be multiplied by the default of 100 years.
- calculation of the natural carbon sink capacity of the Project footprint, and the sum of this lost carbon sink capacity (measured as carbon emissions or removals) for each type of land, not only forested areas. Include the method(s) used, land and vegetation data, and all assumptions made for both construction and operations.

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Response from the Government of the Northwest Territories:

In compiling the Developer's Assessment Report (DAR), the Government of the Northwest Territories (GNWT) followed the Mackenzie Valley Environmental Impact Review Board (MVEIRB)'s 2015 Terms of Reference for the environmental assessment. The information requested falls outside of the scope of information required by the Terms of Reference and scope of this environmental assessment.

The Terms of Reference does not require the assessment of impact to carbon sinks, whether by following the Strategic Assessment of Climate Change (SACC) or other methodology. As presented in the GNWT's response to ORS CanNor-55 (ECCC-8), a simple estimation of carbon sink loss was developed by assuming that the Project's disturbed area land-use class is forested land. The carbon sink impact was estimated using a factor of 0.3802 t CO_2e/ha per year and a Project disturbance area of 2,386 hectares (ha). The factor was derived from the paper "National Research Council of Canada (NRC) Research Press – Carbon in Canada's boreal forest — A synthesis" (Kurtz et al., 2013). The paper reports that, from 1990 to 2008, Canada's managed boreal forest has acted as carbon (C) sink of 28 teragrams (Tg) C per year, with 270 million ha (Mha) of boreal forest in Canada. This results in a flux of 0.1037 t C/ha-year or 0.3802 t CO_2e/ha-year by using the molar ratio [44 g_{CO2}/mol] / [12 g_C/mol].

The carbon sink loss estimation is conservative for the following reasons:

- It was assumed that the Project Development Area (PDA) is entirely composed of forested land. This is a conservative assumption because parts of the PDA are already cleared for the Mackenzie Valley Winter Road (MVWR), and other landcover types are present.
- Abandoned sections of the MVWR right of way (ROW) and access roads will be closed and reclaimed to promote re-establishment of vegetation.

The mitigation measures described in Chapter 12 of the Developer's Assessment Report (Table 12.7 and Section 12.4.3.2), specifically those that pertain to the carbon sink impact are listed below. No additional mitigation measures would be proposed as an outcome of conducting a more detailed assessment of impact to carbon sinks.

- The area of direct ground disturbance will be limited by following the pre-existing MVWR alignment to the extent possible.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).
- Closure and reclamation will promote natural re-establishment of vegetation.
- Temporary access roads, quarries, and workspaces not needed after construction will be closed and reclaimed.

References

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2015. Terms of Reference EA1213-02 Mackenzie Valley Highway Extension Project Wrigley to Norman Wells Government of Northwest Territories. February 13, 2015. PR#66.

ECCC. 2021. Strategic Assessment of Climate Change (SACC) Technical Guide. Guidance on quantification of net GHG emissions, impact on carbon sinks, mitigation measures, net-zero plan and upstream GHG assessment. Revision August 2021. Available at: https://ehq-production-canada.s3.ca-central-1.amazonaws.com/8dc74ea5473aab4741945b51354ec34c91c90d15/original/1628696659/c94bd77e711ab39e596c5cf785673443_Strategic_Assessment_of_Climate_Change_Technical_Guide_EN_-_Final_PDF.pdf?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIA4KKNQAKIOR7VAOP4%2F20240219%2Fca-central-1%2Fs3%2Faws4_request&X-Amz-Date=20240219T185332Z&X-Amz-Expires=300&X-Amz-SignedHeaders=host&X-Amz-Signature=ff2bfdc1d80720058eaf9562db60306b5e834916abd30d4b41e186762db3a86b

Kurtz, W.A., C.H. Shaw, C. Boisvenue, G. Stinson, J. Metsaranta, D. Leckie, A. Dyk, C. Smyth and E.T. Neilson. 2013. Carbon in Canada's Boreal Forest – A Synthesis. Environ. Rev. 21: 260-292. Available at: https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/35301.pdf. Accessed September 2020.

Topic: ECCC-18: Land Use Change- Response to DAR Review Comment ECCC-4

Reviewer Preamble:

ECCC has determined that the Proponent has used a Tier 1 approach to estimate the emissions from land-use changes. Though the Proponent stated they are using a Tier 2 approach, the biomass default values from Intergovernmental Panel on Climate Change (IPCC) documentation used is considered Tier 1. Based on the size of the land being impacted and the carbon sensitivity of the land, a minimum Tier 2 approach should be used and specific regional values for the biomass and land characteristics should be incorporated. In addition, the wetland soil organic carbon (SOC) values used in Table 22.3 appear low for the land type.

Reviewer Request:

ECCC requests the Proponent:

- Use a minimum a Tier 2 approach to estimate emissions from land-use changes as per the Federal Strategic Assessment of Climate Change (SACC) and the Technical Guide, and incorporate specific regional values for the biomass and land characteristics.
- Review the wetland SOC value used in Table 22.3, and provide either an updated value or justification for the value used.

Response from the Government of the Northwest Territories:

Using the Tier 2 approach:

The Government of Northwest Territories (GNWT) agrees that the statement made in response to ORS CanNor-51 (ECCC-4) that the Strategic Assessment of Climate Change (SACC) Tier 2 approach for estimating emissions from land use changes (ECCC, 2021) was applied for the assessment of living biomass, is not correct. The Tier 1 approach was used for the estimation of greenhouse gas (GHG) emissions from land-use change in the Developer's Assessment Report (DAR).

In compiling the DAR, the Government of the Northwest Territories (GNWT) followed the Mackenzie Valley Environmental Impact Review board (MVEIRB)'s 2015 Terms of Reference for the environmental assessment (MVEIRB, 2015). The request to estimate GHG emissions from land-use change based on the SACC falls outside of the scope of information required by the Terms of Reference and scope of this environmental assessment.

As such, the GNWT relied on the SACC Appendix B for guidance only, and the Tier 1 approach was selected to provide a simple, reasonable, and conservative estimation of emissions from land-use change.

The estimation of GHG emissions from land-use change is conservative for the following reasons:

- It is assumed that all vegetation and wetlands will be removed from the Project Development Area (PDA). This is a conservative assumption because areas of the PDA are already cleared for the Mackenzie Valley Winter Road (MVWR).
- Abandoned sections of the MVWR right-of-way (ROW) and access roads will be closed and reclaimed to promote re-establishment of vegetation.

Additionally, the mitigation measures described in Chapter 12 of the DAR (Table 12.7 and Section 12.4.3.2), specifically those that pertain to land-use change, are not expected to change as an outcome of conducting a more detailed assessment of emissions due to land-use change. The following mitigation measures have been proposed and are appropriate for the Project to reduce GHG emissions due to land use change:

- The area of direct ground disturbance will be limited by following the pre-existing MVWR alignment to the extent possible.
- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces to the extent practical.
- Clearing will be limited to areas required for construction and safe operations (i.e., to the width of the ROW and approved access roads).
- Closure and reclamation will promote natural re-establishment of vegetation.
- Temporary access roads, quarries, and workspaces not needed after construction will be closed and reclaimed.

Wetland SOC value:

The Intergovernmental Panel on Climate Change (IPCC) Climate Zone for the Project area was determined to be "Boreal Moist" based on the IPCC 2006 Chapter 3 Figure 3A.5.1 (IPCC, 2006). The wetland soil organic carbon (SOC) value of 116 t C/ha used in the land-use change assessment was obtained from IPCC

2019 Chapter 2 Table 2.3 for the IPCC Climate Zone “Boreal Moist/Dry” and for the IPCC soil class “Wetland soils” (IPCC, 2019).

References

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2015. Terms of Reference EA1213-02 Mackenzie Valley Highway Extension Project Wrigley to Norman Wells Government of Northwest Territories. February 13, 2015. PR#66.

ECCC. 2021. Strategic Assessment of Climate Change (SACC) Technical Guide. Guidance on quantification of net GHG emissions, impact on carbon sinks, mitigation measures, net-zero plan and upstream GHG assessment. Revision August 2021. Available at: https://ehq-production-canada.s3.ca-central-1.amazonaws.com/8dc74ea5473aab4741945b51354ec34c91c90d15/original/1628696659/c94bd77e711ab39e596c5cf785673443_Strategic_Assessment_of_Climate_Change_Technical_Guide_EN_-_Final_PDF.pdf?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIA4KKNQAKIOR7VAOP4%2F20240219%2Fca-central-1%2Fs3%2Faws4_request&X-Amz-Date=20240219T185332Z&X-Amz-Expires=300&X-Amz-SignedHeaders=host&X-Amz-Signature=ff2bfdc1d80720058eaf9562db60306b5e834916abd30d4b41e186762db3a86b

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land-use. Chapter 3: Consistent Representation of Lands. Last updated July 2023.

IPCC. 2019. Generic Methodologies Applicable to Multiple Land-use Categories. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4, chapter 2: Generic Methodologies Applicable to Multiple Land-Use Categories.

Topic: ECCC-17: Emergency Response Plan Training Regimen's Periodicity

Reviewer Preamble:

The Proponent mentions staff training on various aspects of the Management Plans, as outlined in the Draft Emergency Response Plan Framework and Draft Spill Contingency Plan. However, the Proponent does not address the frequency of these training sessions. Establishing an appropriate training schedule is crucial to ensure that staff are consistently updated on any revisions to these plans and remain well-informed about the appropriate response measures in the event of an accident or malfunction. Considering the construction timeline that extends far into the future, considerations for frequency of the training regimen in-place will help reduce the probability and environmental impact of spills.

Reviewer Request:

ECCC requests the Proponent establish a training regimen with defined periodicity.

Response from the Government of the Northwest Territories:

The Contractor(s) selected by the Government of Northwest Territories (GNWT) to construct the Project will be responsible for complying with all permits and licences, including the requirements of each of the management plans. The GNWT agrees that the Contractor will be required to train personnel on the purpose and procedures provided in each of the Plans. The methods and frequency of such training and review of the plans will be at the discretion of the Contractor and the GNWT. For example, training is provided as part of orientation for new personnel, and a review may be required annually. Additional training may be required if there is a change in a procedure identified within the Plan, after an accident or spill or if a non-conformance with the plan is identified.

Topic: ECCC-16: Inconsistencies in Appropriate Setbacks for Lesser Yellowlegs, Other Species

Reviewer Preamble:

ECCC acknowledges the use of Lesser Yellowlegs as a species of focus for the Proponent, given that they are generally known as an umbrella species with behaviour and habitat use that encompasses many other boreal shorebirds. In Appendix 20A: Birds and Bird Habitat Technical Data Report, the nest setback distance for development activities proposed is stated to be 100 m for general development, and 50 m from pedestrian or All-Terrain Vehicle (ATV) activities. In Appendix 20B: Recommended Activity Restriction Guidelines for Sensitive Bird Species, the Proponent lists the nest setback distance of 300 m for Lesser Yellowlegs. Setback distances should be adjusted to the activities causing the greater amounts of disturbance, and reflect the degree of tolerance of the species.

Reviewer Request:

ECCC requests the Proponent:

- Provide a biologically relevant justification for the use of the setback distance(s) proposed in Appendix 20A/B. Include a scientifically defensible rationale that incorporates application of the setback distance(s) based on activity disturbance levels

- Ensure any inconsistencies regarding setbacks in the DAR (namely in the above noted appendices 20A and 20B) are resolved/corrected and transferred/applied to any management plans (such as the Draft Wildlife Management and Monitoring Plan [WMMP]) appropriately.

Response from the Government of the Northwest Territories:

The recommended setback distances for lesser yellowlegs (*Tringa flavipes*) in the Developer's Assessment Report (DAR) reflect information and recommendations outlined in NWT specific guidelines as well as professional judgment. The Government of Northwest Territories (GNWT) (2020) recommends a 100 metre (m) setback for lesser yellowlegs nests, whereas the Northern Land Use Guidelines (GNWT 2015) provide recommended setback distances for species at risk bird nests that vary from 200-350 m. The draft Wildlife Management and Monitoring Plan ([WMMP] Volume 5 of the DAR), recommends a setback distance of 300 m from nests of lesser yellowlegs between May 1 and August 31 (Appendix C).

The GNWT will develop and apply an appropriate setback distance to active nests of lesser yellowlegs in consultation with Environment and Climate Change Canada – Canadian Wildlife Service that reflects Project-related construction disturbance levels, as needed.

Any mitigation measures that have been developed or updated related to nest setback distances for lesser yellowlegs will be provided in subsequent versions of the draft WMMP following regulatory consultation.

References

GNWT (The Government of the Northwest Territories). 2015. Northern land use guidelines: Northwest Territories seismic operations. Yellowknife, NT. 48 pp.

GNWT. 2020. Beneficial management practices for migratory birds in the Northwest Territories. Department of Infrastructure, Government of Northwest Territories, Yellowknife, Northwest Territories.

Topic: ECCC-15: Clarity and Error Correction for Bird Groupings

Reviewer Preamble:

The developer uses a variety of terms to group bird species in the Developer's Assessment Report (DAR). These terms and how species are grouped into them are used inconsistently and often incorrectly. For example (not an exhaustive list):

- Section 3.2.2. of Appendix 20A (Birds and Bird Habitat Technical Data Report) incorrectly lists terns as a type of shorebird
- Appendix 20C (2022 Avian Survey Report), Appendix B, Table B.4 incorrectly lists gulls and jaegers as shorebirds (page B.8-B.9)
- Appendix 20C (2022 Avian Survey Report), Appendix B, Table B.4 duplicates the use of certain names for grouping birds: waterbirds is used as a Group for many species on Table B.4, and also referred to waterbirds as an Order on the same table.
- Appendix 20C (2022 Avian Survey Report), Appendix B, Table B.5 also lists waterbirds such as bitterns, coots and cranes as shorebirds.

The inconsistent and incorrect classifications may cause confusion amongst parties reviewing the Project for its potential effects during the environmental assessment.

Reviewer Request:

ECCC requests the Proponent:

Clearly define terms used to describe bird groupings for clarity and consistency, using biologically understood and standardized nomenclature (e.g. landbirds, waterfowl, waterbirds, shorebirds). Avoid double-grouping species or using terms twice that could have different meanings (e.g. using waterbirds as a large group, then true waterbirds as the order). Update all applicable sections of the DAR (including appendices) to ensure that these terms are used consistently.

Response from the Government of the Northwest Territories:

The bird groupings used in the Developer's Assessment Report (DAR) (Section 20, Birds and Bird Habitat), Appendix A (Bird and Bird Habitat Technical Data Report [TDR]) as well as Appendix C (2022 Avian Survey Report) were developed to support the assessment and do not necessarily reflect taxonomic classifications. Section 3.2.2.2 of the TDR describes the approach by stating that bird families that represent species groups including waterfowl, shorebirds and waterbirds are referred to as "waterbirds" (i.e., waterbirds were used as a larger species group for the purpose of the assessment that included wetland and water dependent birds with potential to occur in the Regional Study Area). In addition, taxonomic classifications of bird species do not necessarily align with Indigenous and local knowledge where waterfowl and breeding duck habitat can be referred to separately (Sahtú Land Use Planning Board, 2023), or where harvested species might be referred to as ducks and geese but not necessarily waterfowl (Sahtú Renewable Resources Board, 2021).

The Government of Northwest Territories (GNWT) acknowledges that bittern (Order Pelecaniformes), coots and cranes (Order Gruiformes) are typically not classified as shorebirds based on taxonomy, but they are included in the species group called waterbirds for the purposes of the assessment. However, it is generally accepted that terns, gulls and jaegers are included in the Order Charadriiformes (shorebirds) (Chesser et al., 2024). Nonetheless, as stated above, all birds associated with water were considered waterbirds for the purpose of the assessment.

The GNWT respectfully submits that updating bird groupings in the DAR and associated appendices for the purpose of the assessment is not necessary to conclude on significance of residual effects. Any changes to taxonomic groupings would not alter the conclusions of the assessment.

References

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Topic: ECCC-14: Derivation of Land Cover Classes in the Developer's Assessment Report (DAR): Accuracy and Age of Data

Reviewer Preamble:

It appears that land cover classes were derived via a desktop review of geospatial data from 2013 – 2017. Details on the origins of the data used to create these classes were not clearly described in the DAR. Landsat satellite imagery used to derive the geospatial data appears to have been derived from 2007-2013 data, as noted in Section 20.4.1.1 of the DAR:

"Land cover classes were quantified using EOSD NWT geospatial data (NRCan and GNWT, 2017). This dataset is part of the Multi-source Vegetation Inventory Project (NRCan, 2020) and uses an unsupervised classification and cluster analysis to classify land cover. The dataset includes cover type and density classes and forest structure height and volume information based on Landsat imagery collected from 2007 to 2013. Mapping was done at a scale of 1:250,000 and was refined through field evaluation by the GNWT (NRCan and GNWT, 2017). Detailed land cover classification methods for this Project are in the Vegetation and Wetlands TDR (K'alo-Stantec, 2022b; Appendix 18A)."

There is an absence of information on recent field verification/validation of land cover classification. Ground-truthing allows for the verification and incorporation of actual conditions on the ground, which may differ significantly from what is observed via Geographic Information System (GIS) data collected one-and-a-half decades earlier. A 2013/2017 dataset (derived from this ~15-year-old data) appears to have been used to inform the spatial modelling for migratory bird species and their potential habitat.

For migratory birds, the time of year when imagery is collected to create habitat classifications (typically August/September) often doesn't match the critical breeding time of year the migratory birds when they make decisions based on water or vegetation availability (typically April-June). Furthermore, habitat classifications in the North are often skewed towards large mammals, or forestry (tree) type, and may not have the class breakdowns appropriate for assessing value to migratory birds.

The Northwest Territories fire-season in 2023 caused significant changes to the landscape and may have had effects on available land cover types in the Project area.

If geospatial data/land cover classifications are inaccurate, there may be over/underestimation of effects to migratory bird species.

Reviewer Request:

ECCC request the Proponent:

- Clarify the age of the data-sources used to derive land cover classes. Confirm whether or not the data originates in whole or in part from the 2007-2013 dataset.
- Describe the confidence in the accuracy of the landcover classifications, taking into account its age.
- Provide an analysis on how the time gap (from year dataset was collected to anticipated year of construction) accurately considered potential change in species demographics, accelerated effects of climate change, and recent (e.g. 2014, 2023) forest fires.

- Given the data is not current and likely does not represent the current state of land cover classes, collect current field data and/or verify the accuracy of the data-sources used in the field. If current data will not be collected, then discuss the uncertainty around the effects predictions, mitigation measures and follow-up monitoring/adaptive management.

- Provide justification on the appropriateness of, applicability to and validity of the land cover classes for migratory birds.

- Explain how the land cover classes used are biologically appropriate for migratory birds.

- Clarify the date(s) when the imagery was taken to derive the land cover classes.

- Use updated/current satellite/GIS data to classify habitat in order to reflect the above noted concerns. If up to date information will not be used, then explain how the above concerns are addressed with the information presented in the DAR.

- Update the land cover classes to reflect the changes to the landscape due to the 2023 wildfires. If the land cover classification will not be updated, then provide a discussion on the strength of the assessment in the absence of this information, and how accurately it can identify effects and mitigation measures.

Response from the Government of the Northwest Territories:

The Government of the Northwest Territories (GNWT) confirms that land cover mapping and subsequent habitat metrics for migratory birds provided in the Developer's Assessment Report (DAR) were derived from the 2007-2013 dataset, which is part of the Earth Observation for Sustainable Development of Forests (EOSD) land cover updates Phase 1, 2, and 3 created by Natural Resources Canada and GNWT (2017).

Several datasets including earth observation products derived from satellite imagery (Landsat TM data), and other federal and regional geographic information have been integrated into the EOSD land cover map of forested areas of Canada (Wood et al., 2002). Landsat images were taken around the year 2000 (CFS, 2007a). The Landsat images used have a 25-metre (m) resolution, which is the highest satellite-derived spatial resolution data available for the total area of Canada (GoC, 2024). Although EOSD data for the NWT was created using older satellite imagery, it represents the best available land cover mapping available for the Local Assessment Area (LAA) and Regional Assessment Area (RAA) for the Vegetation and Wetlands and Birds and Bird Habitat Valued Components (VCs) assessed in the DAR. The NWT in particular is an area for which little satellite data has been processed into a useable form for land cover determination (CFS, 2007b). Validation of the EOSD land cover dataset has shown that the EOSD classifications are approximately 80 percent accurate (CFS, 2007b). A plot-based system of permanent observational units located on a national grid was adopted to cover 1% of Canada's land mass to verify accuracy of the EOSD land cover data (Wood et al., 2002). The GNWT understands that the EOSD dataset for the NWT has not been updated since the DAR was submitted in October 2023.

The GNWT acknowledges the uncertainties associated with potential direct and indirect effects of climate change on bird distribution and abundance, which are discussed in Section 20.7.2 of the DAR. In addition, a more detailed discussion of predicted future conditions related to the potential effects of climate change on migratory birds and bird habitat, including for migratory bird species at risk is provided in GNWT's response to Mackenzie Valley Environmental Impact Review Board Information Request #2.

As discussed in Section 20.4.1.1 and 20.4.3 of the DAR, potential effects of the Project on migratory birds and bird habitat used a habitat-based approach based on EOSD land cover data. Despite the age of data sources used for the EOSD, the GNWT contends that it is sufficient for assessing the potential effects of the Project on migratory birds. The EOSD is based on stand-level attributes such as stand height and crown closure, which provide sufficient information to assess habitat suitability for focal migratory bird species and species groups. A habitat-based approach is a common and accepted method to assess potential direct and indirect habitat loss in environmental assessments. The conservative nature of this approach in relation to bird habitat and fire is discussed in Section 20.4.1.3. The EOSD land cover associations used to quantify breeding habitat for migratory birds and bird species groups is presented in Table 20.10 of the DAR. Land cover associations are considered biologically appropriate for the species assessed and were developed using relevant scientific literature, life history information, and professional judgment. Although recent forest fires and human disturbance are not included as distinct cover classes, they are embedded in the EOSD data under the Exposed Land classification, which includes areas with less than 5% vegetation, including burned areas and areas of human disturbance (CFS, 2003).

For species in Table 20.10 identified as being positively associated with recent fire disturbance (i.e., common nighthawk [*Chordeiles minor*] and olive-sided flycatcher [*Contopus cooperi*]), habitat metrics in the DAR incorporated a 20-year (2001-2021) fire footprint queried from the Canadian National Fire Database in 2022.

The GNWT recognizes that fire plays an important role in shaping northern forests, and the dynamic nature of this ecosystem can rapidly alter the distribution and abundance of habitat available for wildlife species such as migratory birds. Wildfires that occurred in 2023 altered habitat for migratory birds in the LAA and RAA. A summary of EOSD land cover within the 2023 fire footprint in the LAA and RAA is provided in Table 35-1. Approximately 184 ha (8%) of the PDA burned in 2023, along with 5,781 ha (7.7%) and 128,996 ha (12.8%) of the LAA and RAA, respectively. Based on the area of land cover burned, 2023 wildfires have temporarily reduced breeding habitat availability in the LAA for assessed bird species and species groups associated with coniferous forest (e.g., rusty blackbird [*Euphagus carolinus*]) and wetland species (e.g., yellow rail [*Coturnicops noveboracensis*]); whereas habitat for common nighthawk and olive-sided flycatcher is expected to have increased in the LAA.

Table 35-1 Land Cover Types Burned in 2023 in the PDA, LAA, and RAA

Landcover Type	Cover Type Class	PDA	LAA	RAA
		ha	ha	ha
Broadleaf Forest	Broadleaf – Dense	0.2	67.2	3,683.3
	Broadleaf – Open	1.3	38.1	2,817.8
Broadleaf Subtotal		**1.5**	**105.2**	**6,501.2**
Coniferous Forest	Coniferous – Dense	2.8	263.7	6,899.9
	Coniferous – Open	12.5	813.6	37,102.0
	Coniferous – Sparse	11.7	938.1	18,813.2
Coniferous Subtotal		**27.0**	**2,015.3**	**62,815.1**
Mixedwood Forest	Mixedwood – Dense	0.0	62.1	2,229.6
	Mixedwood – Open	2.5	291.4	4,102.0
Mixedwood Subtotal		**2.5**	**353.5**	**6,331.7**
Shrubland	Shrub – Tall	3.3	173.8	1,387.7
	Shrub – Low	17.1	1,259.0	8,037.4
Shrubland Subtotal		**20.4**	**1,432.8**	**9,425.1**
Herbaceous and Un-vegetated	Herb	0.0	0.3	19.4
	Bryoids	0.0	0.0	20.8
	Rock/Rubble	0.0	0.0	325.2
	Exposed Land[1]	108.4	351.7	681.2
Herbaceous and Un-vegetated Subtotal		**108.4**	**352.0**	**1,046.6**
Upland Subtotal		**159.8**	**4,258.8**	**86,119.7**
Wetland	Wetland – Treed	14.3	666.4	18,063.8
	Wetland – Shrub	2.7	280.6	9,161.4
	Wetland – Herb	7.1	574.7	15,650.9
Wetland Subtotal		**24.1**	**1,521.7**	**42,876.1**
Total[2]		**184.0**	**5,781.2**	**128,995.8**

NOTE:
[1] Exposed land includes areas which naturally have less than 5% vegetative cover such as shorelines of rivers and lakes, exposed rock, recently burned areas, and moraines, and includes cleared areas such as roads and areas of infrastructure development.
[2] Total excludes open water

SOURCES:
Land Cover data from: Natural Resources Canada and Government of Northwest Territories (2017)
Fire perimeter data from: GNWT-ECC (2024)
Human disturbance data from: GOC (2020)

References

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CFS. 2007a. EOSD: monitoring our forests from space. Branching out No. 37. Available at: https://ostr-

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GOC (Government of Canada). 2020. 2020 - Anthropogenic disturbance footprint within boreal caribou ranges across Canada - As interpreted from 2020 Landsat satellite imagery. Available at: https://open.canada.ca/data/en/dataset/63e1cda6-debe-4b9b-b075-3666443e30b4

GOC . 2024. Natural Resources Canada Forest Cover map website. Available at: https://natural-resources.canada.ca/our-natural-resources/forests/sustainable-forest-management/measuring-and-reporting/remote-sensing-forestry/forest-cover-map/13433, Accessed September 2024.

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Topic: ECCC-13: Consideration of Impacts to Important Bird Areas (IBAs)

Reviewer Preamble:

ECCC notes that within the Regional Assessment Area for the Project there are two key migratory bird areas identified as important for foraging and migratory stopover: Bracket Lake IBA and the Middle Mackenzie River Islands IBA.

Reviewer Request:

ECCC requests the Proponent provide further details on how impacts to the IBAs were considered, including effects from the Project on migratory birds and their use of these areas, and list specific mitigations relevant to them.

Response from the Government of the Northwest Territories:

The Middle Mackenzie River Islands and Brackett Lake Important Bird Areas (IBAs) are discussed in the Birds and Bird Habitat Technical Data Report (Section 3.2.2.2; Figure 3.6). Because these IBAs overlap with the Birds and Bird Habitat Regional Assessment Area (RAA), the potential effects of the Project on these two IBAs are discussed in Sections 20.4.2.3.1.1 and 20.4.2.3.2.1 of the Developer's Assessment Report (DAR).

As stated in Section 20.4.2.3.1.1 of the DAR, Project routing avoids wetland habitats where possible to mitigate direct and indirect habitat loss and alteration for waterbirds. The Brackett Lake IBA is outside of the Local Assessment Area (LAA) and while the Project will not interact with the IBA, it does provide a notable breeding area for waterbirds within the RAA (IBA Canada, 2020a).

Important migratory stopover sites within the LAA are limited to the Middle Mackenzie River Islands IBA, which supports large numbers of waterfowl species each year, including greater white-fronted goose (*Anser albifrons*), Canada goose (*Branta canadensis*), tundra swan (*Cygnus columbianus*), and snow goose (*Anser caerulescens)* that are important to current land and resources users for traditional purposes (see Section 20.4.2.3.1.1 of the DAR).

Construction of the Project will result in the direct loss of 884.3 ha of the Middle Mackenzie River Islands IBA, a 3.1% decrease from existing conditions. The Project Development Area (PDA) generally remains > 800 metres (m) from the Mackenzie River shoreline and migrating waterfowl and breeding habitat. There will be direct loss of upland habitats within the Middle Mackenzie River Islands IBA; however, migration and potential breeding habitat will remain physically undisturbed by the Project (i.e., open water in the Mackenzie River and adjacent islands and shoreline). However, construction will result in an increase in sensory disturbance, which could reduce habitat use of migratory stopover sites. Waterbirds, shorebirds and waterfowl most likely to be affected are those in smaller wetlands adjacent to the PDA. During operations and maintenance, the Project will also result in potential sensory disturbance as discussed in Section 20.4.2.3.2.1of the DAR; however, most waterfowl are likely to become acclimatized to the low traffic levels associated with the use of the highway during operations and maintenance. Overall, waterfowl are highly mobile and are expected to adjust their daily distributions relative to sensory disturbance. Migrating birds are unlikely to rely heavily on wetlands adjacent to the PDA where sensory disturbance will be greatest (see Section 20.4.2.3.1.1 of the DAR). Increased access for predators and hunters might result in an indirect change in mortality risk. The Project will enhance access along a continuous linear feature that may increase predator efficiency and hunter ease of travel while providing all-season access to portions of the LAA that were previously more isolated. Species most likely to be affected include prey species (e.g., passerines), harvested species (e.g., waterfowl), and those attracted to the PDA (e.g., upland gamebirds) (see Section 20.4.3.1.2).

Mitigation measures proposed to reduce potential effects of the Project on change in bird habitat and mortality risk are discussed in Section 20.4.2.2 and Section 20.4.3.2, respectively. A list of mitigation measures is provided in Table 20.9 of the DAR. Key mitigation measures designed to protect migratory birds are summarized below. These mitigation measures will be applied within the LAA including areas where the Project overlaps the Mackenzie River Islands IBA.

Design-related mitigation measures (Section 5.2.2):

- Use the existing Mackenzie Valley Winter Road alignment to the extent possible to reduce the area of new disturbance

- Limit right of way width to 60 m in width, except where large cut or fill sections are required
- Reduce footprint through areas of traditional, cultural, and ecological importance
- Avoid areas of wetlands, to the extent possible

Key mitigation measures for birds and bird habitat (Table 20.9):

- The Project will use previously disturbed areas for project activities and project infrastructure and workspaces, to the extent practical.
- Wildlife monitors will assess for the presence of nesting birds on or near the PDA during project activities.
- The Wildlife Management and Monitoring Plan (WMMP) will outline how risks to migratory birds will be managed in accordance with ECCC's Guidelines to Reduce Risk to Migratory Birds if activities that could result in risk of harm cannot be avoided (e.g., pre-clearing nest surveys).
- Vegetation clearing will be completed outside the migratory bird nesting period, which extends from approximately May 1 to August 31. This considers Nesting Zone B8 (May 4 to August 22 for Zone B8) and potential species at risk.
- If an active bird nest is found, beneficial management practices (GNWT, 2020) will be followed, including applying an appropriate setback and timing restriction and the GNWT-Environment and Climate Change (ECC) and/or ECCC will be consulted, as appropriate.
- Project staff will take the GNWT's Migratory Bird Awareness Training Webinar and obtain a certificate to demonstrate proof of training.
- Personnel will undergo a wildlife awareness program, which will include prevention measures for wildlife mortality (e.g., bear safety) and reporting procedures for wildlife-related incidents and protocols to follow when a nest, den, or wildlife species of management concern is observed. This includes completing wildlife sighting and wildlife incident report forms included in the WMMP.
- Closure and reclamation of temporary workspaces and sections of the MVWR no longer in use will promote re-establishment of vegetation.
- Borrow source vegetated surface material, where present, will be replaced after development is completed.
- Personnel will not feed, harass, or hunt wildlife while working on the Project.
- Construction and quarry development activities will be limited during sensitive periods for wildlife in accordance with the WMMP.
- Food and other wildlife attractants will be stored in bear-proof containers.
- Equipment, wastes, and contaminated soils will be removed once construction is completed.
- Speed limits will be posted on the public highway.

References

GNWT. 2020. Beneficial management practices for migratory birds in the Northwest Territories. Environment and Natural Resources, Government of Northwest Territories, Yellowknife, Northwest Territories.

IBA Canada. 2020a. IBA site summary: Brackett Lake. Available at: https://www.ibacanada.com/site.jsp?siteID=NT082. Accessed September 2020

IBA Canada. 2020b. IBA site summary: Middle Mackenzie River Islands. Available at: https://www.ibacanada.com/site.jsp?siteID=NT081. Accessed September 2020.

Topic: ECCC-12: Accounting for Interannual Variation in Migratory Bird Surveys

Reviewer Preamble:

The GNWT supplemental avian survey work completed in 2022 compiled one year of breeding-season data. The collection of one year of baseline data is not sufficient to reflect natural variation in species abundance/use of habitat.

ECCC recommends bird surveys over a period of at least two consecutive breeding seasons to account for interannual variation.

Reviewer Request:

ECCC request the Proponent:

- Discuss whether they are planning to conduct additional survey work for migratory birds to supplement the 2022 bird surveys.
- Provide the survey methods/plans to conduct this survey work in order to account for interannual variation.
- Provide a comprehensive justification if further migratory bird data will not be gathered, and how the current data will account for annual variation. Please include any assumptions or extrapolations that could be considered by reviewers if the collection of two additional years of survey data is not feasible

Response from the Government of the Northwest Territories:

The scope of the assessment for birds and bird habitat was prepared to comply with the Terms of Reference (TOR) for the Developer's Assessment Report (DAR) issued for the Project by the Mackenzie Valley Environmental Impact Review Board (MVEIRB, 2015). The TOR pertaining to the presence of birds including species at risk as well as abundance and distribution required for description of baseline conditions in the study area, did not stipulate that two consecutive breeding bird seasons were required to account for interannual variation. The description of baseline conditions for birds and bird habitat was prepared to meet the TOR and was included in Section 20 of the Developer's Assessment Report (DAR), Appendix 20A – Birds and Bird Habitat Technical Data Report (TDR) and Appendix 20C- 2022 Avian Survey Report.

The description of baseline conditions for migratory birds was prepared using data from several reputable sources including:

- 23 autonomous recording unit (ARU) stations deployed to collect data during 2022 for the Project
- Environment and Climate Change Canada (ECCC) breeding bird survey data (ECCC, 2020) from:
    - 53 ARU stations, of which 50 were deployed in the LAA during 2017
    - 34 point count stations in the Local Assessment Area surveyed in 2004 and 2006.
- Boreal Avian Modelling Program (BAMP) data (BAM, 2020)
- Traditional Knowledge and traditional land and resource use information discussed in Section 20 of the DAR and Appendix 20A - Birds and Bird Habitat Technical Data Report
- North American Breeding Bird Survey data (Smith et al., 2019)
- Government of Northwest Territories (GNWT) Wildlife Management Information System (WMIS) bird observations (GNWT, 2020)
- Waterfowl Breeding Population and Habitat Survey data from strata 15 collected from 2011 to 2015 in the Regional Assessment Area (RAA) (USFWS, 2019)
- Important Bird Area Canada data (IBA Canada, 2020)
- eBird data (eBird, 2021)

Although the assessment did not include Project-specific bird survey data collected over two consecutive breeding seasons, baseline conditions for the assessment were evaluated using data collected over multiple breeding seasons including sources noted above.

The GNWT acknowledges that field-based surveys over consecutive breeding seasons might indicate annual variation in relative abundance for some migratory bird species. However, the GNWT contends it is not necessary to complete additional field surveys for migratory birds to account for potential interannual variation in bird abundance because the assessment used a habitat-based approach, which assumes birds are present and potentially affected due to direct and/or indirect habitat loss due to the Project (i.e., a conservative approach that might overestimate potential effects).

Additional field survey data would not improve the assessment of the significance of Project-related effects or change the mitigation measures developed to reduce potential effects on migratory birds including species at risk and species of conservation concern, and no further surveys are planned. However, if ECCC provides additional ARU data that is already processed (i.e., bird species identified), the GNWT will consider how the data could be used to supplement the assessment and/or inform future monitoring efforts.

References

BAMP (Boreal Avian Modelling Project). 2020. BAM generalized national models documentation, Version 4.0. Available at: https://borealbirds.github.io/. Accessed November 2022.

eBird. 2021. Species map. Available at: https://ebird.org/map. Accessed September 2021.

ECCC (Environment and Climate Change Canada). 2020. Breeding bird survey data along the Mackenzie Valley winter road. Data request November 23, 2020. Environment and Climate Change Canada, Yellowknife, NT.

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Topic: ECCC-11: Waterfowl and Data Limitations, Collar Data, Increased Human Access

Reviewer Preamble:

The Proponent notes that migrating waterbirds/waterfowl are "highly mobile and adjust their daily distribution relative to sensory disturbance" (Section 20.4.2.3.2.1). The Developer's Assessment Report (DAR) also notes that Indigenous groups have heightened concern about effects to many specific species of waterfowl (Section 20.2.2.1; Table 20.5).

Given the limited ability of Autonomous Recording Units (ARUs) to estimate the density and abundance of species like waterfowl, limited data in the area and changing climate, ECCC notes that further fieldwork and data collection on waterfowl abundance may be warranted to more reliably identify and manage effects from the Project and determine appropriate mitigation methods.

The proposed highway routing is near riparian habitat and many wetlands. ECCC also notes there are two key Important Bird Areas (IBAs) along the Mackenzie River used for foraging and migratory stopover: Bracket Lake IBA and the Middle Mackenzie River IBA. ECCC has collared waterfowl and existing data on migratory bird use in these particular areas.

Disturbance from construction and operation of the highway may affect the suitable migratory stopover sites in the area for waterfowl. It may also make these species more accessible to human harvesters and predatory wildlife species.

During a February 14th, 2024, meeting with the Proponent, ECCC-Canadian Wildlife Service (CWS) offered to increase the frequency of data collection on Global Positioning System (GPS) collared snow geese (or similar) in the Mackenzie Valley area. This could potentially provide higher resolution data on migratory species in these areas, to better increase the confidence of prediction of effects on such species. However, there is a limited time-window in which to do these adjustments every spring.

ECCC welcomes follow up to the February 14th meeting should the Proponent consider: approaching ECCC-CWS staff to request collaboration and sharing of collar data of waterfowl in the area, and consider the increase in frequency of GPS collar data collection; and further surveys of additional migratory birds that frequent the proposed Regional Assessment Area (RAA) to better understand waterfowl diversity and abundance.

This data could be used by the Proponent for adaptive management to better mitigate Project effects on waterfowl.

Reviewer Request:

ECCC requests the Proponent:

- Provide justification for why the Proponent may or may not be considering a follow up meeting with ECCC-CWS to discuss to waterfowl GPS collar data collection and further migratory bird surveys. If action is being considered, then detail potential plans (which seasons, number of individuals, etc.) and elaborate on how this will help address data gaps.

- Further describe how human access to nesting or staging areas will be incorporated into analysis

of effects to migratory bird species, including changes in harvest pressure on migrant bird species, specifically waterfowl.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) acknowledges that autonomous recording unit (ARU) data is not an appropriate survey method to estimate density and relative abundance of waterfowl. However, as discussed in the GNWT's response to Online Review System (ORS) CanNor-20 (ECCC-22), ECCC-Canadian Wildlife Service (CWS) informed the GNWT Department of Infrastructure and GNWT-Environment and Climate Change of additional migratory bird data collected using ARUs as well as GPS collared snow geese data within the Mackenzie Valley Winter Road corridor in February of 2024, which was after the Developer's Assessment Report (DAR) submission.

The information presented in Section 20.0 of the DAR and Appendix 20A (Birds and Bird Habitat Technical Data Report [TDR]) was prepared using existing databases including Traditional Knowledge and Traditional Land and Resource Use information available at the time of submission. The DAR, as well as the Birds and Bird Habitat Technical Data Report – Appendix 20A of the DAR, discussed waterfowl breeding and staging areas in the Local Assessment Area and Regional Assessment Area based on a review of Important Bird Areas (IBAs) (i.e., Middle Mackenzie River Islands and Brackett Lake IBAs), information provided in the Sahtu Land Use Plan that includes Conservation Zones, as well as summary of population estimates from the Waterfowl Breeding Population and Habitat Survey data collected jointly by the United States Fish & Wildlife Service and Canadian Wildlife Service (see Section 3.2.2.2 and Table 3.3 of the TDR).

Overall, the GNWT considers the data and information used for the DAR as sufficient to support assessment of potential effects of the Project on birds and bird habitat including waterfowl using a habitat-based approach. Additional information related to GPS collar data for snow geese (or similar) is not anticipated to change the effects conclusions based on the predicted confidence discussed in Section 20.7 of the DAR and consideration of gaps and uncertainties (Section 20.7.2 of the DAR). The GNWT is willing to discuss with ECCC the GPS collared snow geese data to determine if the data would help inform additional mitigation measures and/or any future monitoring programs

The potential effects of the Project on bird habitat including waterfowl habitat are discussed in Section 20.4.2 of the DAR and potential effects pathways related to increased harvest pressure are discussed in Sections 20.4.3.1.2 of the DAR. Residual effects on change in mortality risk during operations and maintenance are discussed in Section 20.4.3.3.2 of the DAR and acknowledge that increased access might result in potential increased hunting pressure and predation on harvested species such as waterfowl. Human access to nesting or staging areas were qualitatively addressed in the assessment, and a low magnitude but long-term residual effect on change in mortality risk was predicted (see Section 20.4.3.3.2 of the DAR).

Topic: ECCC-10: Disturbance to Migratory Birds During Other Key Life Periods- Arctic Breeding Migrants; Climate Change Considerations

Reviewer Preamble:

In most of Canada, migratory bird diversity and abundance are highest during the local breeding season, and the disturbance or destruction of this breeding habitat can significantly affect populations. However, disturbing migratory birds while they are molting, migrating, or overwintering can also affect populations (Wolfe et al. 2019), and project impact assessments need to identify any relevant risks and potential population implications for those species. Project proponents must consider their proposed projects' potential impacts on distribution and abundance of migratory birds beyond the local nesting period, particularly for arctic-breeding migrants.

The Mackenzie Valley is a significant migration corridor for arctic-nesting migratory birds. Both northbound (spring) and southbound (fall) migrants use a similar corridor to the proposed Project's routing. The habitats they use within the Regional Study Area (RSA) may be very important to their survival and reproduction.

Other groups, including the Norman Wells Renewable Resources Council (NWRRC) have noted concern with changing bird migration patterns/directions and less frequent appearance of some species (Table 20.1) which may suggest change and uncertainty in migration movements and patterns. These changes could be due to any number of factors including the effects of climate change, the effects of which most scientists acknowledge are amplified in northern Canada.

The Proponent has not provided adequate spring and fall migrant bird surveys, especially survey methods that capture species not easily detected by Autonomous Recording Units (ARU).

Reviewer Request:

ECCC requests the Proponent:

- Describe how the assessment will account for and assess effects to avian species present in and/or potentially using habitats within the RSA during spring and fall migration.
- Include a specific section focused on arctic-breeding species (including waterfowl and shorebirds). This section should explain when and how spring and fall migrant studies will be conducted and/or a description of how this information will be incorporated into the assessment of effects, and the identification of mitigation measures. If ARU data or desktop modelling are being considered to supplement data, explain how the effects to species not easily detected by ARUs will be assessed.
- Describe how the effects of climate change were/will be incorporated into the analysis of effects to migratory bird species.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) agrees the Mackenzie River Valley is an important migration corridor for migratory birds, which is discussed in Appendix 20B - Birds and Bird Habitat Technical Data Report.

The assessment focused on potential effects on birds and bird habitat in the Local Assessment Area because this is where effects from direct and indirect habitat loss due to the Project are expected to occur (see Section 20.1.3 and 20.1.4 of the Developer's Assessment Report [DAR]). Bird habitat that might be affected by the Project and other projects in the larger Regional Assessment Area is addressed as part of the cumulative effects assessment (see Section 20.5 of the DAR).

The GNWT also agrees that Project activities could affect migratory birds during breeding as well as other seasons and that autonomous recording units are not an effective means of surveying for some species of Arctic migrants, which is why the birds and bird habitat assessment used a habitat-based approach. As discussed in Section 20.4.2.3.1.1 of the DAR, the habitat-based approach considered waterbird, waterfowl, and shorebird habitats required throughout the year including during the breeding and migration seasons. The habitat-based approach included potential effects on the Middle Mackenzie River Islands Important Bird Area as well as incorporation of important stopover/staging areas using Traditional Knowledge and information from the Sahtú Land Use Plan (see Section 20.2.2.1 of the DAR).

No spring and fall bird migration studies are planned. The GNWT considers the habitat-based approach together with Traditional Knowledge sufficient to support the DAR and conclusions related to migratory birds including Arctic migrants.

The GNWT acknowledges the uncertainties associated with potential direct and indirect effects of climate change on bird distribution and abundance, which are discussed in Section 20.7.2 of the DAR. A discussion of predicted future conditions related to the potential effects of climate change on birds and bird habitat including species at risk was also provided in the GNWT's response to Mackenzie Valley Environmental Impact Review Board (MVEIRB) Information Request (IR) #2.

Topic: ECCC-09: Data on Migratory Birds and the Reliance on Modelling and ARUs for the Majority of Data

Reviewer Preamble:

Autonomous Recording Units (ARUs) are useful tools for making inferences about densities of territorial singing birds (i.e. most landbirds), but are less effective to identify abundance of semi-colonial birds (e.g. waterfowl) and quieter birds (e.g. shorebirds, which use sound differently than landbirds).

The Proponent draws conclusions on the potential effects of this Project on all migratory birds based mainly on the following data sources:

- BAM (Boreal Avian Modelling project; largely derived from data collected in southern Canada),
- eBird model predictions (largely derived from data collected in southern Canada),
- 2004 and 2006 ECCC- Canadian Wildlife Service (CWS) point-count surveys (Wrigley, Norman Wells and north of Tulita collection sites),
- 2017 ECCC-CWS ARU data (collection sites along winter road between Wrigley and north of Tulita), and
- 2022 Proponent ARU data collected specifically for this Project (collection sites along winter road between Wrigley and north of Tulita).

The proposed Project's study area has limited, or no data presented for waterfowl and shorebirds.

Reviewer Request:
ECCC requests the Proponent:

- Provide the rationale for reliance on ARU data and desktop modelling (BAM, eBird) for the Developers Assessment Report's (DAR) conclusions on migratory birds, particularly on how the use of southern population data can or cannot be used to derive conclusions for northern populations.
- Provide a discussion on how impacts to non-landbird species (such as waterfowl and shorebirds) are considered, given the known limitations of ARU data.
- Comment on the limitations of the data used and the conclusions drawn from it. Explain the implications to non-landbird species groups that do not have recent human observer surveys of bird abundance (point counts, aerial survey, area-based or transect ground searches, etc.). Provide specific information on waterfowl and shorebirds, including populations and seasonal densities, and describe potential Project effects to these migratory birds and how these effects will be mitigated.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) recognizes that autonomous recording units (ARUs) are not an effective method for surveying waterfowl and shorebirds. The Developer's Assessment Report (DAR) included a variety of information and data sources to describe baseline conditions for waterfowl and shorebirds and inform the assessment including the sources listed above as well as input from United States Fish & Wildlife Service and Canadian Wildlife Service aerial waterfowl surveys, engagement input from Indigenous Governments, Indigenous Organizations, and other affected parties, and Traditional Knowledge. Breeding waterfowl population estimates based on 2011-2015 aerial survey data overlapping the Project Regional Assessment Area (RAA) are discussed in DAR Appendix 20A - Birds and Bird Habitat Technical Data Report (see Section 3.2.2.2, Table 3.3).

It should be clarified that field survey effort was focused on deploying additional ARUs in 2022 to specifically increase survey effort for targeted migratory bird species at risk (e.g., yellow rail [*Coturnicops noveboracensis]*) following consultation with Environment and Climate Change Canada - Canadian Wildlife Service.

The GNWT used the Boreal Avian Modelling (BAM) Project data as described in Appendix 20C- 2022 Avian Survey Report to provide estimates of regional breeding bird densities. To clarify, the BAM Project developed separate models for each Bird Conservation Region subunit to improve local prediction accuracy (BAM, 2020). The Project occurs in the Taiga Plains (North), Bird Conservation Region 6-1. The predicted breeding bird densities (at a 1 km resolution) used in the assessment were from the Taiga Plains (North), Bird Conservation Region 6-1 (BAM, 2020), which was considered representative of the regional assessment area for birds and bird habitat.

As discussed in the GNWT's responses to CanNor Information Request (IR) #31 (ECCC-10), and CanNor IR#32 (ECCC-11), the assessment used a habitat-based approach. The assessment addressed potential Project effects on waterbirds, including waterfowl and shorebirds (see Section 20.4.1 and 20.4.2 of the DAR and the GNWT's response to IR #36 for clarification of the term "waterbirds"). Mitigation measures to reduce potential effects of the Project on bird habitat including waterfowl and shorebirds are provided in Section 20.4.2.2 of the DAR. Mitigation measures to reduce potential effects on birds including waterfowl and shorebirds due to increased mortality risk are provided in Section 20.4.3.2 of the DAR.

The limitations of the data used are provided in Section 20.7 of the DAR, which discusses prediction confidence, assumptions, gaps and uncertainty.

References

BAM (Boreal Avian Modelling Project). 2020. BAM generalized national models documentation, Version 4.0. Available at: https://borealbirds.github.io/.

Topic: ECCC-08: Methodology Behind Proponent's 2022 Avian Survey Work

Reviewer Preamble:

ECCC-Canadian Wildlife Service (CWS) was engaged by the Proponent to provide feedback on their draft 2022 Bird Study Scope and Approach document, which was meant to better assess the potential effects of the proposed Project on migratory birds and avian Species at Risk, and propose methods to fill gaps in existing data. This document led to the creation of Appendix 20C in the Developer's Assessment Report (DAR) – the 2022 Avian Survey Report, which subsequently informed Appendix 20A – the Bird and Bird Habitat Technical Data Report. The above two reports inform the Proponent's overall assessment of potential effects on birds (Section 20 of the DAR).

ECCC provided a response letter via email on March 13, 2022 (attached .pdf) stating that ECCC-CWS could not fully support the Proponent's proposed 2022 scope of work. ECCC-CWS had differing views on the adequacy of the approach proposed in the Proponent's draft document. The topics touched on were a) Predictive modelling and the use of Boreal Avian Monitoring Project models; b) Guidance on the number of sample sites per land cover class; c) Standardized point count data to account for imperfect detection; d) Use of bird song recognizers; and e) Data sharing.

No further correspondence on this topic was received from the Proponent after ECCC-CWS advice was offered. ECCC-CWS notes that the Proponent has completed surveys in 2022 using Autonomous Recording Units (ARUs). It is unclear how ECCC-CWS advice was used.

Reviewer Request:

ECCC requests the Proponent:

- Provide detail on how the ECCC advice provided on the bird study design was incorporated into the 2022 Bird Study (Appendix 20C), including any deviations from the advice. The following topics should be covered:
    - Predictive modelling and the use of Boreal Avian Monitoring Project models;
    - Guidance on the number of sample sites per land cover class;
    - Standardized point count data to account for imperfect detection;
    - Use of bird song recognizers; and
    - Data sharing
- Provide a summary that outlines how baseline data was used to inform mitigation measures and adaptive management. Comment on the overall adequacy of the data used to develop a baseline for the Project and inform subsequent predictions on the potential effects to migratory birds in the DAR. Include the level of confidence in this data, and how representative it is of baseline conditions in the Project Development Area, Local Study Area, and Regional Study Area. Note whether there are still gaps in knowledge.
- Comment on whether existing data was used to conduct a power analysis in order to inform sample size requirements per strata (land-cover class), and whether that analysis was then acted

upon to determine sampling size and draw more accurate conclusions on the significance of impacts to migratory birds. If the power analysis was not conducted, then provide rationale for why the analysis was not completed

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) reviewed and considered the guidance provided by Environment and Climate Change Canada (ECCC) – Canadian Wildlife Service (CWS) for each issue of concern outlined above following the March 13, 2022, email. How each of those concerns were addressed in Appendix 20C of the Developer's Assessment Report (DAR) - 2022 Avian Survey Report as well as the adequacy of baseline data to support the assessment, including proposed mitigation measures, are described below.

Predictive Modelling and the Use of Boreal Avian Monitoring (BAM) Project Models

The GNWT acknowledges the disparity of views related to the utility of developing species-specific distribution models to predict breeding bird densities. The GNWT contends that the effort level required to develop species-specific models does not provide sufficient incremental benefit to inform the assessment, or to change proposed mitigation measures to reduce potential effects of the Project on species at risk (SAR) migratory bird habitat or mortality risk.

Previous efforts that have developed species-specific models for all-season road projects in the NWT as per ECCC-CWS recommendations have concluded the results have low predictive power due to the large variation (i.e., large confidence intervals) in predicted mean density associated with each species (Tetra Tech, 2021). Furthermore, the predicted mean densities within local and regional study areas overlapped, which limited their utility to inform potential project effects (i.e., adverse residual effects on change in habitat). Developing species-specific models to predict breeding bird densities may also have marginal value for SAR that typically occur at lower densities. For example, predicted mean breeding bird densities estimated for the Tłı̨chǫ All-Season Road Project indicated models were only possible for species with sufficient sample size, which was limited to 11 common bird species (Golder, 2019). This study also concluded that modelling results did not change the already recommended mitigation measures to protect migratory birds.

Overall, the BAM data (which included the 53 ECCC-deployed autonomous recording units [ARUs] from 2017) was deemed sufficient by the GNWT to support the assessment, by providing predicted mean breeding bird densities, developed using ECCC's preferred modelling approach. Based on the recent assessments for road developments in the NWT which have reported marginal benefits of modeling species-specific breeding bird density (Golder, 2019; Tetra Tech, 2021), the GNWT contends that further field studies or development of species-specific models to add confidence to the assessment is likely not warranted. However, the GNWT is willing to discuss how any additional ARU data collected by ECCC-CWS since the filing of the DAR could be used to inform the assessment (e.g., help validate species-specific habitat associations focusing on SAR [e.g., yellow rail] and/or contribute to mitigation measures to be included in the Wildlife Management and Monitoring Plan [WMMP]).

Guidance on the Number of Sample Sites per Land Cover Class

Initial guidance provided by ECCC-CWS to the GNWT regarding the recommended number of ARUs to be deployed in each land cover class, was approximately 10 ARUs per land cover class (habitat type) (Haché et al., 2018). The GNWT agrees with ECCC-CWS that a minimum of 10 samples per land cover class would not be sufficient to develop adequate precision for most species density and distribution estimates. Though the GNWT maintains that there is little value in collecting additional data to model densities for SAR, a power analysis using the existing data has been provided below to address ECCC's request.

Power Analysis

The GNWT completed additional surveys following recommendations by ECCC to fill a data gap for SAR most likely to interact with the Project that were not effectively captured in the 2017 ARU surveys or in other relevant data sources. As such, an additional 23 ARUs were deployed in the Local Assessment Area (LAA) during 2022 to increase sampling effort in potential yellow rail habitat (n= 3 sites), in under-represented land cover classes and relative to ecoregion as recommended in ECCC guidelines (Haché et al., 2018) (Appendix 20C).

A retrospective power analysis was completed for the ARU survey sampling effort, which included the 2017 ARU data (n=53) and the additional 23 ARUs deployed during 2022 to calculate the power of the combined survey effort (n=76). Significance level (alpha) was set at 0.1. A second power analysis was completed to determine the number of survey stations required to achieve adequate power (e.g., 80%) at both small (d=0.2) and moderate (d=0.4) standardized effect sizes based on Cohen's d (Cohen, 1988). All analyses were completed using the *pwr.t.test* package in R to test for differences between two means (R Core Team, 2022).

A power analysis of the 2017 and 2022 ARU combined survey efforts indicated that the number of ARUs deployed in each land cover class would only detect relatively large differences (effect size) between two samples across all land cover types assuming 80% power and a significance level of 0.1 (Table 29-1). Although coniferous forest had the most ARUs deployed (n=25), that sample size still had low power (16%) to detect a small effect size (see Figure 29-1). As such, an increase in the number of ARUs deployed in each land cover class would be required to improve (reduce) the effect size and increase the power to detect changes in mean abundance.

Table 29-1. Power Analysis of 2017 and 2022 (Combined) ARU Survey Effort by Land Cover Class

Land Cover Class	**Total ARU Sample size (n)**	**Power (1-β)**	**Significance Level**	**Effect Size[1]**	**Effect size category**
Broadleaf Forest	7	0.80	0.1	1.4	Large
Coniferous Forest	25	0.80	0.1	0.7	Large
Mixedwood Forest	12	0.80	0.1	1.1	Large
Shrubland	12	0.80	0.1	1.1	Large
Herbaceous & Unvegetated	4	0.80	0.1	2.0	Large
Wetland	15	0.80	0.1	0.9	Large
Water	1	N/A	N/A	N/A	N/A
Total	**76**				

Notes:
[1] Effect Size based on Cohen's d:
< 0.1 = trivial effect
0.1 - 0.3 = small effect
0.3 - 0.5 = moderate effect
> 0.5 = large difference effect
N/A = Not Applicable (analysis not run on sample size n=1)

The second power analysis indicated that over 300 ARUs would be required to achieve 80% power to detect a small effect size (0.2) within each group (land cover class). Although fewer ARUs would be required to achieve 80% power at a moderate effect size (0.4), the number of ARUs is still relatively large (>75 for each land cover class) (Figure 29-1).

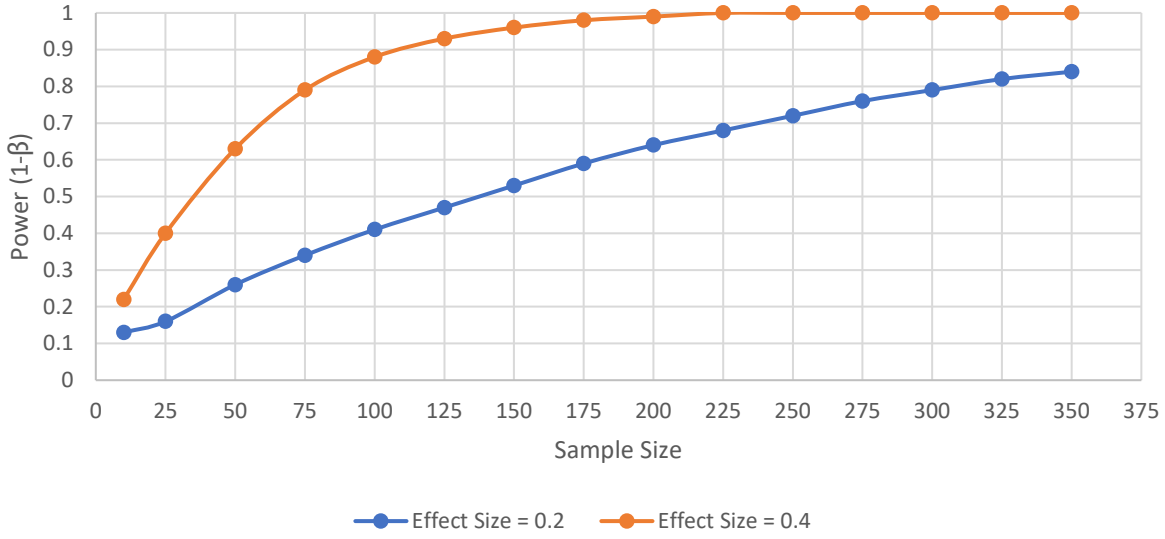


Figure 29-1. The effect of sample size on statistical power to detect small (0.2) and moderate (0.4) effect sizes (difference between means). Sample sizes are per group. Alpha = 0.1.

Overall, the results of the power analyses suggest the ARU survey data from 2017 and 2022 had low power to detect both small and moderate effect sizes. Increasing sample size to achieve 80% power within each land cover class would require over 300 ARUs to be deployed, which is not reasonable, given the remote setting of the Project.

The habitat-based approach used in the assessment is considered sufficient to assess potential effects of the Project on birds and bird habitat. The low power of the ARU survey does not affect the conclusions of the assessment. The quantity and quality of baseline data available were factors considered in prediction confidence and uncertainty to assess the determination of significance, which is discussed in Section 20.7 of the DAR.

Standardized Point Count Data to Account for Imperfect Detection

The GNWT acknowledges that correcting bird count data for imperfect detection can potentially reduce bias associated with species abundance estimates used for the ECCC-CWS preferred modelling approach. However, correcting for imperfect detection does not necessarily improve model predictions for all species, especially for relatively common species (e.g., habitat generalists) where probability of detection can be relatively homogeneous across habitat types (Rota et al. 2011).

As discussed in Appendix 20C, the following five bird species were most frequently detected in the LAA during the ARU surveys completed in 2017 and 2022: Swainson's thrush (*Catharus ustulatus*), hermit thrush (*Catharus guttatus*), white-throated sparrow (*Zonotrichia albicollis*), America robin (*Turdus migratorius*) and dark-eyed junco (*Junco hyemalis*). Two SAR were detected, including olive-sided

flycatcher (*Contopus cooperi*) and common nighthawk (*Chordeiles minor*). Other SAR with the potential to occur in the LAA, including yellow rail (*Coturnicops noveboracensis*), Canada warbler (*Cardellina canadensis*), and rusty blackbird (*Euphagus carolinus*) were not detected. Therefore, similar to other projects, species distribution modelling using standardized point count data, would likely be limited to relatively common species, which would provide limited value for the assessment, which focused on SAR.

Use of Bird Song Recognizers

As discussed in Appendix 20C, Section 2.2.1, the audio recordings of SAR followed ECCC guidance (Haché et al., 2018) where all recordings were examined using automated computer software to target SAR of interest, including common nighthawk, yellow rail, olive-sided flycatcher, Canada warbler, and rusty blackbird. Audio files were analyzed using Kaleidoscope Pro 5.4.8 (Wildlife Acoustics, 2021) cluster analysis, which identifies and groups similar acoustic patterns (i.e., bird vocalizations) using custom classifiers. Advanced classifiers were developed using reference vocalizations for each species and an acceptance threshold of 2.0 maximum distance from cluster centre was used to include all detected vocalizations in the analysis. All other settings were set to the manufacturer's defaults. The vocalization with the lowest distance to each classifier's cluster centre was manually classified by a qualified biologist using Kaleidoscope Pro's Viewer software to confirm species detection / non-detection. A total of 23 clusters were analyzed per ARU, totaling 621 manually identified files.

Mitigation Measures and Adequacy of Data

The GNWT contends the habitat-based approach is sufficient to support the assessment of effects of the Project on migratory birds, including SAR. The habitat-based approach is considered conservative as it assumes birds are present, which might overestimate effects due to direct habitat loss. For example, although common nighthawk and olive-sided flycatcher were detected during the 2022 ARU survey, yellow rail, Canada warbler and rusty blackbird were not detected (Appendix 20C), yet they were assumed present using a habitat-based approach and assessed for effects from direct habitat loss, as discussed in Section 20.4.2.3.1.5 of the DAR (see Table 20.12).

Overall, the proposed mitigation measures described in Section 20.4.2.2 and Section 20.4.3.2 of the DAR are considered adequate to reduce potential effects on change in bird habitat and mortality risk, respectively. Key mitigation measures include the following:

- Routing and design, which integrates the existing Mackenzie Valley Winter Road to the extent practicable, which will reduce change in habitat.
- Vegetation clearing will be completed outside the migratory bird nesting period (May-August).
- Wildlife monitors will assess for the presence of wildlife on or near the Project Development Area during Project construction activities.
- The Wildlife Management and Monitoring Plan will outline how risks to migratory birds will be managed in accordance with ECCC's Guidelines to Reduce Risk to Migratory Birds (ECCC, 2021) if activities that could result in risk of harm cannot be avoided (e.g., pre-clearing nest sweeps).
- If an active bird nest is found, beneficial management practices (GNWT, 2020) will be followed, including applying an appropriate setback and timing restriction and the GNWT-ECC and/or ECCC will be consulted, as appropriate.

Data sharing

The GNWT will provide the ARU data collected during the 2022 survey to ECCC-CWS, as requested.

References

Cohen, J. 1988. Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Golder (Golder Associates Ltd). 2019. Tłı̨chǫ All-Season Road Project 2019 Migratory Bird Baseline Study.

Haché, S., R. Pankratz, and J-F. Dufour. 2018. Recommendations on the use of autonomous recording units (ARUs) technology to meet baseline data requirements in environmental assessments in the Northwest Territories (DRAFT). Canadian Wildlife Service and Environment and Climate Change Canada, Yellowknife, NT.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rota C.T., R.J. Fletcher, J.M. Evans, and R.L. Hutto. 2011. Does accounting for imperfect detection improve species distribution models? Ecography 34: 659–670.

Tetra Tech. 2021. Prairie Creek Mine All-Season Road: Birds Baseline. Consultant report prepared for Canadian Zinc Corporation.

Wildlife Acoustics. 2021. Kaleidoscope pro 5 user guide. Available at: https://www.wildlifeacoustics.com/uploads/user-guides/Kaleidoscope-Pro-User-Guide.pdf. Accessed November 2022.

Topic: ECCC-07: Project- Specific Baseline Information Studies Caribou Current Use of Habitat/Biophysical Attributes

Reviewer Preamble:

The Developer's Assessment Report (DAR) indicates that the assessment of effects on caribou is based on existing habitat information which has been collected over a variety of years, areas and scales, and no additional Project-specific baseline information studies were conducted to validate that the available data is representative of current conditions on-the-ground.

Collar data provided in the DAR spans a wide range of years and, along with land cover type, has been used to develop Technical Data Report – Caribou and Moose Figure 3.2, "Predicted All-Year Habitat Selection by Boreal Caribou" model and map. The Predicted All-Year Habitat Selection Map captures data from 2003-2023. The Proponent has not conducted baseline studies to validate whether the habitat and movement data used to create this map represent current conditions.

Clarity on the current use of habitat/biophysical attributes is needed to understand how caribou are currently using the Local Assessment Area (LAA). Maps which show the land cover type could help reviewers better visualize current land use. Further, the Resource Selection Function (RSF) model referenced in the DAR is used as the basis for habitat loss calculations; the RSF study (ENR, 2020a), is unavailable for review, and if provided could shed some light on how the Proponent has made the reported calculations.

Reviewer Request:

ECCC request the Proponent provide:

1. further justification as to how the existing habitat information is adequate without the need for additional Project-specific baseline data for caribou;
2. the seasonal and all-year habitat RSF study (ENR, 2020a; unpublished) for review; and
3. mapping of land cover type that illustrates and identifies biophysical attributes of boreal caribou habitat

Response from the Government of the Northwest Territories:

1. The assessment of caribou biophysical attributes relied on the outputs of DeMars et al. (2020). The authors conducted a study to assess the biophysical attributes disproportionally used by boreal caribou (i.e., selected habitat) during several seasonal periods, including year-round (all seasons), calving, and late winter. DeMars et al. (2020) used available GPS collar data from boreal caribou in the Sahtu and Dehcho regions of the NT1 range, including from animals located near the Project. Given the comprehensive nature of this study, both in space and time, the Government of Northwest Territories (GNWT) believes the habitat information and maps produced as part of the study are sufficient for caribou baseline data.

2. ENR (2020a; unpublished) refers to unpublished data for the boreal caribou resource selection function maps in the NWT. The data are derived from the outputs by DeMars et al. (2020), which is the primary technical report requested by the reviewer. The report is accessible on the Mackenzie Valley Environmental Impact Review Board (MVEIRB) public registry: https://reviewboard.ca/upload/project_document/Comment-06-Boreal-Caribou-Report-2020-zdn74.pdf

3. Maps of selected habitat (i.e., the combination of biophysical attributes disproportionally used by boreal caribou) are provided for year-round (all seasons), calving, and late winter in the GNWT's response to MVEIRB Information Request (IR) #60. To better interpret these maps, refer to DeMars et al. (2020), including Figures 17 and G 8 in that report, and the GNWT's response to CanNor IR#26.

References

DeMars, C., Hodson, J., Kelly, A., Lamontagne, E., Smith, L., Groenewegen, K., Davidson, T., Behrens, S., Cluff, D., and Gurarie, E. 2020. Influence of Land Cover, Fire and Human Disturbance on Habitat Selection by Boreal Caribou in the NWT. Project 202 of the Government of the Northwest Territories Department of Environment and Natural Resources, Northwest Territories Cumulative Impact Monitoring Program. 70 + 159 app pp.

ENR (Environment and Natural Resources). 2020a. Unpublished Data. All-year predictive resource selection function maps for boreal caribou within the NWT. NWT Wildlife Management Information System. Government of the NWT, Yellowknife, NT.

Topic: ECCC-06: Ground-Truthing of Disturbed and Undisturbed Caribou Habitat in NT1 Range

Reviewer Preamble:

The proposed project overlaps the Northwest Territories Range (NT1) as described in Environment and Climate Change Canada's "Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada" posted on the Species at Risk Public Registry. The Federal Recovery Strategy identifies the amount of habitat disturbance within a boreal caribou range as a key factor determining whether a local population is likely to be self-sustaining over time. The recovery strategy specifies that each responsible jurisdiction manage the habitat disturbance within a range to achieve or maintain a self-sustaining local population through a range plan. The recovery strategy also indicates that maintaining connectivity of boreal caribou habitat between and within ranges is essential for boreal caribou persistence on the landscape.

Several of the potential impacts of the proposed Project have been identified as threats to boreal caribou, as described in the amended (2020) Federal Recovery Strategy. On page 37 of the recovery strategy, it states that, "In ranges with undisturbed habitat equal to or above the threshold, critical habitat is at least 65% undisturbed habitat in a range". At this time, and until the publication of all five finalized regional range plans identifying where that minimum 65% undisturbed habitat is protected, the guiding principle from the recovery strategy is that all undisturbed habitat should be considered critical habitat (habitat necessary for the survival and recovery of the species).

In the Developer's Assessment Report (DAR), Table 10.18 shows existing disturbance and Project contribution in NT1 Boreal Caribou Range, affected range planning regions (Sahtu and southern NWT) and the Caribou and Moose LAA. Table 10.18 presents the amount of disturbed habitat in the entire NT1 range assessed as 27.95% (or ~72% undisturbed total). This is inconsistent with the amended Federal Recovery Strategy (2020) and the Report on the Progress of the Recovery Strategy Implementation (2024), which indicates that NT1 is 35% disturbed (25% being fire and 9% being anthropogenic) with 65% of the range undisturbed habitat. These values were updated in the 2024 Federal Recovery Strategy Progress Report to 30% disturbed (22% fire, 10% anthropogenic). The Proponent states that the disturbance-based approach used to calculate boreal caribou habitat disturbance is based on data from fires ≤ 40 years old (1982-2021) and anthropogenic disturbances (circa 2015, Table 10.18) plus a 500 m buffer. While the calculation is consistent with the recovery strategy, ECCC notes that the human disturbance layer is dated 2015 and likely does not represent the current on-the-ground human disturbance.

Additional information is required in order to validate the Proponent's effects assessment.

Reviewer Request:

ECCC requests the Proponent:

1. Calculate and provide (1) affected area (in ha) of undisturbed habitat, and (2) affected area of existing habitat, using the following standardized equations as derived from the Federal Recovery Strategy:

    a) Effects on undisturbed habitat = (proposed Project footprint + 500 m buffer) - overlapping area(s) already considered disturbed habitat (see Recovery Strategy Glossary for definition)

b) (2) Effects on existing habitat = (proposed Project footprint + 500 m buffer) - overlapping (permanent alterations(s) + 500 m buffer).

2. Provide maps in order to outline the features calculated in above request in a).

3. Describe the level of confidence in the data used to develop conclusions on the effects to boreal caribou individuals and critical habitat.

4. Clarify whether changes to landcover as a result of the 2023 forest fires are reflected in Table 10.18. If the values do not account for this change to the landcover, then explain and provide a rationale for why this information is not relevant when assessing impacts to caribou critical habitat.

5. Clarify the date of "Human disturbance" Geographic Information System (GIS) data-layer used. If data used is circa 2015 (or earlier), then provide rationale to the use of this data, including how it reflects current land use.

6. Clarify whether the data used to conduct the Proponent's effects assessment (including human disturbance, fire, and landcover data) have been, or will be, ground-truthed and provide rationale for this decision.

7. Provide a revised estimate of human disturbance based on current best available data.

8. Revise Table 10.18, as appropriate, taking into consideration the revised estimate of human disturbance based on current best available data from request g).

9. Provide the same calculations outlined in point a) for the NWT range planning regions of the Sahtu and Southern NWT

Response from the Government of the Northwest Territories:

1. **a)** Calculations of the Project's effect on caribou critical habitat using Environment and Climate Change Canada (ECCC)'s definitions of disturbed habitat (i.e., human disturbance + 500 metre [m] buffer, fire disturbance <40 years old) are provided in the Government of Northwest Territories (GNWT)'s response to Mackenzie Valley Environmental Impact Review Board (MVEIRB) Information Request (IR) #52. Calculations are provided for the NT1 Boreal Caribou Range, Sahtu and Southern NWT Range Planning Regions, and the Caribou and Moose Local Assessment Area (LAA). The calculation that the reviewer is requesting corresponds to the column 'New Disturbance Area (ha)' indicating the additional disturbance on the landscape attributable to the Project.

   b) The ECCC disturbance database for the Northwest Territories (https://open.canada.ca/data/en/dataset/63e1cda6-debe-4b9b-b075-3666443e30b4) does not include an attribute for "permanent alterations."

2. Figure CanNor 27-1 included in the GNWT's response to IR CanNor#27 (ECCC-06) demonstrates the overlap between the Project footprint (Project Development Area), plus 500 m buffer, and existing disturbances (i.e., [2020] human disturbance + 500 m buffer and [2023] wildfire disturbance <40 years old).

3. There is a moderate to high level of confidence. The key sources used in the assessment include:

   a. ECCC's 2020 human disturbance layer (https://open.canada.ca/data/en/dataset/63e1cda6-debe-4b9b-b075-3666443e30b4) (used to update DAR Table 10.18 in the GNWT's response to MVEIRB IR#52)

   b. GNWT's 2023 fire disturbance layer (GNWT-ECC, 2024) (used to update DAR Table 10.18 in the GNWT's response to MVEIRB IR#52)

   c. The resource selection function (RSF) habitat model was created within NT1, using caribou collar data and habitat variables within the area of interest (DeMars et al., 2020).

   The first two layers (human disturbance and fire) are key indicators of range conditions that support self-sustaining populations (ECCC, 2011). The third layer (selected habitat within NT1 defined by an RSF modelling process) is specific to habitat conditions in the NT1 range. All data are specific to the conditions found in the Caribou and Moose LAA and relevant to those in the broader NT1 range. There is moderate to high confidence in those data used to characterize boreal caribou habitat conditions in the Caribou and Moose LAA and the broader NT1 range.

   However, the interpretation of the disturbance as noted in the RSF model paper (DeMars et al., 2020), includes some questions, for example, about categorizing fires <40 years old as outright disturbance, and about the functional habitat loss associated with linear disturbance. It is noted that the findings of ECCC (2011) may not be equivalent to caribou response to disturbance conditions in NT1. Therefore, while the data quality is good, there are some outstanding questions about its applicability throughout NT1. Regardless, the data used in the assessment are the best available data, developed within and directly relevant to assessing the effects of the Project within the Caribou and Moose LAA, planning regions, and NT1.

Section 10.7 of the Developer's Assessment Report (DAR) (Prediction Confidence) identifies the assumptions, limitations, data gaps and uncertainties with the assessment and the data involved. To reduce uncertainty, the assessment conservatively identified the requirement for various follow-up and monitoring programs (DAR Section 10.8).

4. Changes to land cover resulting from 2023 forest fires are not reflected in Table 10.18 of the DAR. However, these changes are reflected based on updated data in the GNWT's response to MVEIRB IR#52 (see above). Additionally, an accounting of the land cover classes (biophysical attributes) is available in the GNWT's response to CanNor IR#26 (ECCC-05).

5. The date of human disturbance used in Table 10.18 of the DAR was *circa* 2015. However, ECCC's 2020 human disturbance layer was used in the GNWT's response to MVEIRB IR#52 (see above).

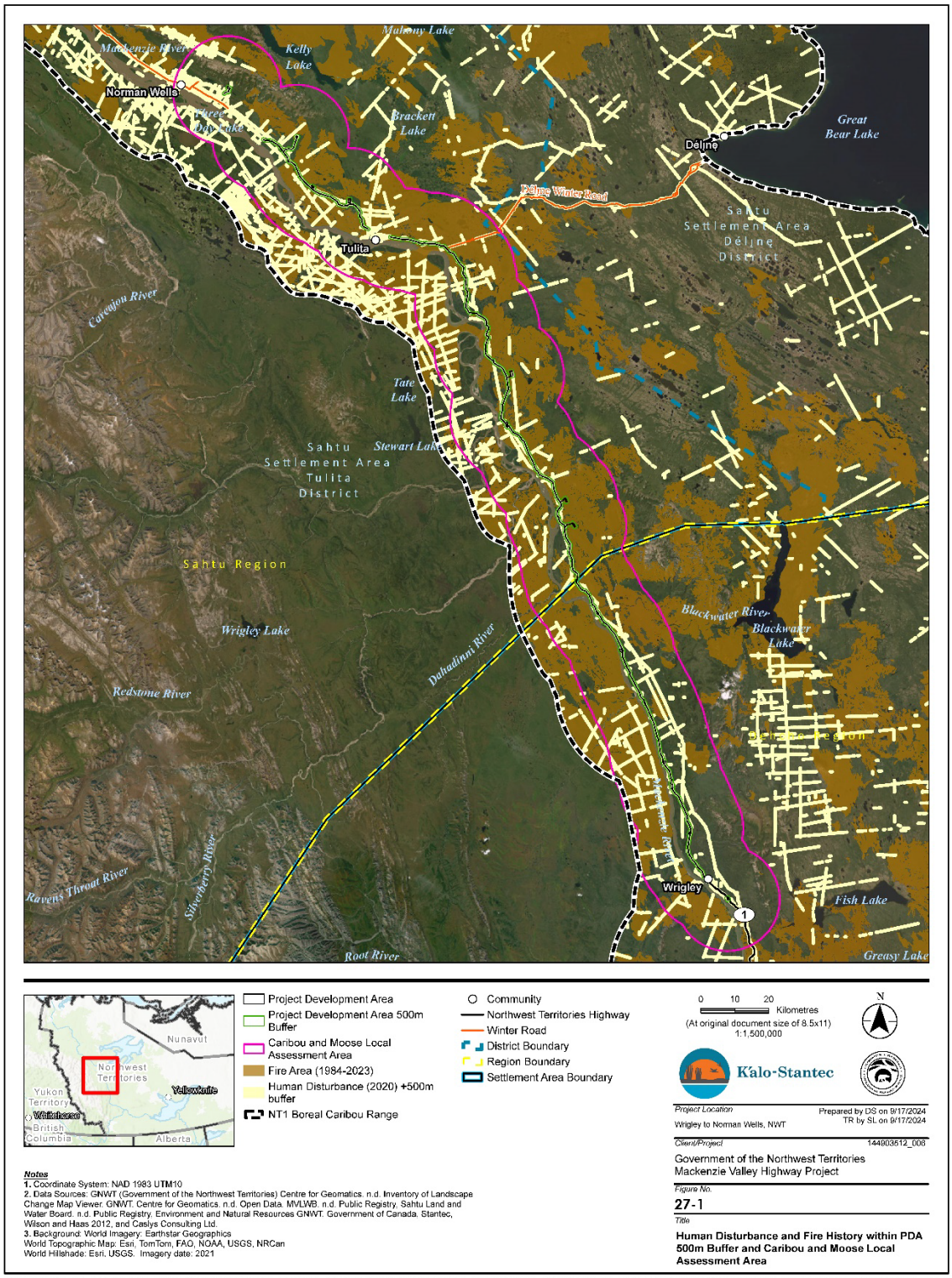
6. The data used to conduct the effects assessment were based on human and wildfire disturbance maps derived from the interpretation of satellite imagery. ECCC's human disturbance layer is based on the interpretation and digitization of human disturbance features visible on Landsat imagery viewed at a scale of 1:50,000 (see https://open.canada.ca/data/en/dataset/63e1cda6-debe-4b9b-b075-3666443e30b4 for more information). Metadata on quality assurance on the human disturbance layer describes the quality review process. The GNWT Department of Environment and Climate Change (ECC) has done some ground-truthing of linear disturbance features mapped by ECCC in the South Slave and Dehcho regions (south of Wrigley) as part of a project funded by the federal Habitat Stewardship Program for Species at Risk and 2 Billion Trees program. This ground-truthing work aims to identify the regeneration status of linear features and locations where habitat restoration may be appropriate. This program could be expanded to include the MVH corridor in future years. Wildfire disturbance was measured using the National Burn Area Composite (NBAC) data available from Natural Resources Canada, which is compiled from data provided by Natural Resource Canada and Provincial, Territorial and Parks Canada agencies. A rule-based decision process is used to select the best data source for each fire event based on factors such as how well the burn polygon follows the shape of the fire as observed on post-burn satellite imagery, the data source itself, and what methods were used to delineate the burn (NRCan, 2024). The procedures and quality assurance processes for deriving the NBAC data are further described in Skakun et al. (2022). While the GNWT does fly some fire perimeters during each wildfire season, and sometimes those perimeters are accurate enough not to require being re-mapped with remote sensing, the vast majority of GNWT's end-of-season fire perimeters are derived from remote sensing (M. Coyle, GNWT-ECC, pers. comm.). The GNWT relies on ECCC to assure the quality of its own published data.

7. A revised estimate of human disturbance using ECCC's 2020 human disturbance layer was provided in the GNWT's response to MVEIRB IR#52 (see above).

8. The outputs in Table 10.18 of the DAR have been revised in the GNWT's response to MVEIRB IR#52. The data to update those values include ECCC's 2020 human disturbance layer and GNWT's 2023 fire disturbance layer (see above).

9. The GNWT's response to MVEIRB IR#52 includes the same Sahtu and Southern NWT Range Planning Regions calculations.

Figure CanNor 27-1. Overlap between the Project footprint (plus a 500 m buffer) and existing disturbed areas in the Caribou and Moose Local Assessment Area.



References

Coyle, M. 2024. GNWT-ECC Forest Management Division personal communication to J. Hodson, Biologist, GNWT-ECC.

DeMars, C., Hodson, J., Kelly, A., Lamontagne, E., Smith, L., Groenewegen, K., Davidson, T., Behrens, S., Cluff, D., and Gurarie, E. 2020. Influence of Land Cover, Fire and Human Disturbance on Habitat Selection by Boreal Caribou in the NWT. Project 202 of the Government of the Northwest Territories Department of Environment and Natural Resources, Northwest Territories Cumulative Impact Monitoring Program. 70 + 159 app pp.

Environment Canada (ECCC). 2011. Scientific Assessment to Inform the Identification of Critical Habitat for Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada. 2011 Update. Canadian Wildlife Service, Ottawa, Ontario. 102 pp. (http://epe.lac-bac.gc.ca/100/200/301/environment_can/2011/scientific_assessment_inform-ef/CW66-296-2011-eng.pdf)

Environment and Climate Change Canada. 2020. Amended Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada. *Species at Risk Act* Recovery Strategy Series. Environment and Climate Change Canada. 143 pp. (http://publications.gc.ca/collections/collection_2021/eccc/En3-4-140-2020-eng.pdf)

GNWT-ECC. 2024. Fire History (NBAC/CNFDB) - NT1 Range. Compiled and edited by J.Hodson and R.Abernethy, Wildlife Division, ECC, GNWT. Data Source: Natural Resources Canada (NRCan) (https://www.geomatics.gov.nt.ca/en/fire-history)

Natural Resources Canada (NRCan). 2024. Metadata for the National Burn Area Composite (NBAC) data. (https://cwfis.cfs.nrcan.gc.ca/downloads/nbac/nbac_1972_2023_20240530_shp_metadata.pdf)

Skakun, R.; Castilla, G.; Metsaranta, J.; Whitman, E.; Rodrigue, S.; Little, J.; Groenewegen, K.; Coyle, M. 2022. Extending the National Burned Area Composite Time Series of Wildfires in Canada. Remote Sens. **2022**, 14, 3050. https://doi.org/10.3390/rs14133050

Topic: ECCC-05: Loss of Biophysical Attributes- Caribou Habitat

Reviewer Preamble:

The Proponent states that the Project Development Area (PDA) will result in direct general habitat loss of 2,315.2 ha, and of that, 94.3 ha are considered selected boreal caribou habitat, and indirect selected habitat disturbance of 1,466 ha. The Proponent has estimated the total combined caribou habitat loss as 1,560.0 ha (94.3 ha direct and 1,466 ha indirect loss).

The Federal Recovery Strategy (pg. 38) describes biophysical attributes as "… the habitat characteristics required by Boreal Caribou to carry out life processes necessary for survival and recovery." Biophysical attributes are also described as a major component of critical habitat in the NT1 range, therefore it is important to understand the types and amounts of biophysical attributes lost as a result of the proposed Project.

The Proponent uses the term 'general' and 'selected' habitat but does not provide a definition of these terms.

Reviewer Request:

ECCC requests the Proponent:

1. Define 'general' and 'selected' habitat. Discuss how the definition aligns with the Federal Recovery Strategy (Section 3.3, Glossary, and Table H-1).
2. Clarify what type of biophysical attributes are present within the 2,315.2 ha that will be lost.
3. Discuss the unique nature of biophysical attributes present in the 94.3 ha that is anticipated to be lost.
4. Clarify what type of biophysical attributes are present within the 1,466 ha that is anticipated to be disturbed.
5. Provide a map in order to illustrate where biophysical attributes are anticipated to be lost along the proposed Project.

Response from the Government of the Northwest Territories:

1. The term 'general' habitat refers to the first component of critical habitat as defined in the Federal Recovery Strategy (ECCC, 2020):

> "*… the area within the boundary of each boreal caribou range that provides an overall ecological condition that will allow for an ongoing recruitment and retirement cycle of habitat, which maintains a perpetual state of a minimum of 65% of the area as undisturbed habitat*".

In the Developer's Assessment Report (DAR) Section 10.4.2 (*Change in Habitat*), this corresponds to the total area disturbed by the Project Development Area (PDA). Calculations of total disturbed area that incorporate existing disturbances (i.e., human disturbances plus 500 metre [m] buffers and wildfires <40 years old) are quantified and presented in DAR Table 10.18. These calculations were updated using the most recent available data on human disturbances (2020) and wildfires (2023) and are provided in the Government of Northwest Territories (GNWT)'s response to Mackenzie Valley Environmental Impact Review Board (MVEIRB) Information Request (IR) #52.

The term 'selected' habitat refers to the second component of critical habitat as defined in the Federal Recovery Strategy (ECCC, 2020):

> "*… biophysical attributes required by boreal caribou to carry out life processes*".

As stated on page 78 of the Federal Recovery Strategy:

> "*… biophysical attributes will vary both between and within boreal caribou ranges. As the biophysical attributes presented in this recovery strategy were developed at a national scale by ecozone and ecoregion, and not by local population, it is anticipated that each provincial and territorial jurisdiction may have or will develop over time, a more refined description of the biophysical attributes required for each range*".

DeMars et al. (2020) quantified the biophysical attributes disproportionately used by boreal caribou (i.e., 'selected' habitat) in Sahtu and Dehcho regions of the NT1 range. Thus, the 'selected' habitat model outputs by DeMars et al. (2020) best reflect the biophysical requirements of boreal caribou in that range and should be used over the general requirements presented in the Federal Recovery Strategy. Updated calculations of direct and indirect effects to 'selected' habitat year-round (all seasons) and during calving and late winter seasons are provided in the GNWT's responses to MVEIRB IR #47 and #52.

2., 3. and 4.

The biophysical attributes selected for and avoided in all year habitat is illustrated in Figure 17 (Second Order) in DeMars et al (2020). Appendix G, Figure G-8 of DeMars et al (2020) illustrates the local contribution of local land-cover variables to mapped bin values of resource selection at a second-order scale across the entire year. Table 26-1 quantifies the amount of general and selected habitat directly and indirectly affected by the Project. In response to Part 3 of the IR, there appears to nothing particularly unique about the area of selected habitat affected by the PDA. The total values are slightly different than those noted in the reviewer comments because they are based on differing geographic projections used for area calculations.

Table 26-1. Summary of biophysical attributes of general and year-round selected boreal caribou habitat directly and indirectly affected by the Project.

Landcover type[1]	Direct Loss (PDA) of Habitat (ha)		Indirect Effect[2] on Habitat (ha)	
	General	Selected[3]	General	Selected
Broadleaf Dense	11.6		294.5	0.6
Broadleaf Open	19.1		274.4	0.7
Bryoids	0.1		1.2	
Conifer Dense	57.4	1.5	1,848.3	21.6
Conifer Open	223.7	45.8	4,108.4	632.8
Conifer Sparse	75.7	18.0	2,332.6	224.9
Herb Wetland	40.4	6.2	751.1	111.2
Lowland Burn 1-10 years old	1.6		191.8	
Lowland Burn 11-20 years old	17.4		341.0	0.0
Lowland Burn 21-30 years old	205.7		5,236.5	0.3
Lowland Burn 31-40 years old	13.8	0.6	402.4	16.2
Lowland Burn 41-60 years old	21.5		783.1	
Mixedwood Dense	20.0	0.6	546.1	12.4
Mixedwood Open	17.3	0.9	497.8	14.8
Non-Treed Burn 1-10 years old	0.1		4.9	
Non-Treed Burn 11-20 years old	40.6		1,103.2	
Non-Treed Burn 21-30 years old	134.2		3,106.6	0.1
Non-Treed Burn 31-40 years old	4.6	0.5	109.2	1.7
Non-Treed Burn 41-60 years old	4.4		193.3	
Short Shrub	15.0	1.9	301.0	34.5
Shrub Wetland	45.8	1.7	925.1	26.7
Tall Shrub	12.5		182.4	3.9
Treed Wetland	65.0	13.9	1,616.0	312.9
Upland Broadleaf Burn 1-10 years old	0.3		3.4	
Upland Broadleaf Burn 11-20 years old	109.2		1.2	
Upland Broadleaf Burn 21-30 years old	11.0		1,495.3	
Upland Broadleaf Burn 31-40 years old	11.4	0.3	232.4	18.7
Upland Broadleaf Burn 41-60 years old	1.9		401.3	
Upland Conifer Burn 1-10 years old	1.2		121.1	
Upland Conifer Burn 11-20 years old	21.7		41.9	
Upland Conifer Burn 21-30 years old	4.1		637.1	
Upland Conifer Burn 31-40 years old		0.7	128.4	10.0
Upland Conifer Burn 41-60 years old	3.6		184.0	
Water	28.3	0.9	2,418.7	19.2
Non-Vegetated	1,063.8	0.1	2,569.4	1.4
Total	**2,304.2**	**93.7**	**33,385.1**	**1,464.6**

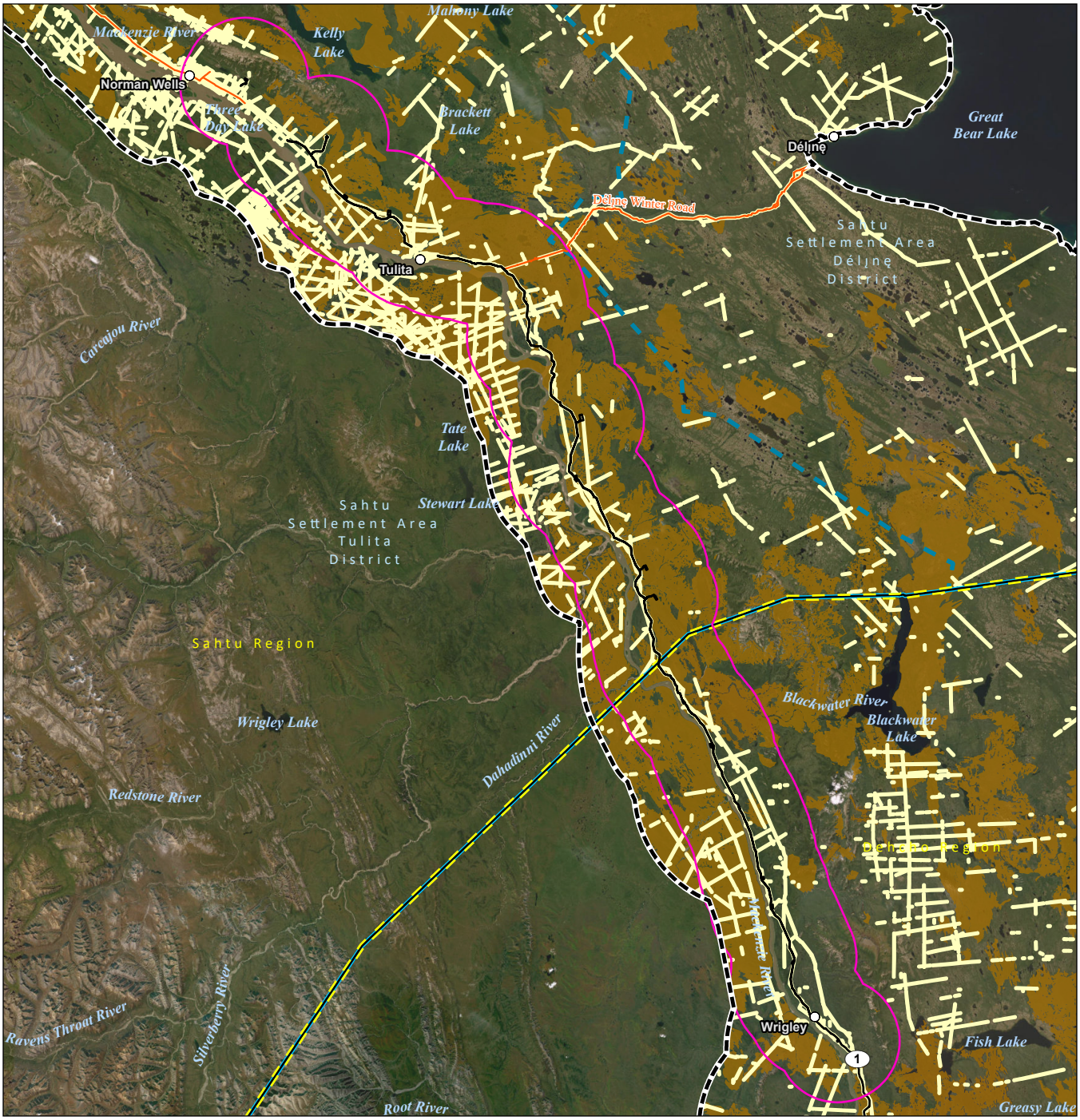
Notes:
[1] Land cover type as identified in Figure G-8 of DeMars et al 2020
[2] Selected and General Habitat within a 500 m buffer of the PDA
[3] Selected habitat are RSF bins ≥6 (DeMars et al 2020)

5. Maps of year-round (all season), calving, and late winter biophysical attributes (i.e., selected habitat) relative to the PDA are provided in the GNWT's response to MVEIRB IR #60.

References

DeMars, C., Hodson, J., Kelly, A., Lamontagne, E., Smith, L., Groenewegen, K., Davidson, T., Behrens, S., Cluff, D., and Gurarie, E. 2020. Influence of Land Cover, Fire and Human Disturbance on Habitat Selection by Boreal Caribou in the NWT. Project 202 of the Government of the Northwest Territories Department of Environment and Natural Resources, Northwest Territories Cumulative Impact Monitoring Program. 70 + 159 app pp.

Environment and Climate Change Canada. 2020. Amended Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population, in Canada. *Species at Risk Act* Recovery Strategy Series. Environment and Climate Change Canada. 143 pp. (https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-CaribouBorealeAmdMod-v01-2020Dec-Eng.pdf)





- Project Development Area
- Caribou and Moose Local Assessment Area
- Fire Area (1984-2023)
- Human Disturbance (2020) +500m buffer
- NT1 Boreal Caribou Range
- Community
- Northwest Territories Highway
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary

0 10 20 Kilometres
(At original document size of 8.5x11)
1:1,500,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 9/17/2024
TR by SL on 9/17/2024

Client/Project
144903512_005

Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
25-1

Title
Human Disturbance and Fire History within Caribou and Moose Local Assessment Area

Notes
1. Coordinate System: NAD 1983 UTM10
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd.
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, TomTom, FAO, NOAA, USGS, NRCan
World Hillshade: Esri, USGS. Imagery date: 2021

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Topic: ECCC-04: Probable Caribou Movement Corridors, PDA Overlap with Existing Disturbed Areas, Effects to Caribou Habitat Connectivity and Movement

Reviewer Preamble:

The Developer's Assessment Report (DAR) discusses potential movement corridors (Section 10.4), as does a report entitled "Mackenzie Valley Highway Project: Inferring the Potential Barriers to Boreal Caribou Movement" (the report) that was provided for review on February 27, 2024, as part of the environmental assessment process (EA1213-02) to the Mackenzie Valley Environmental Impact Review Board (MVEIRB). The report notes there are locations where caribou have crossed and are more likely to cross the Mackenzie Valley Winter Road. The report (pg. iii) also states that the authors "… do not anticipate the highway to pose a barrier to caribou movement". However, probable movement corridors have not been expressly identified in either document.

The report highlights the impacts habitat disturbance has on caribou movements, including habitat avoidance and fragmentation. The Proponent states on page 10-51 of the DAR that "An indirect alteration of boreal caribou or moose habitat is expected through sensory disturbance caused by noise and dust deposition, edge effects on habitat, and fragmentation that can result in habitat avoidance and reduced habitat effectiveness in areas adjacent to the PDA… Edge effects and fragmentation may result from vegetation clearing activities, particularly where the PDA intersects forested habitats."

The Proponent goes on to say that 47.8% of the Project Development Area (PDA) overlaps with previously disturbed areas, which have already created edge effects and fragmentation. The DAR does not provide a map indicating this overlap.

Reviewer Request:

ECCC requests the Proponent:

1. Clarify whether further analysis of boreal caribou movement is planned as part of the Project assessment. If so, then elaborate on whether the analysis will include identification and mapping of probable movement corridors for boreal caribou within the PDA and Local Assessment Area (LAA). If the Proponent is not planning to conduct further analysis on boreal caribou movement, then provide a clear, scientifically defensible rationale as to why this analysis is not needed.

2. Provide a map that illustrates the extent to which the PDA overlaps with existing disturbed areas (as defined in the Federal Recovery Strategy).

3. Identify specific mitigation measures to address impacts to crossing accessibility and to reduce vehicle collisions.

4. Clarify what evidence is available to support the statement that the all-season road will not have a greater impact on movement and connectivity than the winter road.

Response from the Government of the Northwest Territories:

1. No further movement studies are planned as part of the Project assessment, as the Government of Northwest Territories (GNWT) believes that the requests are addressed in the current analyses, and as follow-up included in the GNWT's response to MVEIRB IR#56 noted below.

Map 3 (early to mid-winter) and Map 4 (calving to post-calving) in the report *Mackenzie Valley Highway Project: Inferring the Potential Barriers to Boreal Caribou Movement* (EDI 2024) provide 'predicted' crossing locations based on simulated boreal caribou paths. In those maps, red line segments indicate locations where caribou crossings are likely to occur but are hindered by the Dél̨ı̨ne Winter Road. The GNWT's response to MVEIRB IR#56 also provides a map of all known crossing locations along the Mackenzie Valley Winter Road based on available GPS collar data (2003–2023).

2. Figure CanNor 25-1 demonstrates the overlap between the Project Development Area and existing disturbed areas, including Human Disturbances (plus 500 m buffers, as of 2020) and wildfires <40 years old (as of 2023).

3. Mitigation measures to address impacts on crossing accessibility and to reduce vehicle collisions are described in Table 10.8 in the Developer's Assessment Report (DAR). Signage may be used to specify speed limits and warnings at wildlife crossing locations (DAR Section 10.5.4.2, *Mitigation for Cumulative Effects*). Also, refer to the GNWT's response to MVEIRB IR#56B for a summary of proposed mitigation measures to prevent vehicle collisions with wildlife at known crossing locations.

4. Evidence to support the statement that the "all-season road is unlikely to cause greater impacts on boreal caribou compared to the winter road" is discussed in detail in EDI (2024). This is specifically in reference to the impacts of existing natural barriers, disturbances, and habitat distribution. Please refer to Section 4 (*Discussion*) of EDI (2024) for a discussion on this conclusion. Further context and summaries are also provided in the GNWT's response to MVEIRB IRs #44 and #45.

Figure CanNor 25-1. Project development area overlaps with existing disturbed areas in the Caribou and Moose Local Assessment Area.

[see separate]

References

EDI Environmental Dynamics Inc. 2024. Mackenzie Valley Highway Project: Inferring the Potential Barriers to Boreal Caribou Movement. Prepared for K'alo-Stantec Limited for use by the Government of Northwest Territories, Calgary, Alberta. 55 + 14 app pp.

Topic: ECCC-03: Cumulative Effects Analysis to Boreal Caribou: Past, Present and Reasonable Foreseeable Projects

Reviewer Preamble:

The Mackenzie Valley Environmental Impact Review Board (MVEIRB)'s Environmental Impact Statement Guidelines (2004) state that proponents will "assess the impacts of the development in combination with the impacts of all other past, present and reasonably foreseeable future developments and human activities".

Current Imperial Oil operations are well within the Local Assessment Area (LAA) as designated by the Proponent, yet oil operations are absent from the cumulative effects assessment (Section 10.5.1, Table 10.17).

Imperial Oil has been operating in the Norman Wells area of the Northwest Territories since 1920. This ongoing oil and gas activity likely had (and will continue to have) impacts on boreal caribou. Imperial Oil recently rescinded an environmental assessment of a waste management facility expansion (MVEIRB EA 2223-01). While this application has been withdrawn, a more detailed application is anticipated to be put forward at a later date. A waste management facility expansion would be an activity within the LAA defined by the Proponent in the Developer's Assessment Report (DAR). Remediation of the entire Imperial site may also be a "reasonably foreseeable" human activity. Past, present or reasonably foreseeable potential future project activity in the area could have cumulative impacts on boreal caribou.

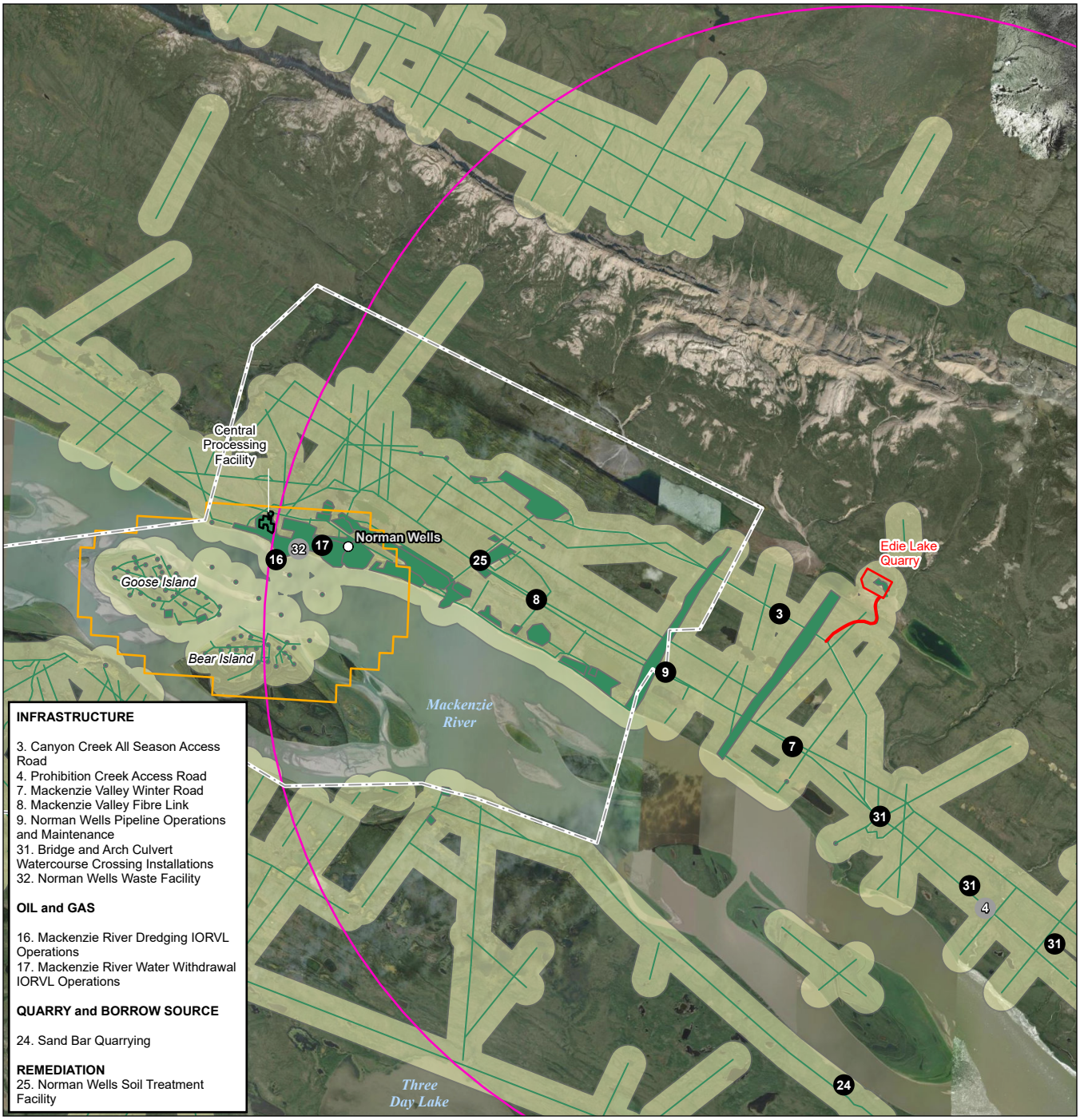
Reviewer Request:

ECCC requests the Proponent revise the cumulative effects assessment for boreal caribou to include Imperial Oil activities in the Norman Wells area (past, present and reasonably foreseeable future activities). This should include a thorough pathways of effects analysis (e.g. changes to habitat, movement, mortality risk and health, significance determinations, etc.), as well as a list of assumptions. If the Proponent does not revise the cumulative effects assessment for boreal caribou, then provide a clear, scientifically defensible rationale as to why they are not.

Response from the Government of the Northwest Territories:

The ongoing operations of the Imperial Oil Resources N.W.T. Limited (Imperial) Norman Wells Operations (NWO) was not included in the cumulative effects assessment project inclusion list (PIL) (Section 4.6.1 of the Developer's Assessment Report [DAR]), as most of the existing facility areas (Goose and Bear Islands wells and flowlines, Mainland facilities), do not overlap spatially with the largest Regional Assessment Area (RAA) identified for assessment of cumulative effects (which is the same area as the Caribou and Moose Local Assessment Area [LAA]). Figure 24-1 shows existing human disturbances (green) in relation to the Project Development Area (red), Caribou and Moose LAA (mauve). The NWO facility areas are located within the larger Norman Wells Proven Area, which is shown in orange. Projects included in the PIL are identified numerically, as they were in Figure 4.1 of the DAR. The exact location of a possible waste management facility for the NWO is not known at this time but it is likely to be situated within the Town of Norman Wells boundary.

Specific activities associated with NWO were identified for inclusion of cumulative effects in the DAR, such as ongoing water withdrawal from, and dredging in, the Mackenzie River, and the operation and maintenance of the Norman Wells Pipeline. Irrespective of this, all existing areas of human disturbance within the RAA/Caribou and Moose LAA, including those within the Norman Wells Proven Area and the Town of Norman Wells, buffered by 500 m, have been included in the assessment of cumulative effects on boreal caribou from changes to habitat (direct and indirect; see for example Table 10.18 of the DAR). It is not anticipated that a possible waste management facility, as identified above, would change this assessment and its conclusions, as its potential location is likely to already be accounted for in disturbed areas, and as is also discussed in the Government of the Northwest Territories (GNWT)'s response to MVEIRB IR#51.





Status of Project
- Past / Present
- Reasonably Foreseeable
- Project Development Area
- Caribou and Moose Local Assessment Area
- Existing Human Disturbance (2020)
- Existing Human Disturbance +500m Buffer
- Community
- Norman Wells Municipal Boundary
- Norman Wells Proven Area

0 1 2 Kilometres
(At original document size of 8.5x11)
150,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by DS on 9/26/2024
TR by EB on 9/26/2024

Client/Project
123514886_002
Government of the Northwest Territories
Mackenzie Valley Highway Project

Figure No.
24-1

Title
Existing Human Disturbance (2020) - Norman Wells Area

Notes
1. Coordinate System: NAD 1983 UTM10
2. Data Sources: GNWT (Government of the Northwest Territories) Centre for Geomatics. n.d. Inventory of Landscape Change Map Viewer, GNWT. Centre for Geomatics. n.d. Open Data, MVLWB. n.d. Public Registry, Sahtu Land and Water Board. n.d. Public Registry, Environment and Natural Resources GNWT, Government of Canada, Stantec, Wilson and Haas 2012, and Caslys Consulting Ltd. Imperial Oil Application for Variance of Operations.
3. Background: World Imagery: Earthstar Geographics
World Topographic Map: Esri, TomTom, FAO, NOAA, USGS, NRCan
World Hillshade: Esri, USGS. Imagery date: 2021

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Topic: ECCC-02: Clarification of Study/Assessment Area for Boreal Caribou: LSA/LAA and RSA/RAA

Reviewer Preamble:

The Proponent uses the terms Local and Regional Study Area (LSA/RSA) and Local and Regional Assessment Area (LAA/RAA) seemingly interchangeably in the Developer's Assessment Report (DAR). The main section of the DAR discussing the assessment of potential effects on caribou and moose (Section 10) uses the term RAA while the technical data report (Appendix 10A) uses the more common terms LSA and RSA. Section 10 of the DAR excludes the use of an RAA/RSA for boreal caribou, stating the LSA will appropriately substitute for the RSA.

Reviewer Request:

ECCC requests the Proponent:

1. Clarify and define which terms are to be used when discussing impacts to caribou in the DAR (i.e. LSA/RSA or LAA/RAA), and use these terms consistently.
2. Provide the rationale, including advantages and disadvantages, to exclude an RAA/RSA from the assessment for boreal caribou, and to have the LSA serve as the RAA/RSA (Section 10 of the DAR).

Response from the Government of the Northwest Territories:

1. The terms Local Study Area (LSA) and Regional Study Area (RSA) were used to characterize *existing conditions* for Valued Components, including boreal caribou. The study of existing conditions (Caribou and Moose Technical Data Report, Developer's Assessment Report [DAR] Appendix 10A) predates assessing potential effects in the DAR. The DAR defines the spatial scope used for the *assessment of potential effects* on VCs; the terms Local Assessment Area (LAA) and Regional Assessment Area (RAA) are used for this. Caribou and moose are assessed within the Caribou and Moose Local Assessment Area (Caribou and Moose LAA), which is separate from the LAA and Regional Assessment Area (RAA) used for other wildlife (DAR Section 10.1.4), because there is no RAA for the assessment of caribou and moose. The Caribou and Moose LAA assesses Project-specific effects on caribou and moose.

2. For further discussion on why the Caribou and Moose LAA is an appropriate spatial extent for assessing boreal caribou, refer to the DAR Section 10.1.4 and the Government of Northwest Territories' response to Mackenzie Valley Environmental Impact Review Board Information Request #44.

Topic: ECCC-01: Selection of Appropriate Spatial Assessment Boundaries for Boreal Caribou and Cumulative Effects

Reviewer Preamble:

The Proponent outlines their analysis of the cumulative effects boundaries applicable to boreal caribou for this Project in Section 10.1.4.1 – Spatial Boundaries.

The Proponent uses a Local Assessment Area (LAA) to assess cumulative effects to boreal caribou. The LAA is defined as the area within a 15 km radius of the Project Development Area (PDA - the area of direct project disturbance/footprint). The Proponent notes there is no Regional Assessment Area (RAA) defined for caribou in the Developer's Assessment Report (DAR). Part of the Proponent's justification for this boundary is that 15 km is "the estimated maximum distance caribou moved in 24 hours" (Section 10.1.4.1, pg. 10-11). The Proponent stated they avoided an area as large as the Northwest Territories Range (NT1) habitat planning unit range for assessing effects, as the Mackenzie Valley Environmental Impact Review Board (MVEIRB) found the scale of NT1 to be "inappropriately large and diluted the effects on caribou" for the similarly assessed project, the Tlicho All-Season Road (Section 10.1.4.1, pg. 10-11).

The area of the NT1 range is over 44 million hectares. The Proponent-selected caribou LAA is only slightly over 1 million hectares (Table 10.18). It is not clear how the Proponent chose the current LAA size. The Proponent did not rationalize that this selection is of a sufficient size to accurately capture other projects that may be relevant to the survival of boreal caribou in the area or reflect biologically relevant regional habitat conditions.

Reviewer Request:

ECCC requests the Proponent:

1. Provide further rationale and clarity for the selection of the LAA (15 km buffer) as the relevant scale for the cumulative effects assessment area for boreal caribou.

2. Clarify whether areas other than the proposed LAA were considered, and if not, then explain why. If other areas were considered, then provide the rationale to disregard them in favour of the 15 km buffer along the PDA. Outline what ecological factors and/or Indigenous groups' perspectives were considered when evaluating which potential area(s) would be better at "identifying and assessing current projects/activities as well as any foreseeable future projects/activities" that may affect boreal caribou that interact with the Project.

Response from the Government of the Northwest Territories:

1. The Caribou and Moose Local Assessment Area (LAA) (15-kilometre buffer) was used to assess cumulative effects because it encompasses "*… known past, present, and reasonably foreseeable projects and physical activities that could overlap spatially and temporally with the [Project's] residual effects*". Larger spatial scales were also used to assess cumulative changes to caribou habitat to align with the Federal Recovery Strategy (ECCC, 2020), which identifies disturbance thresholds for critical caribou habitat that ensure self-sustaining local populations. These additional spatial scales included the NT1 Boreal Caribou Range and Sahtu and Southern NWT Range Planning Regions (GNWT, 2019). Cumulative habitat loss at each scale was first reported in Table 10.18 of the Developer's Assessment Report (DAR). Since then, newer data sources on human disturbances (circa 2020; https://open.canada.ca/data/en/dataset/63e1cda6-debe-4b9b-b075-3666443e30b4) and wildfires (GNWT-ECC, 2024) have become available. Thus, cumulative habitat loss calculations have been updated using these newer data sources and are presented in the Government of the Northwest Territories (GNWT)'s response to Mackenzie Valley Environmental Impact Review Board (MVEIRB) Information Request (IR) #52. Therefore, while the Caribou and Moose LAA was used as the spatial area for the cumulative effects assessment, other, larger spatial scales were used to assess cumulative effects on boreal caribou (e.g., range planning boundaries, NT1).

2. As stated in the first response (above), the NT1 Boreal Caribou Range and Sahtu and Southern NWT Range Planning Regions were also considered in the assessment of cumulative effects on caribou from changes to habitat. Please refer to the GNWT's responses to the following MVEIRB IRs for further information on: (1) spatial scale and study extent —MVEIRB IR #44, and (2) update to Table 10.18 in the DAR's cumulative effects assessment —MVEIRB IR #52.

References

ECCC. 2020. Amended Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada. Species at Risk Act Recovery Strategy Series. Environment and Climate Change Canada, Ottawa. xiii + 143pp.

Government of the Northwest Territories (GNWT). 2019. A Framework for Boreal Caribou Range Planning. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 87 pp. Available at: https://www.gov.nt.ca/ecc/sites/ecc/files/resources/boreal_caribou_range_planning_framework_2019_-_cadre_de_planification_de_laire_de_repartition_du_caribou_boreal_2019.pdf

GNWT-ECC. 2024. Fire History (NBAC/CNFDB) - NT1 Range. Compiled and edited by J.Hodson and R.Abernethy, Wildlife Division, ECC, GNWT. Data Source: Natural Resources Canada (NRCan) (http://cwfis.cfs.nrcan.gc.ca/datamart)

Topic: DFO-12: Offsetting

Reviewer Preamble:

A Fisheries Act authorization will likely be necessary for the construction of the MVH, along with offsetting measures to compensate for any lost or altered fish habitat. The DAR does not present conceptual offsetting options. Given the challenges of finding suitable offsetting options in the North and the need to consult impacted Indigenous Groups, it is crucial to start planning for offsetting early in the project's life cycle.

Reviewer Request:

DFO Recommend the Proponent develop a preliminary conceptual Offsetting Plan.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) looks forward to further discussing with the Department of Fisheries and Oceans Canada (DFO) how the requirements of the *Fisheries Act* apply to the Project. The GNWT understands the potential for the Project to require Authorization under the *Fisheries Act*; however, the GNWT notes that offsetting requirements, if any, will be more precisely defined during the Project's detailed design and regulatory phase. Opportunities for offsetting, if required, will be identified through review of existing field data and through discussion with local communities to support early consultation. Opportunities for offsetting will be evaluated with consideration for DFO's offsetting policy (DFO 2019). Following review of the Project, should DFO determine Authorization under the *Fisheries Act* is required, the GNWT will develop a conceptual Offset Management Plan as part of the application for Authorization under the *Fisheries Act* for further discussion with DFO.

It is the GNWT's view that it is reasonable to initiate DFO's detailed review of the Project under the *Fisheries Act* as part of the regulatory approvals stage of the Project, which will follow completion of the environmental assessment. Per the GNWT's response to CanNor IR#15 and CanNor IR#18, the GNWT would be pleased to answer any additional questions from DFO regarding the scope of the Project.

References

DFO (Fisheries and Oceans Canada). 2019. Policy for Applying Measures to Offset Adverse Effects on Fish and Fish Habitat Under the Fisheries Act. Fisheries and Oceans Canada. Ottawa.

Topic: DFO-11: Bull Trout Habitat Suitability

Reviewer Preamble:

The Proponent provided the following rationale on why habitat at the proposed stream crossings is considered unsuitable for Bull Trout:

Most of the watercourses that may be crossed by the Project are small second or third order streams of low gradient that drain directly into the Mackenzie River, a river with relatively turbid water. In contrast, bull trout prefer higher gradient watercourses connected to larger relatively clear downstream rivers such as the Keele and South Nahanni Rivers (Mochnacz et al. 2013).

Most of the watercourses that may be crossed by the Project have substrates dominated by fines and organics. In contrast, adult bull trout (the life stage most likely to access watercourses on the eastern side of the Mackenzie River), prefer habitat with cobble to boulder substrates (Mochnacz et al. 2004). Juveniles are less likely to make the long migration from western headwater streams of the Mackenzie River to eastern tributaries of the Mackenzie River due to the increased risk in predation and energy cost.

Most of the watercourses that may be crossed by the Project are shallow and lack deep pools suitable for bull trout overwintering; most watercourses that may be crossed by the Project freeze to the bottom in winter.

DFO mostly agrees with the rationales but would like to point out that in Mochnacz et al (2021) attached, Bull Trout were sampled in the Prairie Creek watershed in streams with gradients ranging from 0.7 to 13.8 %. The article also states that in the Prairie Creek watershed, adult bull trout move into first to third-order habitat patches in the late summer to spawn and then migrate downstream into larger tributaries in the fall. Additionally, juvenile bull trout rear for 3-5 years in second and third-order streams. Finally, in Alberta, juvenile and adult bull trout overwinter in small, shallow (max depth 0.4 to 1.5 m) pools that are isolated from one another, have little cover, and receive flow from groundwater springs (Stewart et al., 2007).

References:

Mochnacz, N. J., et al. (2021). "Fringe effects: detecting bull trout (Salvelinus confluentus) at distributional boundaries in a montane watershed." Canadian Journal of Fisheries and Aquatic Sciences 78: 1030-1044.

Stewart, D. B., et al. (2007). Fish life history and habitat use in the Northwest Territories: bull trout (Salvelinus confluentus) Winnipeg, Mb, Fisheries and Oceans Canada. 2801: i-46.

Reviewer Request:

DFO recommends the proponent not assume a stream does not support Bull Trout based on stream morphology alone.

Response from the Government of the Northwest Territories:

A supplementary field program is being conducted by qualified environment professionals which includes fish sampling, eDNA sampling, and fish habitat assessments at watercourses crossed by the Project. This supplementary field data, in addition to data provided in the Developer's Assessment Report, will be compared to studies conducted in the Northwest Territories regarding bull trout. Fish habitat information and in-situ water quality data will be compared to the recovery strategy for the Saskatchewan – Nelson Rivers population of bull trout to determine if there are waterbodies that may provide suitable bull trout habitat based on the features and attributes provided in table 6 of the recovery strategy (DFO, 2020). The Government of Northwest Territories (GNWT) understands the value of indirect bull trout habitat (e.g., surface water inputs from drainages), and seasonal habitat. Evaluation of the habitat potential for bull trout at each proposed watercourse crossing will be included in a single compiled report. This report will be submitted to the Department of Fisheries and Oceans Canada (DFO) for review as part of the *Fisheries Act* regulatory review process following completion of the environmental assessment. The GNWT looks forward to reviewing this, and other Project-specific information with DFO.

References

DFO (Fisheries and Oceans Canada). 2020. Recovery Strategy for the Bull Trout (*Salvelinus confluentus*), Saskatchewan – Nelson Rivers populations, in Canada [Final]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. viii + 130 pp.

Topic: DFO-10: Riparian Vegetation in Bull Trout Habitat

Reviewer Preamble:

In their response, the Proponent clarified that a 30 m wide area of riparian vegetation will be trimmed at watercourse crossings, that vegetation management within is required to maintain sight lines for driver safety and that in riparian areas vegetation will be cut more than 10 centimeters above the ground surface to retain root structure.

DFO would like to note that a proposed recovery strategy exists for Bull Trout in the Saskatchewan-Nelson Rivers that considers riparian habitat to extend to 30 m from a stream high water mark, due to a strong reliance for providing food, instream structure, shade, moderating water temperature and regulating the amount of sediment entering the water. Although the Mackenzie River Bull Trout population is not considered in this recovery strategy, DFO is of the opinion that vegetation clearing within 30 m from each water course should be avoided or minimized.

In addition, as mentioned in DAR Review comment DFO 19, Bull Trout (Western and Arctic populations) are currently under reassessment by COSEWIC and may be listed as Threatened after the assessment (potentially as early as 2025). If the listing for Bull Trout is changed, the 30 m wide riparian zone may be considered critical habitat at the time of project review and a reassessment of fish and fish habitat would be required for the project.

Reviewer Request:

DFO recommends that vegetation clearing within 30 m from each water course that has the potential to be Bull Trout habitat should be avoided or minimized as proposed in the Bull Trout, Saskatchewan-Nelson Rivers recovery strategy.

Response from the Government of the Northwest Territories:

It is unlikely that bull trout are present in the watercourses crossed by the Project, as described in the Developer's Assessment Report. The Mackenzie Gas Project completed fish assessments over multiple years and multiple seasons and did not capture bull trout in the watercourses crossed by the proposed Project. In addition, fish sampling conducted by the Government of Northwest Territories (GNWT) between 2020 and 2024 has not captured any bull trout; however, the Project is within the distribution of the western Arctic population of bull trout (DFO 2024). In order to further refine the potential presence of bull trout within watercourses crossed by the Project, the GNWT is currently conducting supplementary sampling of specific watercourses crossed by the Project for environmental deoxyribonucleic acid (eDNA) analyses which will be reviewed to evaluate whether bull trout are present. The eDNA analyses are being conducted on a selection of larger watercourses which may have a higher likelihood of the presence of bull trout as well as smaller watercourses that are expected to have a lower likelihood of bull trout presence.

Large watercourses along the proposed Project alignment have existing crossings (i.e., culvert, bridge), with the exception of the Great Bear River, which is not part of this Project (see the GNWT's response to CanNor Information Request #15). These existing crossings are sufficiently high above the watercourse bed such that limited or no clearing/brushing is required within 30 metres of the watercourse. Depending on the geometry of the final road embankment, reducing the amount of clearing at these locations may be possible, while still maintaining the required lines of sight for public safety. The riparian areas on either side of each crossed watercourse will not be removed but may require trimming to maintain the lines of sight for public safety.

As described in the recovery strategy for bull trout (Saskatchewan – Nelson Rivers population, listed as Threatened under Schedule 1 of the *Species at Risk Act*) (DFO 2020), existing anthropogenic disturbances, such as watercourse crossings (i.e., existing crossings along the Mackenzie Valley Winter Road), are not considered critical habitat; however, the western Arctic population of bull trout is considered of Special Concern and therefore does not have designated critical habitat. The GNWT understands the value of intact riparian zones adjacent to watercourses, including those that support sensitives species such as bull trout, and will minimize vegetation clearing wherever practicable.

References

DFO (Fisheries and Oceans Canada). 2020. Recovery Strategy for the Bull Trout (*Salvelinus confluentus*), Saskatchewan-Nelson Rivers populations, in Canada [Final]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. viii + 130 pp.

DFO. 2024. Aquatic species at risk map. Accessed September 9, 2024, from: https://www.dfo-mpo.gc.ca/species-especes/sara-lep/map-carte/index-eng.html

Topic: DFO-09: Culvert Verses Bridge Crossings Rationale

Reviewer Preamble:

DFO requested the Proponent provide a rationale on why bridges are not proposed to be installed, especially in larger watercourses. The Proponent responded that "bridges impose many more constraints on road geometry than culverts, such as: road width, longitudinal and transverse slopes and corner radius. These constraints negatively affect road safety for bridges more than for culverts. Therefore, culvert crossings are often safer than bridge crossings for the type of highway proposed".

DFO acknowledges the response and the importance of safety when building new roads. However, bridges can facilitate the natural flow of water and have minimal impact on the streambed and surrounding riparian zone, thereby limiting their impact compared to culverts. Additionally, bridges can reduce the risk of flooding, as observed on the Inuvik to Tuktoyaktuk Highway. DFO encourages the Proponent to consider installing bridges at crossings where sensitive migratory species such as Bull Trout and Arctic Grayling may be present (e.g., Four Mile Creek, Twelve Mile Creek, Prohibition Creek), provided it does not create safety issues.

Reviewer Request:

The Proponent should demonstrate that installing a bridge at crossings where sensitive migratory species may be present (such as Four Mile Creek, Twelve Mile Creek, Prohibition Creek) would negatively affect road safety.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) wishes to clarify, per Section 5.3.1 of the Developer's Assessment Report, that the Project will use existing and planned watercourse crossing structures (single-lane bridges and bridge-sized culverts) located over major watercourses located on the Mackenzie Valley Winter Road (MVWR) between Wrigley and Norman Wells. The Information Request refers to crossings which are already in place and in use.

Existing watercourse crossing structures along the MVWR include:

- Hodgson Creek (bridge)
- Ochre River (bridge)
- White Sand Creek (bridge)
- Big Strawberry Creek (culvert)
- Small Strawberry Creek (culvert)
- Vermillion Creek South (bridge)
- Bob's Canyon Creek (culvert)
- Dam Creek (bridge)
- Blackwater River (bridge)
- Steep Creek (bridge)
- Saline River (bridge)
- Seagrams Creek (bridge)
- Little Smith Creek (bridge)
- Big Smith Creek (bridge)
- Gotcha Creek (bridge)
- Twelve Mile Creek (bridge)
- Four Mile Creek (culvert)
- Jungle Ridge Creek (bridge)
- Notta Creek (bridge)
- Vermillion Creek North (bridge)
- Prohibition Creek (bridge)
- Christina Creek (bridge)

- Hellava Creek (bridge)
- Francis Creek (bridge)
- Canyon Creek (bridge)

Existing bridge and culvert crossings between Hodgson Creek and Prohibition Creek are identified in Appendix 5A (Project Mapbook). A shapefile of existing bridge locations was previously made available to the Department of Fisheries and Oceans Canada in the GNWT's response to Online Review System ADKFN#30 (DFO-1).

The GNWT additionally notes that at certain crossings the road approaches to single lane bridges are constrained by the need to yield to oncoming traffic. As the design criteria for bridge-sized culvert crossings are double-lane width (10 metres, per Table 5.1 of the Developer's Assessment Report), approaches to these crossings are less constrained by factors such as the need to provide sufficient distance at one or either approaches to the bridge for vehicles to yield to oncoming traffic. Vehicles are not required to yield at culvert crossings, thus improving safety.

The GNWT will consider installing open bottom (arch) culverts similar to the one at Four Mile Creek at a wide watercourses to meet the hydrotechnical and environmental requirements, where such requirements cannot be met with embedded culverts.

Topic: DFO-08: Culvert Crosses- Type of Culverts

Reviewer Preamble:

The proponent did not specify which type of culverts would be used at different crossings. DFO encourages the use of open bottom culverts or embedded oversized arched culverts instead of circular culverts as they allow maintaining a more natural stream bed and can accommodate higher flow volumes.

Reviewer Request:

DFO recommends the Proponent install open bottom or embedded oversized arched culverts at fish bearing crossings.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) understands the reasons for Fisheries and Oceans Canada's preference for arch culverts or embedded oversized culverts. The GNWT will consider this recommendation during the detailed design of watercourse crossings that are at fish bearing streams. As noted in the GNWT's response to CanNor Information Request#13, the GNWT has been developing updated design guidelines for large-diameter culverts, which will address design requirements to maintain adequate fish passage, including considerations for embedment, camber, permafrost, and construction practices.

Topic: DFO-07: Culvert Crossings in Large Watercourses

Reviewer Preamble:

At the time of assessment, the following crossings had large channel widths, likely due to the presence of beaver dams:

- Site 919.9 Unnamed Watercourse (37m wide)
- Site 820.7 Unnamed Watercourse (15.5m wide, but 95m to 100m wide downstream)
- Site 891.4 Unnamed Watercourse (12.5m wide)

It is unclear how culvert crossings will be constructed in those locations

Reviewer Request:

The Proponent to provide examples, accompanied by photographs, of culvert crossings that have been constructed by the Proponent in wetlands (streams with large, wetted widths). If the Proponent has no such examples, they can provide best practices that would be applied in these situations.

Response from the Government of the Northwest Territories:

Figures 16-1 to 16-8 below represent examples of culvert crossing that have been constructed for Highway 3 and Inuvik Tuktoyaktuk Highway (ITH) by the Government of Northwest Territories in streams with large, wetted widths.

Figure 16-1 shows a culvert constructed at Highway 3, kilometre (km) 302.4 that looks south from the north side of Highway 3, showing an improved rock bed within the culvert.

Figure CanNor 16-1 Hwy 3 Km 302.4 Upstream – Beside Culvert (2018 photos)



Figure 16-2 shows the same culvert looking North on the north side of Highway 3, including a 40 metres (m) wide area of broad overland flow towards the culvert.

Figure CanNor 16-2 Hwy 3 Km 302.4 Upstream – Above Culvert (2018 photos)



Figure 16-3 shows the same culvert looking North from the south side of Highway 3 and an improved rock bed within the culvert.

Figure CanNor 16-3 Hwy 3 Km 302.4 Downstream – Beside Culvert (2018 photos)



Figure 16-4 shows the same culvert looking South on the side of highway 3, including a small receiving water body for flow from the culvert

Figure CanNor 16-4 Hwy 3 Km 302.4 Downstream – Above Culvert (2018 photos)



Figure 16-5 shows a culvert constructed at ITH, km 22 that looks North on the east side and shows one of the three crossing upstream ends, with the dominant flow channel in the area of broad overland flow straight ahead and to the right.

Figure CanNor 16-5 ITH Highway 10 Crossing 15 km 22 Downstream Side (2024 photos)



Figure 16-6 shows the same culvert looking at the same direction, but the photograph was taken from approximately 20 m further away.

Figure CanNor 16-6 ITH Highway 10 Crossing 15 km 22 Downstream Side (2024 photos)

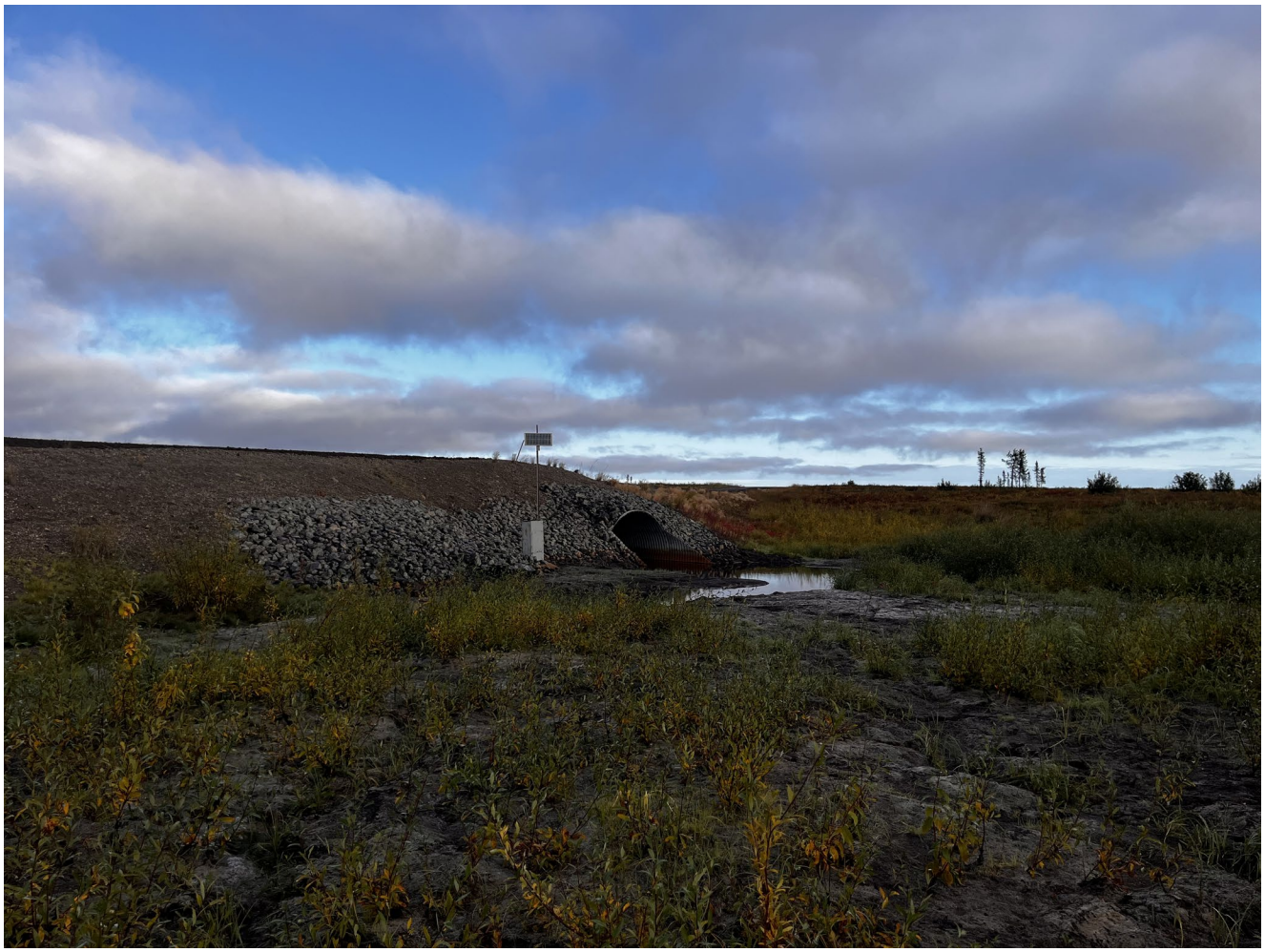


Figure 16-7 shows the same culvert looking North on the west side of the ITH and one of the three crossing upstream ends, with the dominate flow channel in the area of broad overland flow moving to the left.

Figure CanNor 16-7 ITH Highway 10 Crossing 15 km 22 Upstream Side (2024 photos)



Figure 16-8 shows the same culvert looking South on the west side of the ITH and two of the three crossing upstream ends, with the area of broad overland flow to the right.

Figure CanNor 16-8 ITH Highway 10 Crossing 15 km 22 Upstream Side (2024 photos)



Topic: DFO-06: Fisheries Monitoring at Crossings

Reviewer Preamble:

As per the DAR, monitoring at the crossings will include routine periodic inspection of culverts to determine if they are functioning as per design (e.g., allow fish passage) and for evidence of erosion and sedimentation. However, despite the design intentions, flaws in culvert construction and maintenance may compromise a culvert's structural integrity and impede fish passage. DFO believes that additional field monitoring should be conducted in high-risk streams (e.g., where sensitive migratory species such as Bull Trout and Arctic Grayling may be present, such as Four Mile Creek, Twelve Mile Creek, Prohibition Creek) to demonstrate that the culverts do not impede fish passage.

Reviewer Request:

DFO recommends post-construction field monitoring be conducted at high-risk crossings (e.g., in streams where sensitive migratory species such as Bull Trout and Arctic Grayling may be present, such as Four Mile Creek, Twelve Mile Creek, Prohibition Creek) to demonstrate that the culverts do not impede fish passage. Field monitoring may include:

- Velocity monitoring at the culvert to validate model prediction
- Fish sampling upstream of the culverts

DFO recommends the Proponent develop a Conceptual Post-Construction Fish Monitoring Plan, as part of the Fish and Fish Habitat Protection Plan, to verify whether the culverts allow fish passage throughout the open-water season. The Plan may include:

- Summary of pre-construction conditions
- Sampling schedule
- Description of success criteria and associated measures of success
- Monitoring methods, including locations, target species, and data to be collected.
- Description of data analysis to be performed
- Reporting schedule
- Thresholds for acceptable performance
- Response Plans for addressing any issue identified

Response from the Government of the Northwest Territories:

Information about proposed watercourse crossings will continue to be collected by the Government of Northwest Territories (GNWT) to inform the detailed design phase of the Project, which will follow completion of the environmental assessment. This information includes baseline data and fish species presence information, and site-specific hydrotechnical data which will be used to inform the specific hydrotechnical design for crossing structures. The crossings will be designed to maintain flow and fish passage past the crossing structures. The GNWT will develop a post-construction monitoring plan and submit the plan to Fisheries and Oceans Canada for review as part of the *Fisheries Act* regulatory review process, following completion of the environmental assessment.

The GNWT notes that there are existing watercourse crossings (i.e., bridges, culverts) across large watercourses along the current Mackenzie Valley Winter Road alignment, with the exception of the Great Bear River. These existing watercourse crossings are listed in Table 5.8 of the Developer's Assessment Report and identified in Appendix 5A. These existing watercourse crossings, including the Great Bear River crossing, are not part of this Project; however, the Project will tie into these existing crossings. Where practical and within the Project footprint, the post-construction monitoring plan will consider where the Project ties into existing crossings.

Topic: DFO-05: Baseline Fish Sampling

Reviewer Preamble:

DFO understands the GNWT has taken a precautionary approach by assuming which stream crossings are fish-bearing and the fish species that may be present in a stream crossed by the Project. However, fish sampling was limited due to freezing conditions, and observations were only carried in the fall. Conducting sampling at different times of the year is essential for capturing the full spectrum of fish presence and habitat use. DFO is of the opinion that the baseline information collected is incomplete and sometimes outdated (2004, 2011). Although culverts will be designed to allow for fish passage, having baseline data provides a reference point for assessing the effectiveness of the culverts and any unforeseen negative effects of the road on fish populations, and making necessary adjustments. Additional baseline data would be valuable scientific information that would inform fisheries management.

Reviewer Request:

The Proponent to work with DFO in identifying higher risks crossings, identifying specific baseline data gaps at these crossings, and developing a Baseline Monitoring Plan to supplement the existing baseline data. DFO will have a better understanding of any potential data gaps after receiving responses to IR DFO-02 and DFO-03.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) has undertaken a supplementary fisheries field program which is currently ongoing. Information about fish species presence and fish habitat potential at watercourse crossings will continue to be collected in order to inform the detailed design phase of the Project, which will follow completion of the environmental assessment. The fish species presence information and collected baseline data will be compiled into a single report and submitted to Fisheries and Oceans Canada (DFO) as part of their review under the *Fisheries Act*. This compiled information will support the detailed design of each crossing structure to confirm the crossings are designed to maintain flow and fish passage past crossing locations. The detailed design phase will follow completion of the environmental assessment. The GNWT looks forward to further discussing with DFO how the requirements of the *Fisheries Act* apply to the Project.

Topic: DFO-04: Lessons Learned from Inuvik to Tuktoyaktuk Highway- Crossings- Response to DAR Review Comment DFO-3

Reviewer Preamble:

DFO previously requested that the Proponent provide information (e.g., literature or lessons-learned from other roads) on the effectiveness of the use of geotextile membranes at culverts to maintain structural integrity, thus preventing fish passage issues, and provide information on whether other types of isolation (e.g., polystyrene) were considered and why they were not chosen. The Proponent did not respond to the specific questions.

To elaborate on our request, we would like to add that the Proponent encountered issues related to fish passage and habitat on other projects such as the Inuvik to Tuktoyaktuk Highway, including:

- Perched culverts due to lack of embedment and shifting of Permafrost impeding fish passage
- Inadequate culvert sizes causing yearly (at freshet) road wash outs and sedimentation into fish bearing waters
- In-water works not conducted according to plans approved under Water Licence. (e.g. Gunghi Creek)
- Inadequate responses to erosion and sedimentation events leading to enforcement actions by DFO

Reviewer Request:

Based on the Proponent's experience from the construction of the Inuvik to Tuktoyaktuk Highway, please provide design considerations, modifications to the construction techniques, mitigation measures and responses that will be implemented to avoid similar issues from occurring at the MVH crossings. Information should focus on:

- Effectiveness of the use of geotextile membranes at culverts to maintain structural integrity, thus preventing fish passage issues
- Effectiveness of water management and erosion and sediment control measures and responses during sedimentation events
- Culvert sizing

Response from the Government of the Northwest Territories:

Based on the Government of Northwest Territories' (GNWT) ongoing operation and maintenance of NWT Highways, including the Inuvik to Tuktoyaktuk Highway, the GNWT has been developing updated design guidelines for large-diameter culverts, which will address design requirements to maintain adequate fish passage, including considerations for embedment, camber, permafrost, and construction practices. These are in addition to those outlined in the GNWT's Standard Specifications for Bridge Construction (GNWT, 2021). These design guidelines will also address hydrotechnical design criteria for culvert sizing, including scour protection and possible icing effects.

During construction of the Inuvik to Tuktoyaktuk Highway, culvert embedment was intentionally minimized due to concerns about a shallow active zone and permafrost degradation. Outside of Inuvik to Tuktoyaktuk Highway construction specifically, the GNWT utilizes the practice of embedding culverts to address perching issues.

All designs for large-diameter culverts in fish habitat will be reviewed by the Department of Fisheries and Oceans Canada (DFO), and concerns will be addressed prior to construction.

Lessons learned from the construction of the Inuvik to Tuktoyaktuk Highway included findings such as:

- Ensuring adequate material cover over culverts during construction is essential.
- Heavy construction loads during construction often create culvert perching issues.
- Having a clear understanding of the inlet and outlet elevations is critical to placing the culverts.
- Snow cover often is a challenge when laying culverts in the winter, as the substrate material can be obscured.
- Designing on topographical bases, such as LIDAR, rather than ground surveys can create inaccuracies.

Erosion and sedimentation control measures include design features, such as geotextile and rip rap, and additional control measures such as silt fencing. As noted by the GNWT in the response to ORS CanNor-03 (DFO-21), geotextiles are used to provide embankment stability and separation of granular materials and rip rap from native materials. The performance of erosion and sedimentation control measures is regularly inspected by road maintenance personnel to confirm the integrity and performance of the controls (see for example draft Erosion and Sedimentation Control Plan in Volume 5 of the Developer's Assessment Report).

References

Government of the Northwest Territories (GNWT). 2021. Standard Specifications for Bridge Construction. Accessed September 15, 2024, at: SSBC, Edition 1, 2021 (gov.nt.ca)

Topic: DFO-03: Crossing Summary Tables- Response to DAR Review Comments DFO-18, -28, and -29

Reviewer Preamble:

To assist with the review, DFO requested the Proponent resubmit Appendix 17A Tables 4.2 and 4.3 with additional information, such as channel width, wetted width, the size/number of culverts needed per crossing, and the year/month the fish assessment was conducted. The Proponent responded that DFO should refer to habitat assessment cards in Appendix 17A. Compiling this information in tables will help parties understand the potential impacts at water crossings more efficiently. Searching through multiple pages of appendices for this specific information is not efficient. Additional details, such as stream type and gradient, would also aid DFO in their review.

Reviewer Request:

To help with the review, DFO requests the Proponent resubmit Appendix 17A Tables 4.2 and 4.3 with the following additional information for each crossing:

- Specific ID
- Stream type
- Channel width
- Wetted width
- Gradient
- Estimated number, size, and type of culverts
- Year/month the fish assessment was conducted]
- Fish species (confirmed and potential)
- Reason why crossings were considered unlikely to be non-fish bearing (i.e., downstream barrier to fish passage.)
- Connecting waterbodies
- Availability of photographs (and reference to photograph # or page #, if applicable)

Response from the Government of the Northwest Territories:

Information about watercourse crossings will be used to inform the detailed design phase of the Project, which will follow the environmental assessment. Supplementary field data, as applicable, in addition to the existing information provided in the Developer's Assessment Report, will be compiled into a single document. This compiled document will be provided to Fisheries and Oceans Canada as part of their review under the *Fisheries Act* during the regulatory phase of the Project. At proposed watercourse crossings, physical data (e.g., channel with, wetted width, fish species presence, in-situ water quality) and photographs will be collected and available for review. Thus far, the information has been presented to support the environmental assessment, not regulatory authorizations.

Topic: DFO-02: Photographs of Proposed Culvert Crossings- Response to DAR Review Comments DFO-27 and -28

Reviewer Preamble:

Photographs are not available for all proposed culvert crossings and photographs available are not compiled in one document. This makes it more difficult for the reviewer to access and evaluate information. Photographs of each crossing will be requested to be compiled - in one document that is clear, concise, and follows either a chronological or spatial logic for ease of review - as part of the Fisheries Act Authorization application.

Reviewer Request:

As part of the Fisheries Act Authorization application, photographs of each crossing will be requested and shall be compiled in one document and in an orderly fashion. DFO recommends the Proponent gather all photographs available into one document, and plan to collect photographs at the crossings where they are currently unavailable.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) is currently undertaking a supplementary field program, which includes the collection of physical data (e.g., wetted width, substrate composition) and photographs of watercourse crossings along the Project alignment. This data will be used to inform the detailed design of the Project, which will be prepared following the environmental assessment.

The GNWT will compile the supplementary field data, in addition to the information provided in the Developer's Assessment Report, into a single supporting document for DFO as part of their review under the *Fisheries Act* following the environmental assessment and during the upcoming regulatory phase of the Project. The GNWT looks forward to further discussing how the requirements of the *Fisheries Act* apply to the Project.

Topic: DFO-01: Attachment Not Provided- Response to DAR Review Comment DFO-27

Preamble from the Mackenzie Valley Environmental Impact Review Board (Review Board):

The Proponent mentioned in their response that a memo entitled "Mackenzie Valley Highway Alignment, Sahtu Region – Fish Assessments by Tetra Tech" dated December 2021 was attached to their response (Attachment CANNOR-45A). However, no attachment was provided.

Request from the Review Board:

Proponent to please provide memo titled "Mackenzie Valley Highway Alignment, Sahtu Region – Fish Assessments by Tetra Tech" dated December 2021.

Response from the Government of the Northwest Territories:

The requested attachment has been provided as part of the response package. Note it was mis-referenced in the DAR and the correct reference is "Mackenzie Valley Highway Alignment, Sahtu Region – Fish Assessments by Tetra Tech" dated January 2022.

TETRA TECH

January 17, 2022

ISSUED FOR USE
FILE: 704-ENG.WTRI03067-01

Stantec Architecture Ltd.
4910 53rd Street
Yellowknife, NT X1A 2P4

Attention: Doug Chiperzak, Senior Fisheries Biologist, Stantec

Subject: Mackenzie Valley Highway Alignment, Sahtu Region – Fish Assessments

1.0 SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) has prepared the following for the Government of Northwest Territories on behalf of Stantec Architecture Ltd (Stantec). Included below are figures, site cards and photographs of each site assessed for fish and fish habitat along the proposed Mackenzie Valley Highway alignment (Sahtu Region) between September 28 and October 12, 2021.

2.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Stantec, the Government of Northwest Territories, and their agents. Tetra Tech Canada Inc. (operating as Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Stantec and the Government of Northwest Territories, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

3.0 CLOSURE

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

Respectfully submitted,
Tetra Tech Canada Inc.

FILE: 704-ENG.WTRI03067-01
FILE: 704-ENG.WTRI03067-01

Theresa McCaffrey, M.Sc.
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Principal Consultant
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APPENDIX

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

NATURAL SCIENCES

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

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Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

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

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by persons other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL ISSUES

The ability to rely upon and generalize from environmental baseline data is dependent on data collection activities occurring within biologically relevant survey windows.

It is incumbent upon the Client and any Authorized Party, to be knowledgeable of the level of risk that has been incorporated into the project design or scope, in consideration of the level of the environmental baseline information that was reasonably acquired to facilitate completion of the scope.

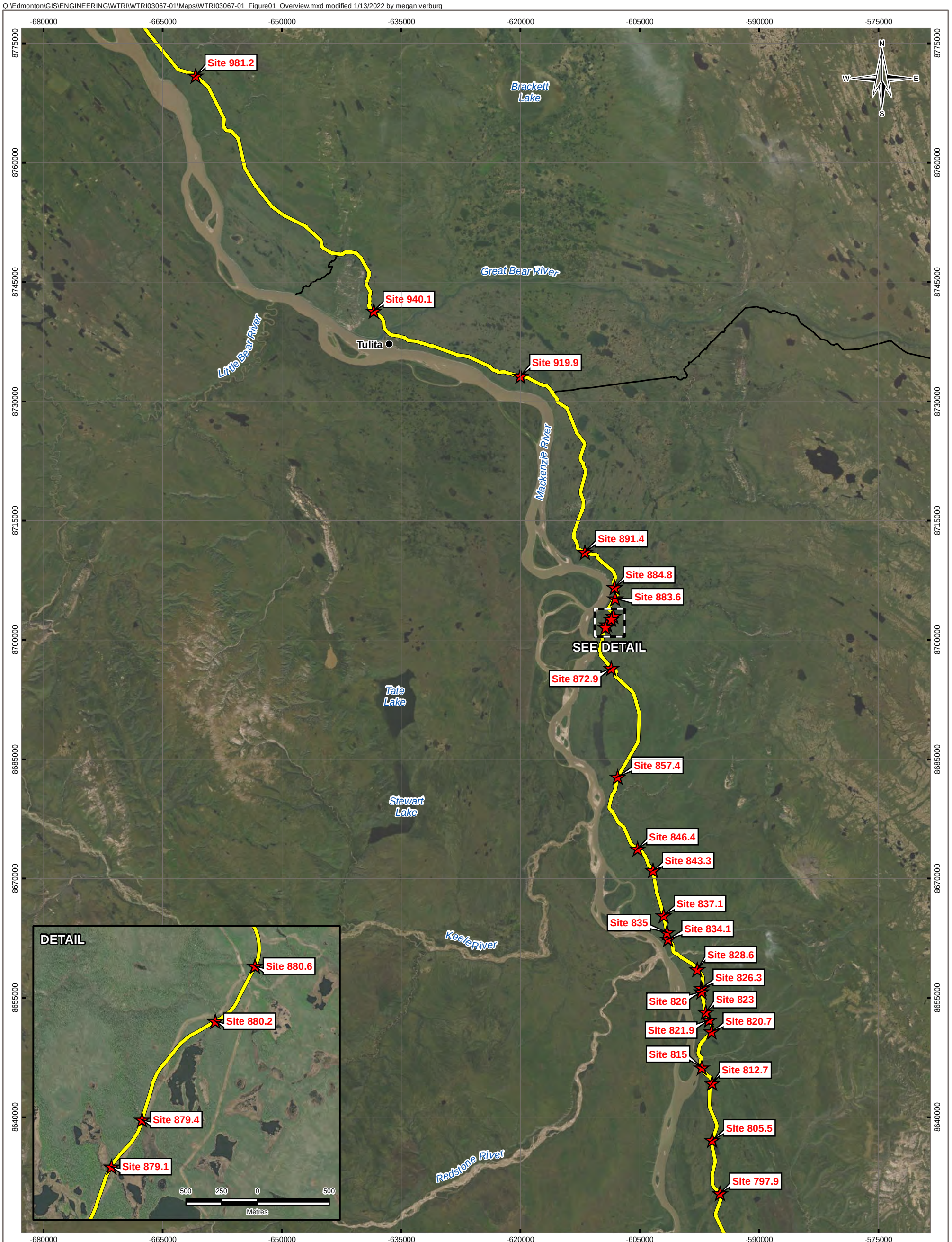
1.8 NOTIFICATION OF AUTHORITIES

TETRA TECH professionals are bound by their ethical commitments to act within the bounds of all pertinent regulations. In certain instances, observations by TETRA TECH of regulatory contravention may require that regulatory agencies and other persons be informed. The client agrees that notification to such bodies or persons as required may be done by TETRA TECH in its reasonably exercised discretion.

FIGURE

Figure 1 Overview

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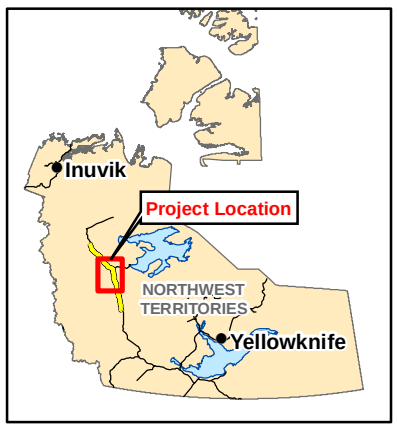


LEGEND

- Watercourse Crossing
- Mackenzie Valley Highway Extension

Base Data

- Populated Place
- Other Road



NOTES
Base data source: Imagery provided by ESRI; Maxar
CanVec 1:250,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Overview

PROJECTION Northwest Territories Lambert		**DATUM** NAD83		**CLIENT** Northwest Territories
Scale: 1:450,000 — 8 4 0 8 — Kilometres				TETRA TECH
FILE NO. WTRI03067-01_Figure01_Overview.mxd				
OFFICE Tt-EDM	**DWN** MRV	**CKD** SL	**APVD** TM	**REV** 0
DATE January 13, 2022	**PROJECT NO.** ENG.WTRI03067-01			**Figure 1**

SITE 797.9



LEGEND

- Watercourse Crossing
- Minnow Trap
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 797.9

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

TETRA TECH

FILE NO.
WTRI03067-01_Figure02_Site7979.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

Figure 2

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Mackenzie Valley Highway

Site 797.9 Unnamed Watercourse

UTM Location: 10W 437740 7101829 **Survey Date:** 10/1/2021; 10:55

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	4.1	5.8	4.3	13.0	16.8	-
Wetted Width (m)	2.7	3.7	3.7	7.1	5.6	-
Depth at LDB + 25% (m)	0.4	0.3	0.9	0.9	0.2	-
Depth at LDB + 50% (m)	0.3	0.6	0.9	1.2	0.4	-
Depth at LDB + 75% (m)	0.3	0.6	0.5	0.8	0.4	-
Max.BankfullDepth (m)	1.3	1.0	1.2	0.90	0.72	-
Gradient (%)	1	1	1	1	1	-
Dominant Habitat Unit	DD	FL	FL	FL	DD	WL
Stream Bed						
Substrate (% of Transect Area) Organics	50	20	40	30	60	100
Fines	50	80	60	70	30	0
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.9	1.0	1.0	0.6	0.2	0.2	0.3	0.3	0.4	0.3	-	-
Bank Slope (°)	90	60	50	50	90	60	30	30	80	50	-	-
Bank Stability	US	US	MS	MS	S	S	S	S	MS	MS	-	-
Dom. Bank Material	F	F	F	F	F	F	O	F	O	F	-	-
Subdom. Bank Material	O	O	O	O	O	O	F	O	F	BL	-	-
Dom. Riparian Veg.	G	G	G	G	G	G	G	G	C	M	G	G
Subdom. Riparian Veg.	S	S	G	D	G	G	M	C	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	10
Dom. Instream Cover:	WD	Dom. Overhead Cover:	C
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	S
Maximum Depth (m)	1.2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	10:55
Water Temperature (°C):	4.5
Dissolved Oxygen (mg/L):	10.49
Sp. Conductivity (µs/cm):	339
pH:	7.50
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	O
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Flood

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None-Poor	None-Poor
Overwintering:	Poor-Moderate	Poor-Moderate	Poor-Moderate
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	72.0	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
BROOK STICKLEBACK	-	13	-	0.18	2.5%
PEARL DACE	-	20	-	0.28	3.9%
-	-	1	-	0.01	0.2%
FINESCALE DACE	-	477	-	6.63	93.3%

General Comments

Grasses in stream, slight undercutting and exposed roots on left bank 100 m upstream. Logjams upstream and downstream of crossing. Occasional vegetation bars. Crossing was cleared for winter road, abundant grasses instream. Old beaver dam 300m downstream prior to wetland area. Could not measure some aspects due to flooding. The one fish not identified in the table is tentatively identified as Northern redbelly dace.



Photo 1: Site 797.9—Facing downstream at 100 m upstream from centerline.



Photo 2: Site 797.9—Facing downstream at 100 m upstream from centerline.



Photo 3: Site 797.9—Aerial photo facing downstream looking at Centre-line.



Photo 4: Site 797.9—Facing downstream at 300 m downstream from centerline.



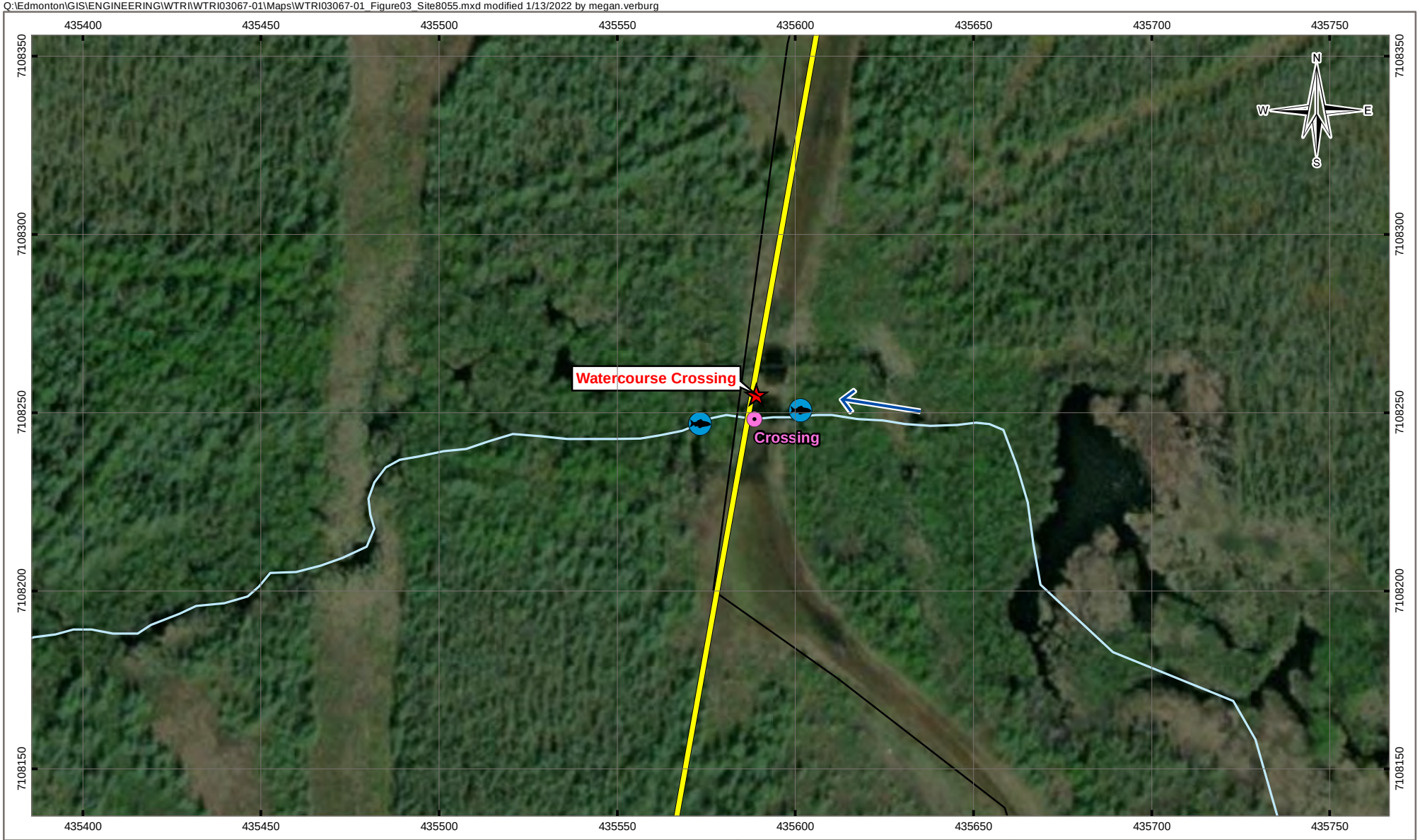
Photo 5: Site 797.9— Crossing location facing north and looking upstream.



Photo 6: Site 797.9—Channel at crossing, looking downstream.

SITE 805.5

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LEGEND

- Watercourse Crossing
- Minnow Trap
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

Scale: 1:1,500
30 15 0 30
Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure03_Site8055.mxd

CLIENT Northwest Territories

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 805.5

Figure 3

TETRA TECH

Mackenzie Valley Highway

Site 805.5 Unnamed Watercourse

UTM Location: 10W 435589 7108255 **Survey Date:** 10/1/2021; 13:13

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	13:13
Water Temperature (°C):	4.1
Dissolved Oxygen (mg/L):	9.10
Sp. Conductivity (µs/cm):	257
pH:	7.53
Turbidity (NTU):	Clear

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Good	None	None
Overwintering:	Poor-moderate	Poor	Poor
Rearing:	Good	Poor-moderate	Poor-moderate
Passage:	Moderate	Poor-moderate	Poor-moderate

Habitat Inventory / Reach Data

Instream Cover (%):	-	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	-
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	-	Dom. Aquatic Veg. Type:	-

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	44.4	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
BROOK STICKLEBACK	-	106	-	2.39	67.9%
PEARL DACE	-	50	-	1.13	32.1%

General Comments

The site was a flooded wetland and only had a defined channel at the crossing location. An assessment at the crossing identified the substrate to be 20% organics and 80% fines. Channel width as it crossed the winter road was 0.3 m but was undefined upstream and downstream of the crossing due to flooding. Wetted width at the crossing was 0.14m and the average depth was 0.45 m (0.36 m to 0.62m). Dominant riparian vegetation was grasses with shrubs.



Photo 1: Site 805.5—Facing downstream at 50 m downstream from centerline.



Photo 2: Site 805.5—View of winter road crossing wetland.

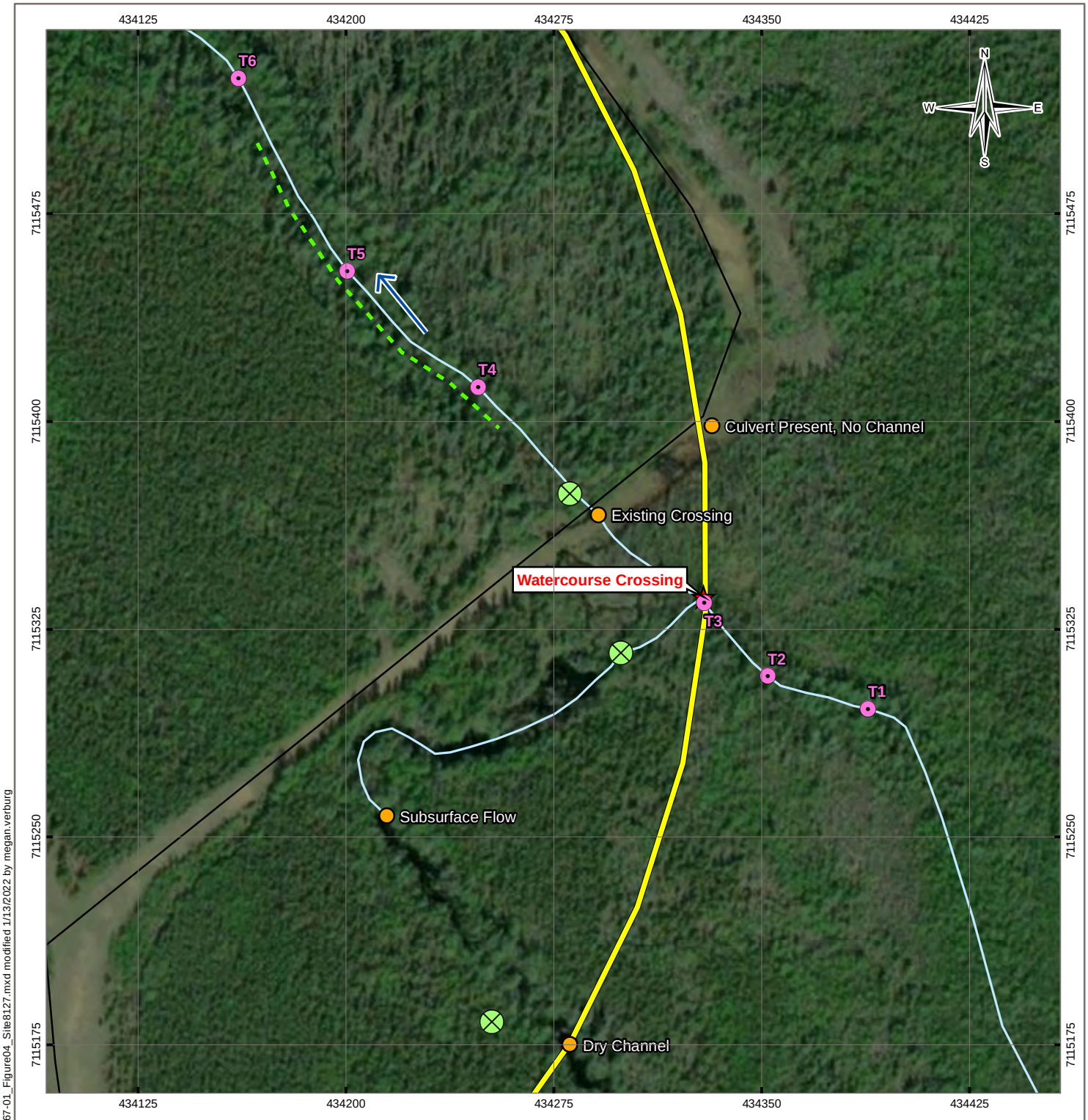


Photo 3: Site 805.5—Aerial view of crossing and upstream habitat.



Photo 4: Site 805.5—Aerial photo facing the centerline.

SITE 812.7



LEGEND

- Watercourse Crossing
- Beaver Dam
- Site Feature
- Transect
- Flow Direction
- Electrofishing
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 812.7

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure04_Site8127.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

TETRA TECH

Figure 4

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Mackenzie Valley Highway

Site 812.7 Unnamed Watercourse

UTM Location: 10W 434329 7115337 **Survey Date:** 10/1/2021; 16:17

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	-	1.3	1.37	1.18	1.6	1.8
Wetted Width (m)	-	0.76	1.12	0.75	0.75	1
Depth at LDB + 25% (m)	-	0.13	0.18	0.38	0.13	0.09
Depth at LDB + 50% (m)	-	0.21	0.14	0.51	0.17	0.09
Depth at LDB + 75% (m)	-	0.25	0.11	0.57	0.19	0.09
Max.BankfullDepth (m)	-	0.55	0.7	0.95	0.75	0.56
Gradient (%)	1	1	1	1	2	3
Dominant Habitat Unit	R2	R3	FL	FL	R2	RF
Stream Bed						
Substrate (% of Transect Area) Organics	100	30	50	0	0	0
Fines	0	20	50	30	10	20
Small Gravel	0	50	0	40	30	30
Large Gravel	0	0	0	0	10	40
Cobble	0	0	0	10	50	10
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	20	0	0
Embeddedness	N	M	N	L	N	L

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	-	-	0.3	0.3	0.5	0.6	0.5	0.4	0.6	0.6	0.43	0.52
Bank Slope (°)	-	-	90	70	80	80	80	80	70	75	50	45
Bank Stability	-	-	S	S	S	S	MS	MS	MS	MS	S	S
Dom. Bank Material	O	O	SG	SG	O	O	F	F	SG	SG	F	F
Subdom. Bank Material	F	F	O	O	F	F	O	O	F	F	O	O
Dom. Riparian Veg.	D	D	D	D	S	S	D	D	D	D	D	D
Subdom. Riparian Veg.	S	S	S	S	D	D	S	S	S	S	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	70
Dom. Instream Cover:	Co	Dom. Overhead Cover:	M
Subdom. Instream Cover:	UCB	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:17
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	12.53
Sp. Conductivity (µs/cm):	435
pH:	7.74
Turbidity (NTU):	CLEAR

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	DC
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Good	Poor	Poor
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate	Moderate

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	263	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
225	30	12	150

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED	-	-	-	-	-
	-	-	-	-	
	-	-	-	-	
	-	-	-	-	
	-	-	-	-	

General Comments

This channel had excellent spawning potential, and consisted of good fish habitat. There is a small change in grade near 300 m downstream but this would not affect fish passage. There is woody debris throughout and some minor logjam which may create partial barriers to fish passage. There is trace undercut banks upstream, and channel becomes poorly defined with low water depths at 100 m upstream. There were several beaver dams at this site. One at the crossing on the downstream side of centerline, one at a tributary to the channel approximately 50 m upstream, and one further upstream the tributary watercourse (however, this channel was dry). The second channel goes runs parallel to the winter road and goes subsurface near an abandoned and dry beaver dam.



Photo 1: Site 812.7—Facing upstream at 100 m upstream from centerline.



Photo 2: Site 812.7—Facing downstream at 100 m downstream from centerline.



Photo 3: Site 812.7—Facing downstream at 200 m downstream from centerline.



Photo 4: Site 812.7—Facing upstream 300 m downstream from centerline.



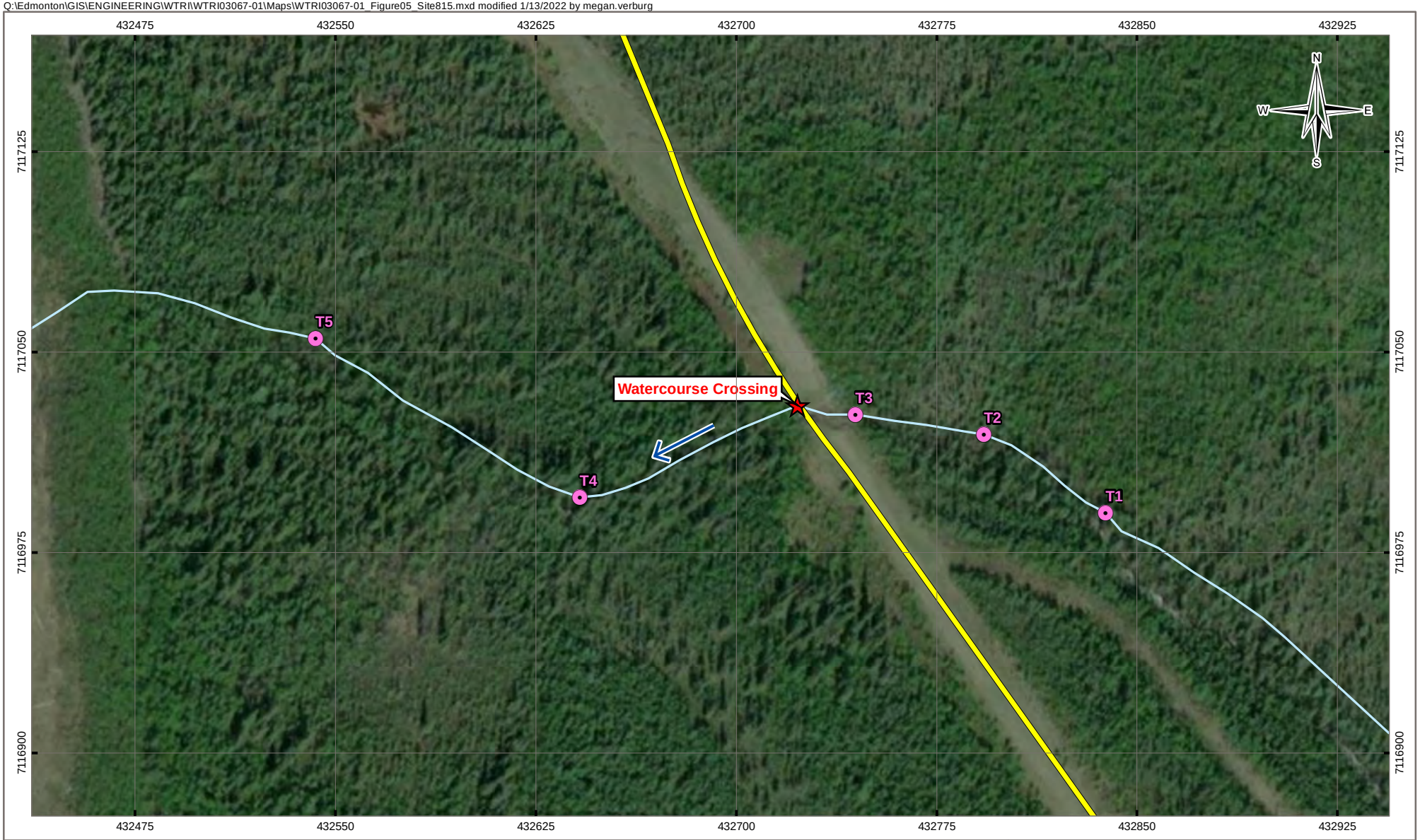
Photo 5: Site 812.7—Existing crossing with the winter road, approximately 40 m downstream from proposed line.



Photo 6: Site 812.7— Water in clearing approximately 50 m north of site 812.7. N

SITE 815

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LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:2,000

40 20 0 40

Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure05_Site815.mxd

CLIENT Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 815

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 5

Mackenzie Valley Highway

Site 815 Unnamed Watercourse

UTM Location: 10W 432721E 7117031N **Survey Date:** 10/2/2021; 13:05

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.8	2.4	1.9	1.8	2.5	-
Wetted Width (m)	1.3	1.0	1.4	1.0	0.6	-
Depth at LDB + 25% (m)	0.1	0.1	0.1	0.0	0.0	-
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.0	0.1	-
Depth at LDB + 75% (m)	0.1	0.0	0.1	0.0	0.0	-
Max.BankfullDepth (m)	0.5	0.6	0.4	0.4	0.1	-
Gradient (%)	-	-	-	-	-	-
Dominant Habitat Unit	R2	DD	R2	IP1	WL	-
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	10	10	90	-
Substrate (% of Transect Area) Fines	30	0	60	10	10	-
Substrate (% of Transect Area) Small Gravel	30	20	20	40	0	-
Substrate (% of Transect Area) Large Gravel	20	40	0	20	0	-
Substrate (% of Transect Area) Cobble	20	40	10	20	0	-
Substrate (% of Transect Area) Boulder	0	0	0	0	0	-
Substrate (% of Transect Area) Bedrock	0	0	0	0	0	-
Embeddedness	L	N	L	M	H	-

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.3	-	-	-	-
Bank Slope (°)	70	60	30	80	50	30	90	90	-	-	-	-
Bank Stability	MS	MS	MS	MS	MS	MS	MS	MS	-	-	-	-
Dom. Bank Material	O	O	F	F	O	F	SG	F	SG	F	-	-
Subdom. Bank Material	F	F	O	O	SG	SG	O	O	O	O	-	-
Dom. Riparian Veg.	S	S	S	S	S	S	D	D	D	D	-	-
Subdom. Riparian Veg.	C	D	G	G	G	G	S	S	S	S	-	-

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	80
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	G
Maximum Depth (m)	-	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:05
Water Temperature (°C):	2.3
Dissolved Oxygen (mg/L):	12.13
Sp. Conductivity (µs/cm):	760
pH:	8.37
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	FC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	Poor	None-Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor-Moderate	Poor-Moderate	None-Poor
Passage:	Poor-Moderate	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings			
Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

Fish habitat is poor, unlikely to hold fish due to lack of outlet downstream (converts to wetland) and logjams upstream. Crossing is eroded with two culverts that are not in line with watercourse. Not deep enough for minnow traps and too much woody debris/ too narrow for electrofishing. Not suitable for fish due to woody debris barriers throughout crossing section and poor connectivity. Minor undercutting of banks upstream.



Photo 1: Site 815—Facing upstream from 100 m upstream from centerline.



Photo 2: Site 815—Facing upstream from 50 m upstream from centerline.



Photo 3: Site 815—Facing upstream at 100 m downstream from centerline.



Photo 4: Site 815—Facing downstream from 200 m downstream from centerline.



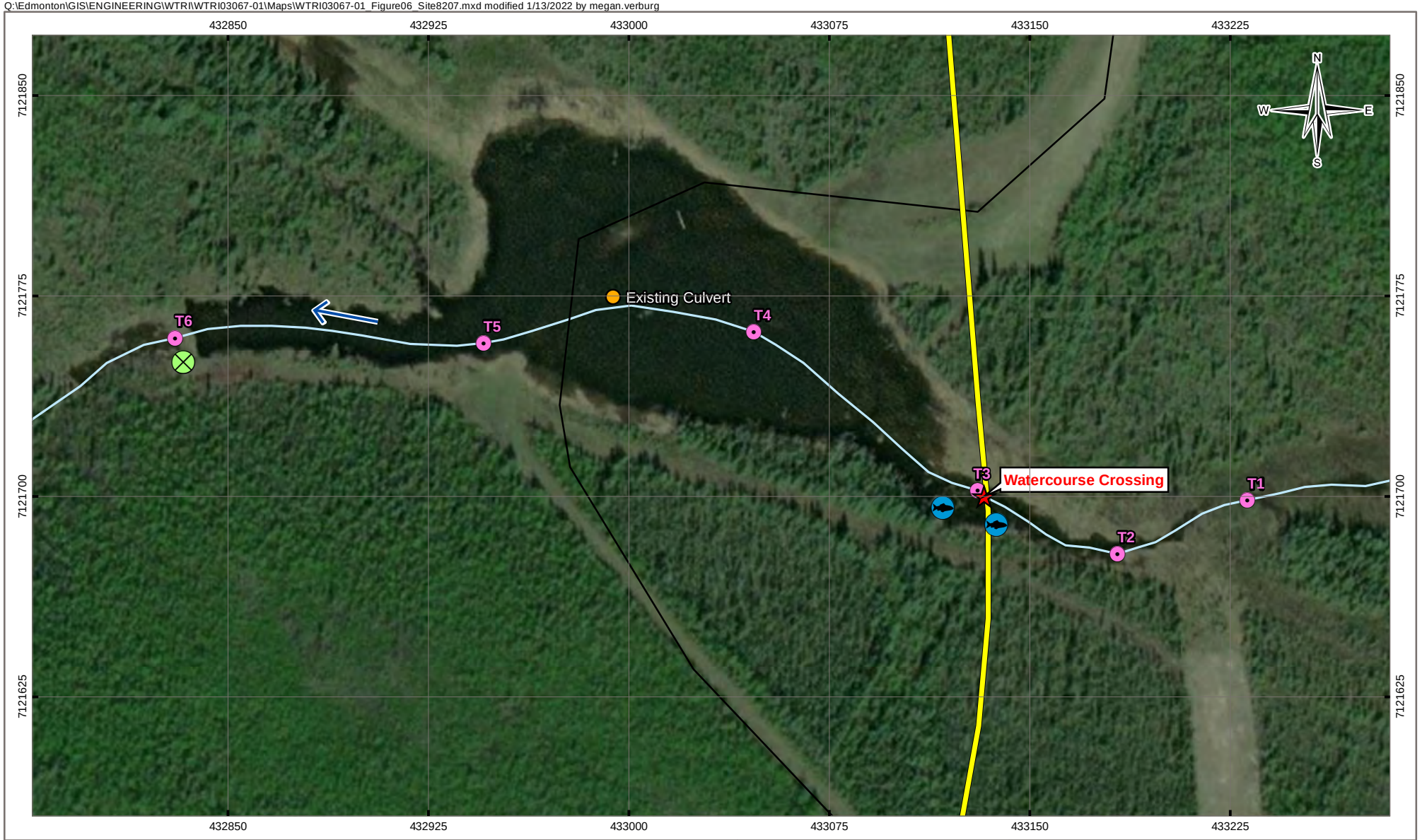
Photo 5: Site 815—aerial view of centerline.



Photo 6: Site 815—Existing culvert, facing downstream at centerline.

SITE 820.7

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LEGEND

- Watercourse Crossing
- Beaver Dam
- Minnow Trap
- Site Feature
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

Scale: 1:2,000
40 20 0 40
Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure06_Site8207.mxd

CLIENT: Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 820.7

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 6

Mackenzie Valley Highway

Site 820.7 Unnamed Watercourse

UTM Location: 10W 433131 7121700 **Survey Date:** 10/6/2021; 14:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	3.4	13.5	15.5	95.0	7.1	3.2
Wetted Width (m)	3.4	4.9	11.6	25.0	4.9	1.2
Depth at LDB + 25% (m)	0.1	0.1	0.2	0.2	0.4	0.1
Depth at LDB + 50% (m)	0.2	0.1	0.2	0.2	0.5	0.1
Depth at LDB + 75% (m)	0.1	0.1	0.3	0.3	0.4	0.1
Max.BankfullDepth (m)	0.0	1.3	0.7	2.0	1.0	0.5
Gradient (%)	2	2	1	1	1	2
Dominant Habitat Unit	FL	FL	IP1	IP1	IP1	BD
Stream Bed						
Substrate (% of Transect Area) Organics	100	30	100	60	100	0
Fines	0	0	0	40	0	25
Small Gravel	0	30	0	0	0	20
Large Gravel	0	20	0	0	0	25
Cobble	0	10	0	0	0	10
Boulder	0	10	0	0	0	20
Bedrock	0	0	0	0	0	0
Embeddedness	N	H	N	N	N	H

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.0	0.2	0.4	1.3	0.2	0.4	0.3	0.3	0.2	0.5	0.20	0.20
Bank Slope (°)	10	10	15	3	10	40	10	30	30	40	30	70
Bank Stability	US	US	MS	US	MS	S	MS	MS	MS	MS	US	US
Dom. Bank Material	O	O	O	O	O	O	O	O	F	F	F	SG
Subdom. Bank Material	F	F	F	F	F	F	F	F	O	O	O	LG
Dom. Riparian Veg.	S	S	G	G	G	G	G	G	G	G	G	G
Subdom. Riparian Veg.	G	G	S	S	S	C	M	M	D	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	5
Dom. Instream Cover:	G	Dom. Overhead Cover:	C
Subdom. Instream Cover:	EV	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Quality Data		Channel Characteristics	
Time of Day (HH:MM):	14:01	Pattern:	ME
Water Temperature (°C):	2.3	Islands:	O
Dissolved Oxygen (mg/L):	10.47	Bars:	N
Sp. Conductivity (µs/cm):	731	Coupling:	DC
pH:	7.72	Confinement:	OC
Turbidity (NTU):	Clear	Flow Stage:	Pooled

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	None	None
Overwintering:	Poor	Poor	None-Poor
Rearing:	Moderate	Poor	None-Poor
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	50.0	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Poorly defined channel within floodplain with pockets of grasses throughout. Upstream of 300 m downstream is a beaver dam. There was limited crown cover due to flooded region, which likely fills during freshet. Aquatic vegetation growing throughout. Exposed culvert along winter road.



Photo 1: Site 820.7—Facing downstream at 50 m upstream from centerline.



Photo 2: Site 820.7—Facing downstream at 100 m downstream from centerline.



Photo 3: Site 820.7—Facing downstream from 200 m downstream from centerline.



Photo 4: Site 820.7—Facing upstream at 300 m downstream from centerline.



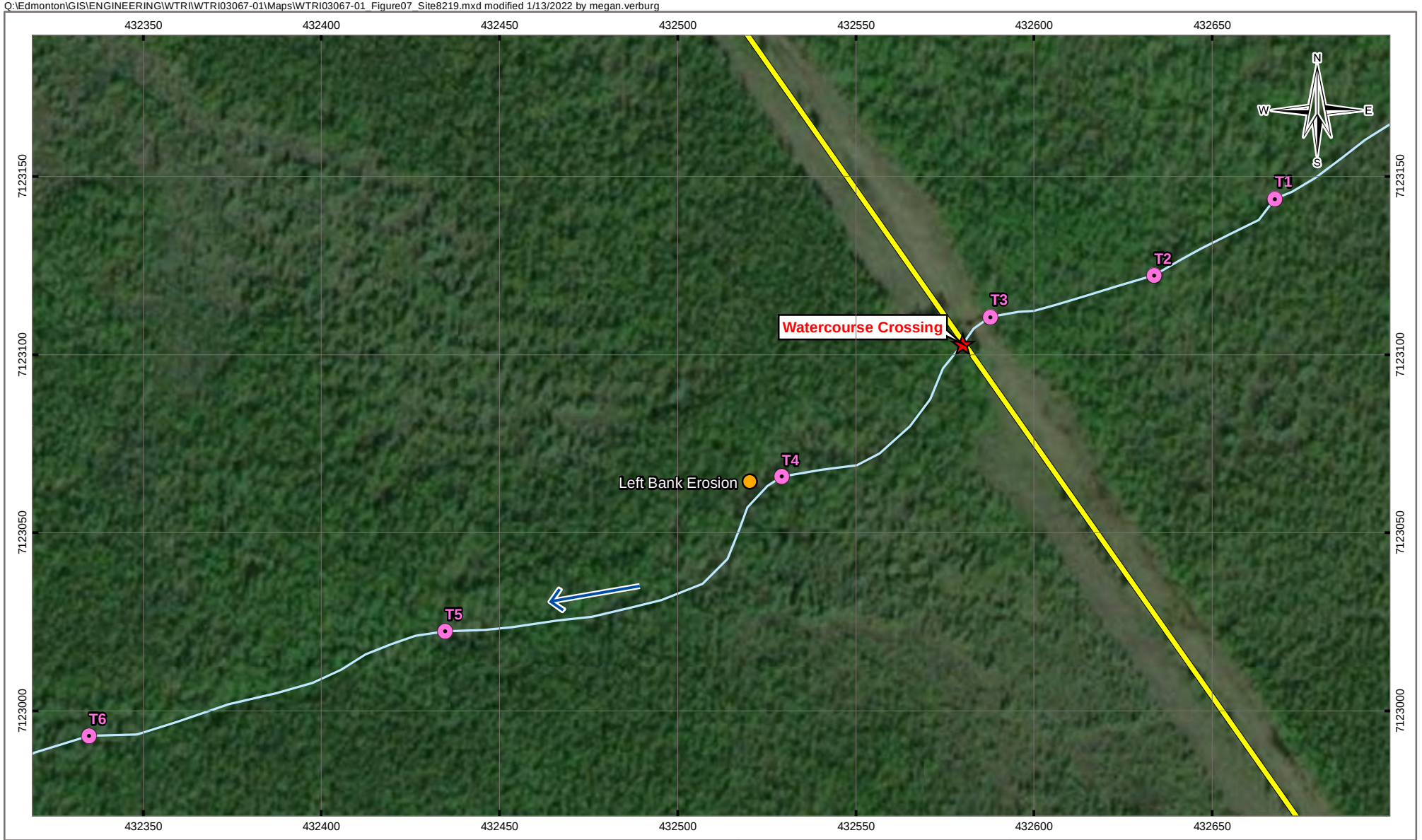
Photo 5: Site 820.7—Aerial view of the site looking west.



Photo 6: Site 820.7—Damaged culvert at existing centerline.

SITE 821.9

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LEGEND

- Watercourse Crossing
- Site Feature
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:1,500

30 15 0 30

Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure07_Site8219.mxd

CLIENT
Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 821.9

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 7

Mackenzie Valley Highway

Site 821.9 Unnamed Watercourse

UTM Location: 10W 432580 7123103 **Survey Date:** 10/9/2021; 11:13

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.2	1.5	1.3	1.4	1.2	2.1
Wetted Width (m)	1.3	1.3	0.9	1.0	0.2	0.9
Depth at LDB + 25% (m)	0.1	0.2	0.4	0.0	0.0	0.1
Depth at LDB + 50% (m)	0.3	0.3	0.4	0.2	0.0	0.1
Depth at LDB + 75% (m)	0.3	0.2	0.4	0.1	0.0	0.1
Max.BankfullDepth (m)	0.57	0.49	0.71	0.70	0.23	0.68
Gradient (%)	2	2	1	2	2	1
Dominant Habitat Unit	P3	IP3	R2	R2	DR	FL
Stream Bed						
Substrate (% of Transect Area) Organics	20	40	0	0	40	30
Fines	30	0	50	0	30	40
Small Gravel	50	60	30	100	30	30
Large Gravel	0	0	20	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.1	0.2	0.6	0.6
Bank Slope (°)	40	60	90	90	30	20	90	100	45	45	30	30
Bank Stability	US	US	US	US	MS	MS	US	US	MS	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	M	S	S	D	D	S	S	C	S
Subdom. Riparian Veg.	D	D	M	S	G	G	D	D	D	D	S	C

Habitat Inventory / Reach Data

Instream Cover (%):	-	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	WD
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.4	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	11:13
Water Temperature (°C):	1.4
Dissolved Oxygen (mg/L):	7.52
Sp. Conductivity (µs/cm):	1,097
pH:	7.78
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Moderate	Moderate
Overwintering:	Poor	Poor	Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort
No Electrofishing	- (s)
No Trapping	- (hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Some sign of grasses under snow as well. Undercut on left bank occasionally in upstream reach. Abundant woody debris and leaves resting on top of sediment throughout, Dry channel between 100 m and 200 m downstream, frozen to bed and not enough flow. Debris buildup occasionally thoughout,the watercourse creating potential barriers to fish. Woody debris overhanging throughout. No fishing conducted due to freezing conditions.



Photo 1: Site 821.9—Upstream view of 100 m downstream from centerline.



Photo 2: Site 821.9— Downstream view of 50 m upstream from centerline.



Photo 3: Site 821.9— Upstream view of channel at centerline.



Photo 4: Site 821.9—downstream view of crossing from aerial view.



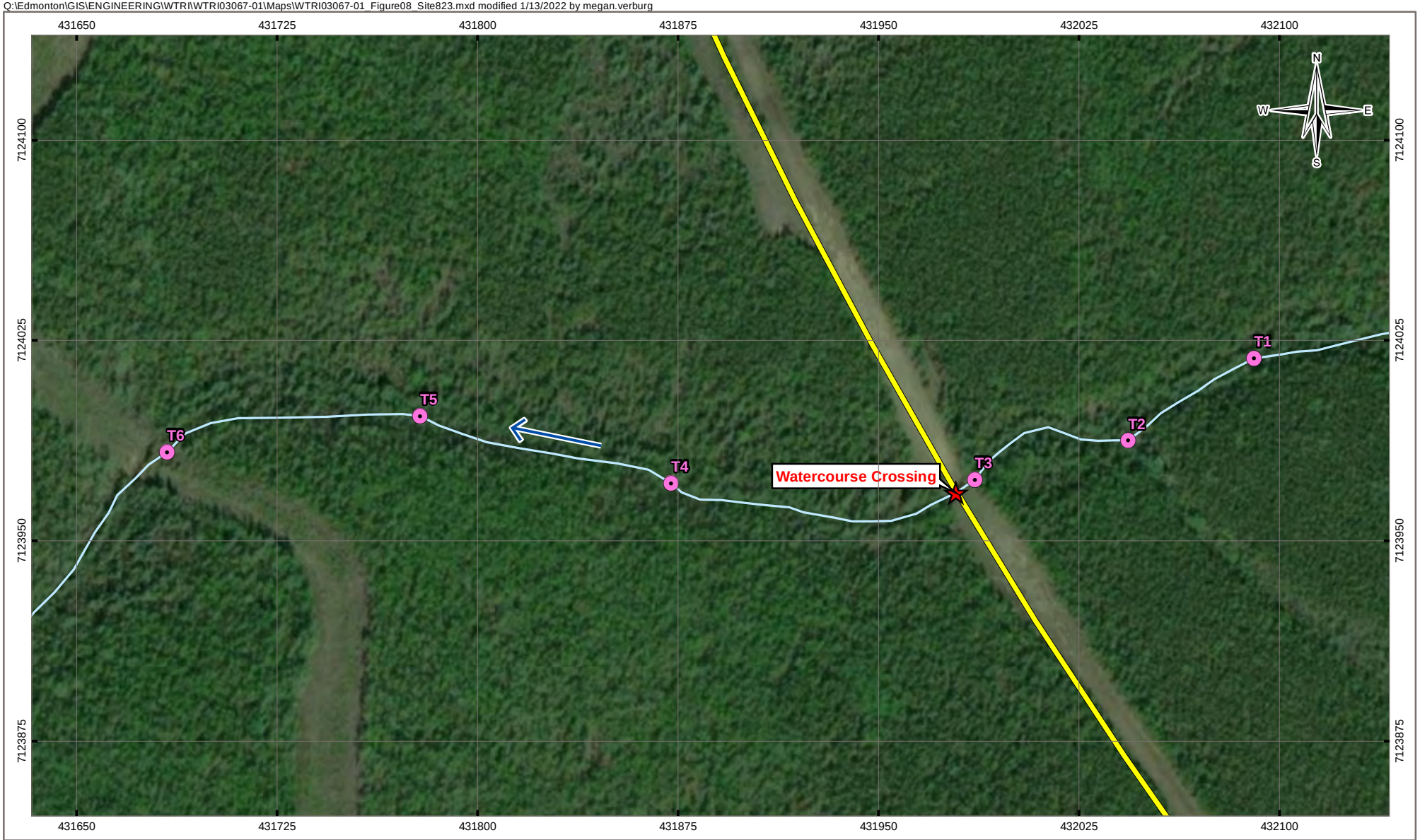
Photo 5: Site 821.9— View of winter road looking northwest toward watercourse crossing.



Photo 6: Site 821.9—view of existing crossing.

SITE 823

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LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:2,000

40 20 0 40

Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure08_Site823.mxd

CLIENT
Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 823

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 8

TETRA TECH

Mackenzie Valley Highway

Site 823 Unnamed Watercourse

UTM Location: 10W 431979 7123968 **Survey Date:** 10/6/2021; 16:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.9	1.3	0.2	0.2	0.1	0.0
Wetted Width (m)	2.5	1.0	0.1	0.0	0.1	0.0
Depth at LDB + 25% (m)	2.2	1.7	0.2	0.2	0.3	0.0
Depth at LDB + 50% (m)	3.0	1.0	0.1	0.2	0.1	0.0
Depth at LDB + 75% (m)	1.7	1.4	0.4	0.4	0.3	0.0
Max.BankfullDepth (m)	4.1	2.3	0.97	0.84	0.77	0.43
Gradient (%)	3	2	2	2	1	1
Dominant Habitat Unit	R1	RF	R1	R1	R1	R1
Stream Bed						
Substrate (% of Transect Area) Organics	0	0	0	0	0	0
Fines	0	0	0	10	40	0
Small Gravel	0	0	0	30	20	10
Large Gravel	20	30	30	40	30	20
Cobble	30	30	30	20	0	60
Boulder	45	39	30	0	10	10
Bedrock	5	1	20	0	0	0
Embeddedness	L	L	N	L	L	L

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	0.8	1.1	0.6	0.4	0.6	0.4	0.4	0.4	0.5	0.4	0.4	0.4
Bank Slope (°)	90.0	80.0	65.0	40.0	80.0	80.0	30.0	60.0	80.0	60.0	30.0	70.0
Bank Stability	MS	MS	MS	MS	MS	MS	MS	MS	US	US	MS	MS
Dom. Bank Material	F	F	O	O	F	F	F	F	O	O	O	O
Subdom. Bank Material	O	O	F	F	O	O	O	O	F	F	F	F
Dom. Riparian Veg.	D	C	S	S	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	S	S	C	C	C	C	M	M	C	C	C	C

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	60
Dom. Instream Cover:	Co	Dom. Overhead Cover:	S
Subdom. Instream Cover:	UCB	Subdom. Overhead Cover:	C
Maximum Depth (m)	3.0	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:00
Water Temperature (°C):	0.3
Dissolved Oxygen (mg/L):	11.60
Sp. Conductivity (µs/cm):	1,123
pH:	8.14
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ST
Islands:	I
Bars:	N
Coupling:	CO
Confinement:	OC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Poor-Moderate	Poor
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Low water levels at time of assessment and was mostly frozen. Abundant woody debris and logjams throughout reach, some bank erosion and some undercut banks. No fishing was conducted due to freezing and frozen conditions.



Photo 1: Site 823—Upstream view of 300 m downstream from centerline, located within the pipeline clearing.



Photo 2: Site 823—Upstream view of 100 m downstream from centerline/



Photo 3: Site 823—Upstream view from crossing location.



Photo 4: Site 823— Upstream view of 100 m upstream from centerline.



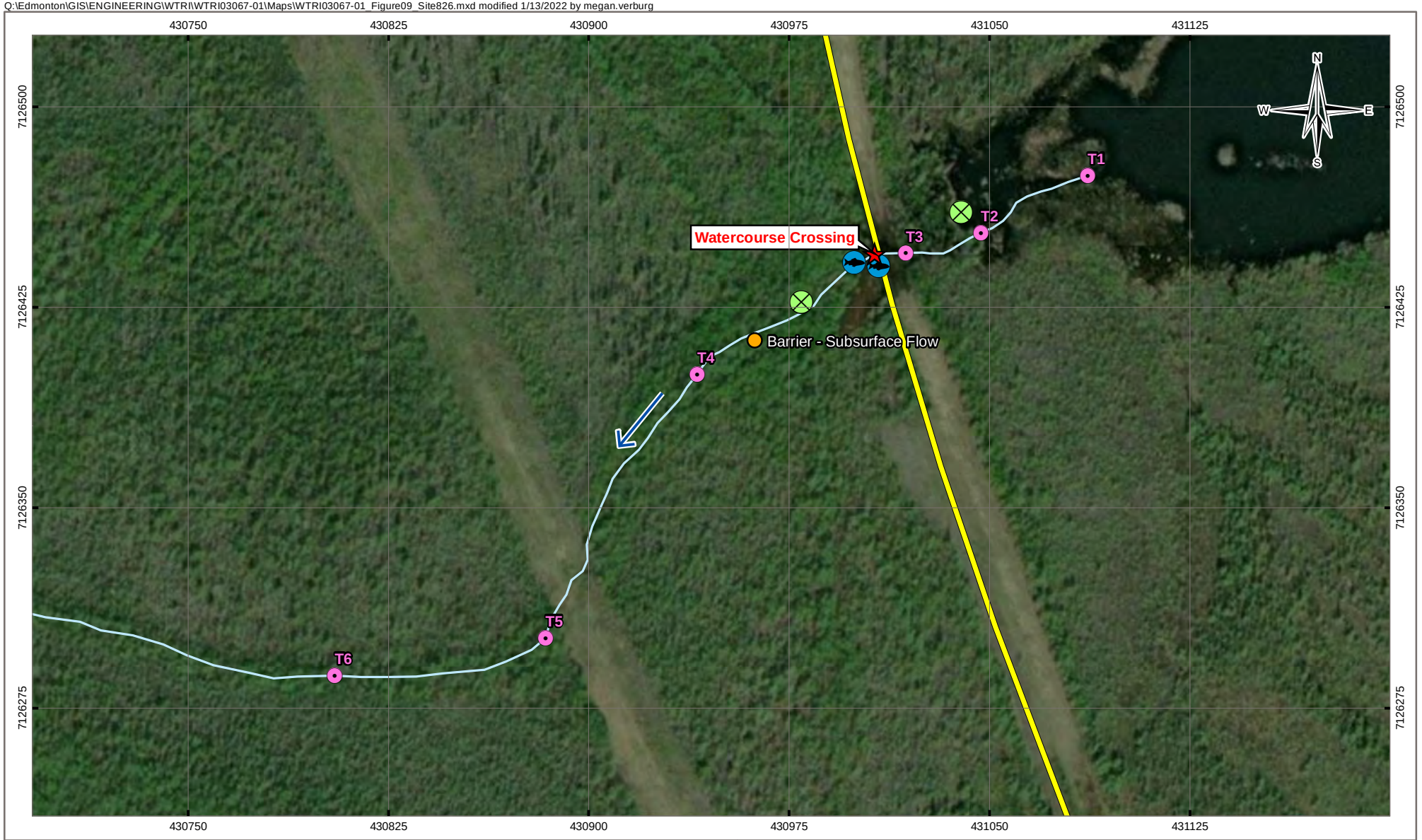
Photo 5: Site 823—View of existing culvert at centerline, looking downstream.



Photo 6: Site 823— View of centerline from existing clearing, looking southeast.

SITE 826

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LEGEND

- Watercourse Crossing
- Beaver Dam
- Minnow Trap
- Site Feature
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:2,000

40 20 0 40

Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure09_Site826.mxd

CLIENT Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 826

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

Figure 9

Mackenzie Valley Highway

Site 826 Unnamed Watercourse

UTM Location: 10W 431007 7126445 **Survey Date:** 10/8/2021; 13:37

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	3.0	0.8	1.8	1.3	1.0	1.0
Wetted Width (m)	2.1	0.6	1.1	0.6	0.8	0.6
Depth at LDB + 25% (m)	0.2	0.3	0.3	0.0	0.2	0.1
Depth at LDB + 50% (m)	0.2	0.3	0.3	0.1	0.2	0.1
Depth at LDB + 75% (m)	0.2	0.2	0.2	0.2	0.2	0.1
Max.BankfullDepth (m)	0.54	0.51	0.69	0.34	0.46	0.48
Gradient (%)	2	2	2	3	4	4
Dominant Habitat Unit	FL	R3	R3	DD	DD	DD
Stream Bed						
Substrate (% of Transect Area) – Organics	0	0	60	100	100	100
Substrate (% of Transect Area) – Fines	100	100	40	0	0	0
Substrate (% of Transect Area) – Small Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Large Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Cobble	0	0	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.4	0.2	0.2	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.4
Bank Slope (°)	45	60	45	45	80	90	10	10	80	50	50	50
Bank Stability	MS	US	MS	MS	MS	MS	US	US	US	US	US	US
Dom. Bank Material	O	O	O	O	F	F	O	O	O	O	F	O
Subdom. Bank Material	F	F	F	F	O	O	F	F	F	F	O	F
Dom. Riparian Veg.	G	G	G	G	G	G	S	S	S	S	S	S
Subdom. Riparian Veg.	S	S	S	S	S	S	G	G	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	80	Overhead Cover (%):	80
Dom. Instream Cover:	WD	Dom. Overhead Cover:	WD
Subdom. Instream Cover:	DP	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:40
Water Temperature (°C):	2.0
Dissolved Oxygen (mg/L):	11.82
Sp. Conductivity (µs/cm):	439
pH:	7.82
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Pooled

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	None	None
Overwintering:	Moderate-Good	Moderate	Poor-Moderate
Rearing:	Moderate-Good	Moderate-Good	Moderate-Good
Passage:	Moderate	Moderate	Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	44.7	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Upstream has a ponded area that may provide good overwintering habitat. The channel is irregular with poor connectivity upstream of centerline with limited overhanging vegetation and subsurface flow around historic beaver dam. Downstream has abundant woody debris over channel and good cover from shrubs. There is evidence that there was a fire previously here. Approximately 200 m downstream, banks are unstable with occasional erosion throughout stretch. Most of the overhanging vegetation is shrubs.



Photo 1: Site 826— Aerial view of crossing, looking upstream.



Photo 2: Site 826— Downstream view of 300 m downstream from centerline.



Photo 3: Site 826— Downstream view from 100 m upstream from centerline.



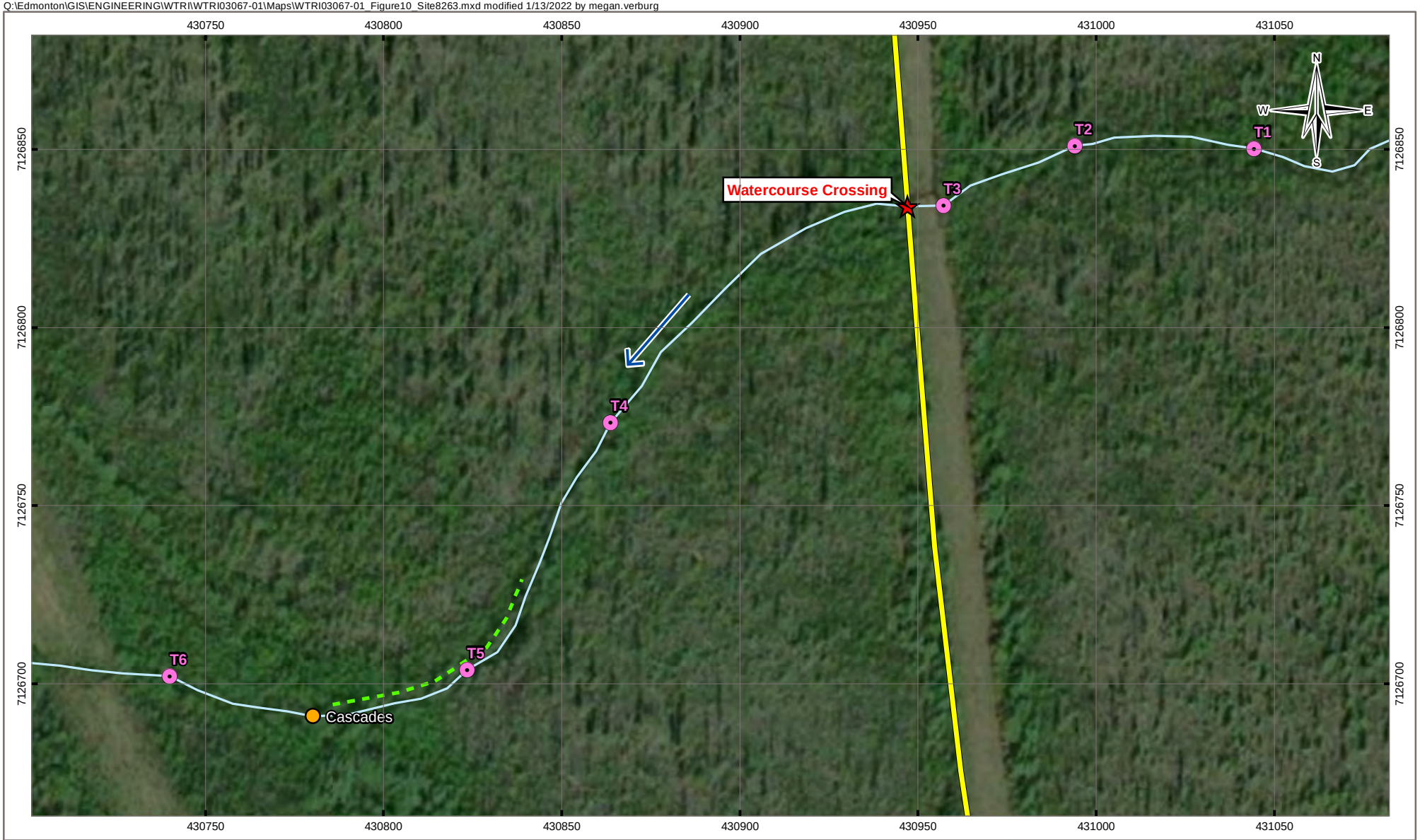
Photo 4: Site 826— Upstream view from 50 m upstream from centerline.



Photo 5: Site 826— View of crossing from centerline, looking downstream.

SITE 826.3

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LEGEND

- Watercourse Crossing
- Site Feature
- Transect
- Electrofishing
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:1,500

30 15 0 30

Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure10_Site8263.mxd

CLIENT
Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 826.3

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 10

Mackenzie Valley Highway

Site 826.3 Unnamed Watercourse

UTM Location: 10W 430947 7126834 **Survey Date:** 10/8/2021; 15:17

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	4.0	2.7	1.1	1.6	2.9	1.1
Wetted Width (m)	4.0	2.3	0.9	1.1	1.8	0.8
Depth at LDB + 25% (m)	0.1	0.2	0.1	0.1	0.1	0.1
Depth at LDB + 50% (m)	0.2	0.3	0.1	0.2	0.2	0.2
Depth at LDB + 75% (m)	0.1	0.3	0.1	0.1	0.2	0.2
Max.BankfullDepth (m)	1.6	0.52	0.34	0.41	0.70	0.40
Gradient (%)	2	2	2	2	2	2
Dominant Habitat Unit	DD	R3	R3	R3	R3	R3
Stream Bed						
Substrate (% of Transect Area) Organics	100	90	100	100	70	100
Fines	0	10	0	0	30	0
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	1.4	0.3	0.2	0.2	0.2	0.1	0.3	0.1	0.5	0.4	0.2	0.2
Bank Slope (°)	85.0	20.0	30.0	30.0	70.0	40.0	50.0	50.0	60.0	60.0	40.0	20.0
Bank Stability	US	MS	MS	MS	US	US	US	MS	US	US	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	G	G	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	C	C	S	S	C	C	C	C	D	D	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	50
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	15:17
Water Temperature (°C):	1.2
Dissolved Oxygen (mg/L):	10.08
Sp. Conductivity (µs/cm):	663
pH:	7.81
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	O
Bars:	BR
Coupling:	CO
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	None	None
Overwintering:	Poor	None	None
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	None-Poor	Poor	Poor

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	164	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
225	30	12	280

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					-

General Comments

Braided with debris jams throughout. Inconsistent wetted width due to channel interrupted by shrub islands. Poor connectivity despite defined channels. Natural debris jam throughout. Signs of historic fire in upland area. Some erosion on left bank 100 m downtream that could couple the channel. The crossing has coupling potential as well. Upstream pond may provide limited overwintering potential for forage fish but shallow water depth and organic substrate would make it unlikely coarse or sportfish could overwinter.



Photo 1: Site 826.3— Aerial view of centerline and upstream.



Photo 2: Site 826.3—Upstream view of 300 m downstream of centerline.



Photo 3: Site 826.3—Upstream view of 100 m upstream from centerline.

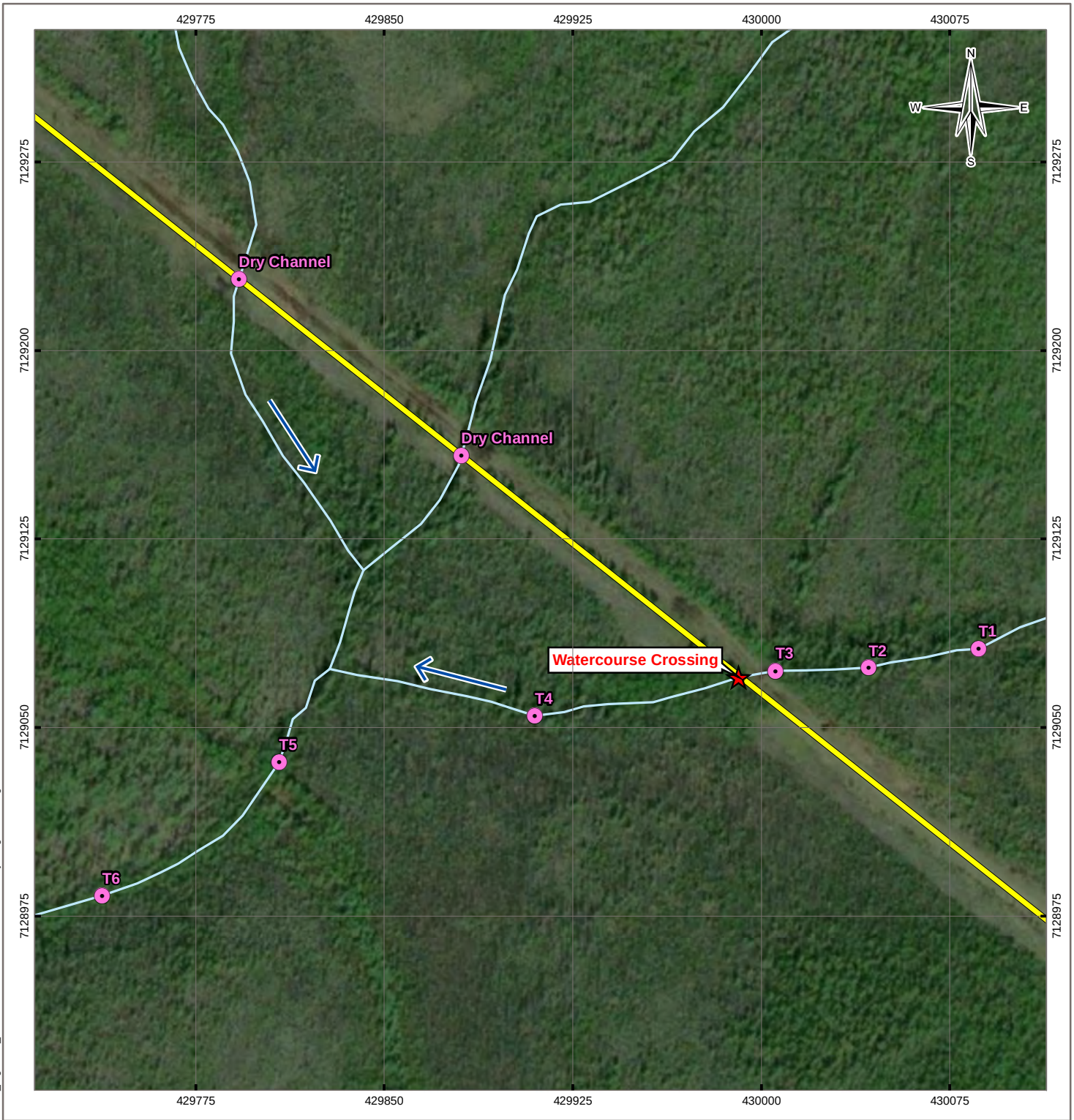


Photo 4: Site 826.3—Downstream view of 100 m downstream from centerline.



Photo 5: Site 826.3—View of watercourse crossing at centerline.

SITE 828.6



LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 828.6

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,200
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure11_Site8286.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 11

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Mackenzie Valley Highway

828.6 Unnamed Watercourse

UTM Location: 10W 429991 7129070 **Survey Date:** 10/9/2021; 13:30

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	0.9	0.6	0.8	1.8	1.9	1.6
Wetted Width (m)	0.3	0.6	0.7	0.8	1.3	0.6
Depth at LDB + 25% (m)	0.1	0.5	0.4	0.3	0.4	0.3
Depth at LDB + 50% (m)	0.2	0.5	0.4	0.4	0.5	0.3
Depth at LDB + 75% (m)	0.2	0.5	0.3	0.4	0.3	0.3
Max.BankfullDepth (m)	0.76	0.81	0.49	0.98	0.83	0.88
Gradient (%)	1	1	3	1	1	1
Dominant Habitat Unit	R2	R2	R2	R2	R2	R2
Stream Bed						
Substrate (% of Transect Area) – Organics	0	0	0	0	10	0
Substrate (% of Transect Area) – Fines	60	0	60	40	40	40
Substrate (% of Transect Area) – Small Gravel	40	30	30	40	40	60
Substrate (% of Transect Area) – Large Gravel	0	40	10	20	10	0
Substrate (% of Transect Area) – Cobble	0	30	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	L	L	L	L	M	L

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	0.6	0.3	0.3	0.3	0.1	0.1	0.47	0.54	0.4	0.3	0.6	0.5
Bank Slope (°)	80	20	45	45	20	10	65	65	30	70	50	80
Bank Stability	MS	MS	S	S	S	S	MS	MS	MS	MS	S	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	C	S	M	M	S	S	S	S	D	D	D	D
Subdom. Riparian Veg.	S	G	G	G	C	C	G	M	S	S	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	70
Dom. Instream Cover:	WD	Dom. Overhead Cover:	WD
Subdom. Instream Cover:	UCB	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.5	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:37
Water Temperature (°C):	0.3
Dissolved Oxygen (mg/L):	11.31
Sp. Conductivity (µs/cm):	733
pH:	7.92
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	FC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	Poor	None	None
Rearing:	Poor-Moderate	Poor-Moderate	Poor-Moderate
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Some instream grasses in upstream reach. Woody debris overhanging throughout. Crossing is cleared, coupled area with grasses and same channel width. Downstream has moderate riffles over woody debris and trace undercut banks. New growth in upland due to historic fire. No fishing conducted due to freezing conditions.



Photo 1: Site 828.6– Upstream view from 100 m downstream from centerline.



Photo 2: Site 828.6—Upstream view of 50 m upstream from centerline.



Photo 3: Site 828.6—Downstream view of 300 m downstream from centerline.



Photo 4: Site 828.6—Downstream view of 200 m downstream from centerline.



Photo 5: Site 828.6—Aerial view of centerline.



Photo 6: Site 828.6—View of crossing at centerline.

SITE 834.1



LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 834.1

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure12_Site8341.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 12

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TETRA TECH

Mackenzie Valley Highway

Site 834.1 Unnamed Watercourse

UTM Location: 10W 425724 7132189 **Survey Date:** 10/10/2021; 13:51

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	0.9	1.1	1.1	1.3	0.9	0.9
Wetted Width (m)	0.9	0.9	0.6	0.7	0.7	0.9
Depth at LDB + 25% (m)	0.1	0.1	0.1	0.1	0.1	0.1
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.1	0.1	0.1
Depth at LDB + 75% (m)	0.1	0.1	0.1	0.1	0.6	0.2
Max.BankfullDepth (m)	0.20	0.30	0.49	0.87	0.76	0.50
Gradient (%)	1	1	1	1	1	1
Dominant Habitat Unit	R1	R1	R2	R1	R1	R1
Stream Bed						
Substrate (% of Transect Area) Organics	20	20	0	0	0	0
Substrate (% of Transect Area) Fines	80	80	100	20	60	10
Substrate (% of Transect Area) Small Gravel	0	0	0	30	30	40
Substrate (% of Transect Area) Large Gravel	0	0	0	10	10	30
Substrate (% of Transect Area) Cobble	0	0	0	40	0	20
Substrate (% of Transect Area) Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	L	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.1	0.1	0.2	0.1	0.4	0.4	0.8	0.5	0.2	0.1	0.34	0.24
Bank Slope (°)	20	20	20	20	90	90	70	70	30	30	80	80
Bank Stability	US	US	US	US	US	US	US	US	MS	MS	US	US
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	G	S	S	D	D	S	S	S	S	S	S
Subdom. Riparian Veg.	S	S	D	D	G	G	D	D	D	D	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	70
Dom. Instream Cover:	UCB	Dom. Overhead Cover:	S
Subdom. Instream Cover:	C	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	13:50
Water Temperature (°C):	1.1
Dissolved Oxygen (mg/L):	9.42
Sp. Conductivity (µs/cm):	736
pH:	7.44
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	None-Poor	None-Poor	None
Rearing:	Moderate	Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort
No Electrofishing	- (s)
No Trapping	- (hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Upstream has low flow with some pooling. Thick deciduous forest throughout. Mostly overhanging vegetation and shrubs for cover. Minor undercutting downstream on both banks. Downed woody debris throughout, signs of bank erosion and logjams throughout. No fishing conducted due to freezing conditions.



Photo 1: Site 834.1— Upstream view of 300 m downstream from centerline.



Photo 2: Site 834.1—Downstream view of 100 m downstream from centerline.



Photo 3: Site 834.1— Downstream view of 100 m upstream from centerline.



Photo 4: Site 834.1—Upstream view at centerline.



Photo 5: Site 834.1— View of centerline, snow covering crossing.



Photo 6: Site 834.1—Upstream view at centerline.

SITE 835



LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 835

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000

40 20 0 40

Metres

FILE NO.
WTRI03067-01_Figure13_Site835.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 13

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Mackenzie Valley Highway

Site 835 Unnamed Watercourse

UTM Location: 10W 425405 7132988 **Survey Date:** 10/10/2021; 14:56

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.1	1.4	1.9	1.0	1.0	1.0
Wetted Width (m)	0.3	0.3	1.1	1.0	0.5	0.8
Depth at LDB + 25% (m)	0.1	0.1	0.1	0.2	0.1	0.1
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.2	0.1	0.1
Depth at LDB + 75% (m)	0.1	0.1	0.2	0.1	0.1	0.1
Max.BankfullDepth (m)	0.39	0.48	0.58	0.58	0.37	0.42
Gradient (%)	3	2	1	1	2	1
Dominant Habitat Unit	R2	R2	R1	R1	DD	R2
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	0	0	100	80
Substrate (% of Transect Area) — Fines	10	10	10	40	0	20
Substrate (% of Transect Area) — Small Gravel	30	30	40	20	0	0
Substrate (% of Transect Area) — Large Gravel	40	40	40	10	0	0
Substrate (% of Transect Area) — Cobble	20	20	10	30	0	0
Substrate (% of Transect Area) — Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) — Bedrock	0	0	0	0	0	0
Embeddedness	L	N	L	M	L	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.3	0.4	0.3	0.4	0.4	0.3	0.2	0.3	0.3	0.34	###
Bank Slope (°)	45	45	90	70	90	90	70	70	40	80	45	50
Bank Stability	MS	MS	MS	MS	US	US	MS	MS	US	US	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	S	S	D	D	D	D	D	D	M
Subdom. Riparian Veg.	G	G	G	G	G	G	S	S	S	S	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	50	Overhead Cover (%):	70
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	UCB	Subdom. Overhead Cover:	D
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	15:00
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	11.78
Sp. Conductivity (µs/cm):	1,001
pH:	8.07
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	CO
Flow Stage:	High

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Moderate	Poor-Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Fire evidence in upland. Abundant woody debris throughout. Shallow water with unstable banks at the centerline. Some undercut banks in downstream reach. Snow covering site at time of visit and mostly frozen over. No fishing conducted due to freezing conditions.



Photo 1: Site 835— Upstream view of 300 m downstream from centerline.



Photo 2: Site 835—Upstream view of 100 m upstream from centerline/



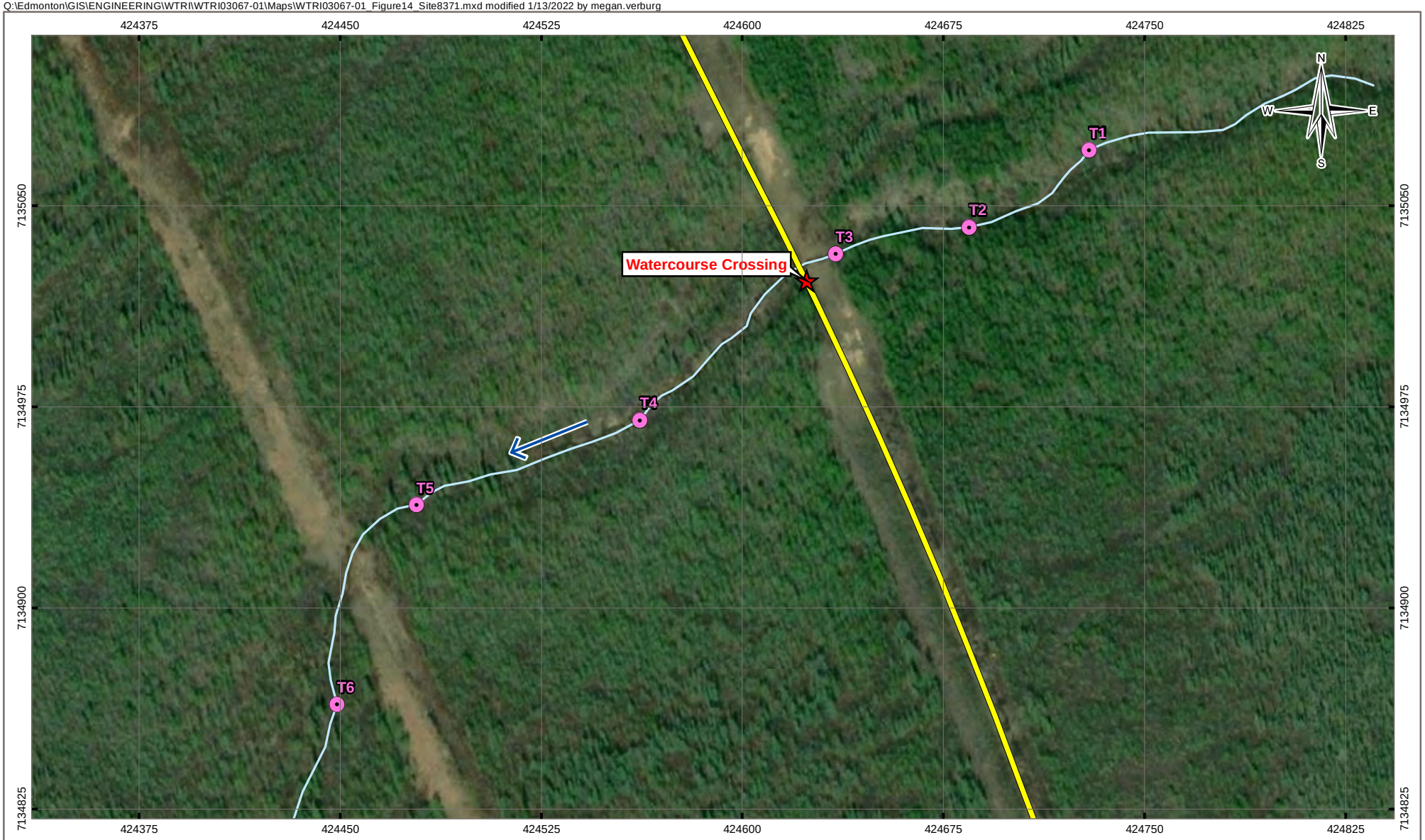
Photo 3: Site 835— View of crossing at centerline, looking upstream.



Photo 4: Site 835—View of crossing at centerline, looking downstream.

SITE 837.1

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LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:2,000
40 20 0 40
Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure14_Site8371.mxd

CLIENT Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 837.1

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 14

TETRA TECH

Mackenzie Valley Highway

Site 837.1 Unnamed Watercourse

UTM Location: 10W 424624 7135022 **Survey Date:** 10/11/2021; 12:34

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	1.7	1.2	2.7	2.1	1.9
Wetted Width (m)	1.3	1.3	0.9	1.3	1.0	1.4
Depth at LDB + 25% (m)	0.2	0.2	0.1	0.0	0.1	0.2
Depth at LDB + 50% (m)	0.2	0.2	0.2	0.1	0.1	0.2
Depth at LDB + 75% (m)	0.0	0.2	0.1	0.1	0.1	0.1
Max.BankfullDepth (m)	0.65	0.59	0.45	0.45	0.41	0.62
Gradient (%)	2	3	3	5	3	3
Dominant Habitat Unit	R2	R2	R2	RF	R2	R2
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	0	0	0	0
Substrate (% of Transect Area) — Fines	0	0	0	0	0	10
Substrate (% of Transect Area) — Small Gravel	10	25	20	10	20	30
Substrate (% of Transect Area) — Large Gravel	30	30	35	45	30	45
Substrate (% of Transect Area) — Cobble	30	30	10	30	40	5
Substrate (% of Transect Area) — Boulder	30	10	25	20	10	0
Substrate (% of Transect Area) — Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.4	0.4	0.2	0.4	0.2	0.3	0.4	0.3	0.2	0.3	0.4	0.3
Bank Slope (°)	90	90	70	70	70	70	10	10	30	20	60	55
Bank Stability	MS	US	US	US	US	US	MS	MS	MS	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	LG	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	SG	SG	F	F	F
Dom. Riparian Veg.	C	S	S	S	S	C	S	S	S	S	S	S
Subdom. Riparian Veg.	S	C	D	D	C	S	G	G	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	10
Dom. Instream Cover:	C	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	12:34
Water Temperature (°C):	1.1
Dissolved Oxygen (mg/L):	12.27
Sp. Conductivity (µs/cm):	482
pH:	8.20
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	SD
Coupling:	DC
Confinement:	OC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Moderate	Moderate
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Moderate	Moderate	Moderate
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Step pools created naturally from downed woody debris in upstream reach. Downstream has emergent boulders and cobbles instream. Minor undercutting of bank in downstream. Fire history in upland. Gravel bar on left bank 200 m downstream. Limited overhanging vegetation in downstream reach. Downed trees created step pools. Challenging for forage fish but good habitat. No fishing conducted due to freezing conditions.



Photo 1: Site 837.1— Upstream view of 100 m downstream from centerline.



Photo 2: Site 837.1— Upstream view of 100 m upstream from centerline.



Photo 3: Site 837.1—Downstream view of 200 m downstream from centerline.



Photo 4: Site 837.1—Downstream view of 300 m downstream from centerline.



Photo 5: Site 837.1—View of centerline crossing.



Photo 6: Site 837.1—view of crossing at the cutline approximately 250 m downstream.

SITE 843.3



LEGEND

- Watercourse Crossing
- Site Feature
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 843.3

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO. WTRI03067-01_Figure15_Site8433.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE January 13, 2022
PROJECT NO. ENG.WTRI03067-01

TETRA TECH

Figure 15

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TETRA TECH

Mackenzie Valley Highway

Site 843.3 Unnamed Watercourse

UTM Location: 10W 422310 7140408 **Survey Date:** 10/11/2021; 14:20

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	14:20
Water Temperature (°C):	0.5
Dissolved Oxygen (mg/L):	11.83
Sp. Conductivity (µs/cm):	577
pH:	8.07
Turbidity (NTU):	Clear

Habitat Inventory / Reach Data

Instream Cover (%):	80	Overhead Cover (%):	60
Dom. Instream Cover:	G	Dom. Overhead Cover:	D
Subdom. Instream Cover:	WD	Subdom. Overhead Cover:	S
Maximum Depth (m)	-	Dom. Aquatic Veg. Type:	0

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Maximum depth was 0.39 m. Substrate was 30% fines, 30% small gravel, 30% large gravel and 10% cobble. Snow cover at the site at time of visit, most of the downstream reach was a flooded area within the trees and no defined channel. No suitable fish habitat for any fish.



Photo 1: Site 843.3— upstream view from centerline.



Photo 2: Site 843.3— 100 m downstream from centerline.



Photo 3: Site 843.3— Upstream view of 100 m upstream from centerline.



Photo 4: Site 843.3—Centerline view of water and undefined channel.

SITE 846.4

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LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:1,500
30 15 0 30
Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure16_Site8464.mxd

CLIENT Northwest Territories

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 846.4

Figure 16

Mackenzie Valley Highway

Site 846.4 Unnamed Watercourse

UTM Location: 10W 419947 7142715 **Survey Date:** 10/11/2021; 15:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	-	-	-	2.5	2.3	2.1
Wetted Width (m)	-	-	-	2.3	1.9	1.7
Depth at LDB + 25% (m)	-	-	-	0.5	0.2	0.1
Depth at LDB + 50% (m)	-	-	-	0.7	0.5	0.5
Depth at LDB + 75% (m)	-	-	-	0.8	0.2	0.4
Max.BankfullDepth (m)	-	-	-	1.5	0.84	0.63
Gradient (%)	-	-	-	1	1	1
Dominant Habitat Unit	P1	P1	P1	P1	R1	R1
Stream Bed						
Substrate (% of Transect Area): Organics	-	-	-	40	40	40
Substrate (% of Transect Area): Fines	-	-	-	60	60	60
Substrate (% of Transect Area): Small Gravel	-	-	-	0	0	0
Substrate (% of Transect Area): Large Gravel	-	-	-	0	0	0
Substrate (% of Transect Area): Cobble	-	-	-	0	0	0
Substrate (% of Transect Area): Boulder	-	-	-	0	0	0
Substrate (% of Transect Area): Bedrock	-	-	-	0	0	0
Embeddedness	-	-	-	0	0	0

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	-	-	-	-	-	-	0.7	0.3	0.3	0.2	0.1	0.1
Bank Slope (°)	-	-	-	-	-	-	90	90	70	20	5	40
Bank Stability	-	-	-	-	-	-	MS	MS	MS	MS	MS	MS
Dom. Bank Material	-	-	-	-	-	-	O	O	O	O	O	O
Subdom. Bank Material	-	-	-	-	-	-	F	F	F	F	F	F
Dom. Riparian Veg.	-	-	-	-	-	-	S	S	S	S	S	S
Subdom. Riparian Veg.	-	-	-	-	-	-	G	G	D	D	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	30	Overhead Cover (%):	30
Dom. Instream Cover:	WD	Dom. Overhead Cover:	-
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	14:00
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	12.21
Sp. Conductivity (µs/cm):	264
pH:	7.97
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	SI
Islands:	S
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate-Good	Poor-Moderate	Poor
Passage:	Poor	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

The upstream area was flooded with no defined channel and frozen over with snow cover at time of assessment. Most of the downstream reach was flooded as well until approximately 100 m downstream, where the channel banks became more defined. The channel developed sinuous meanders downstream. Current crossing is not suitable for fish passage. No fishing conducted due to freezing conditions.



Photo 1: Site 846.4— 100 m downstream from centerline.



Photo 2: Site 846.4— Upstream view from 200 m downstream of centerline.



Photo 3: Site 846.4— Flooded area 50 m upstream of centerline.

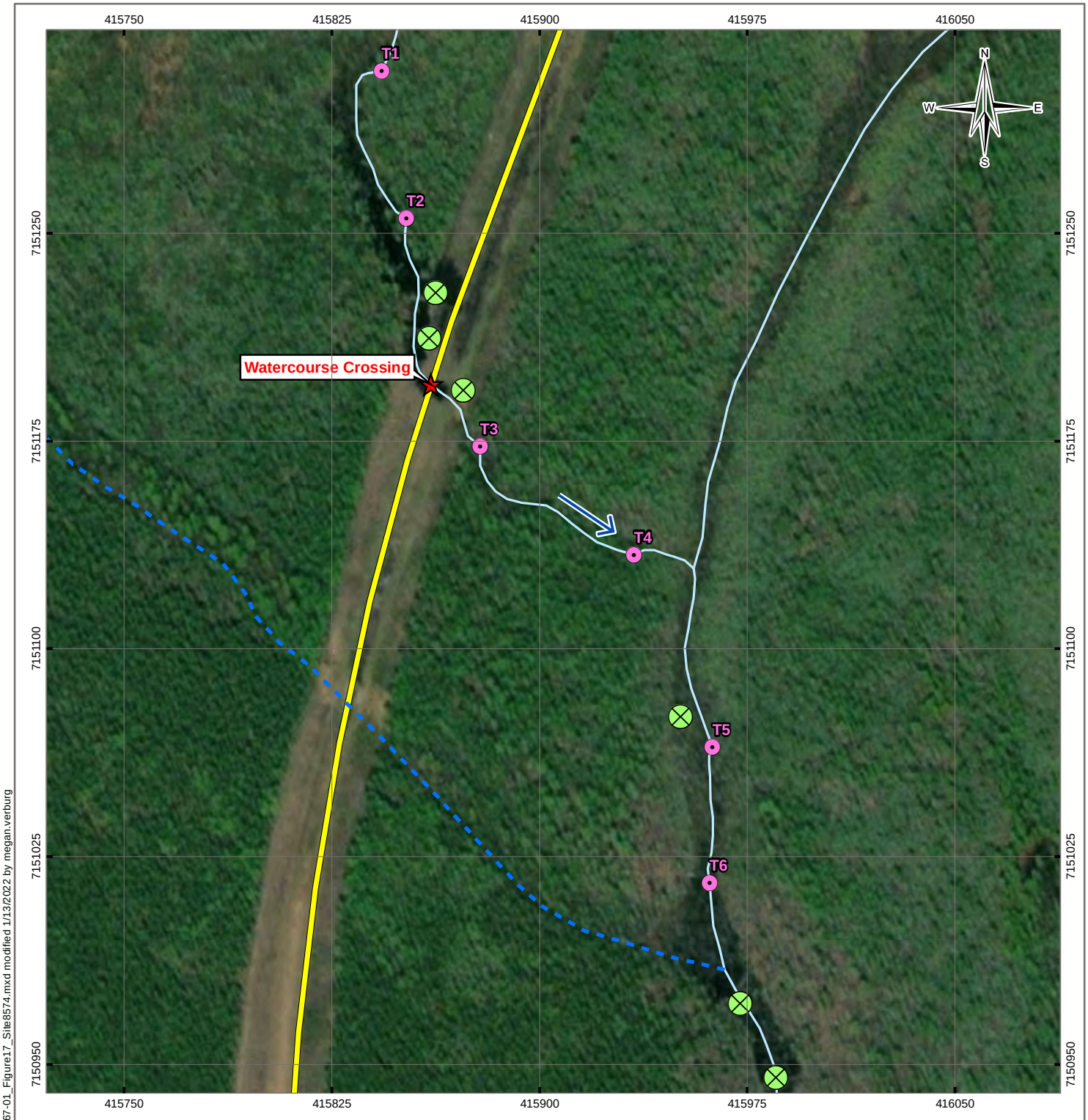


Photo 4: Site 846.4— Upstream view of 300 m downstream of centerline.



Photo 5: Site 846.4— View of centerline from the cutline.

SITE 857.4



LEGEND

- Watercourse Crossing
- Beaver Dam
- Transect
- Dry Channel
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 857.4

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure17_Site8574.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 17

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Mackenzie Valley Highway

Site 857.4 Unnamed Watercourse

UTM Location: 10W 415860 7151196 **Survey Date:** 10/11/2021; 16:28

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	10.0	2.3	0.6	2.3	-
Wetted Width (m)	1.4	10.0	1.4	0.5	2.0	-
Depth at LDB + 25% (m)	0.2	0.5	0.2	0.2	0.5	-
Depth at LDB + 50% (m)	0.2	-	0.4	0.3	0.6	-
Depth at LDB + 75% (m)	0.1	-	0.2	0.2	0.4	-
Max.BankfullDepth (m)	0.28	0.50	0.56	0.40	0.73	0.00
Gradient (%)	1	1	2	2	1	1
Dominant Habitat Unit	R1	IP1	BD	R3	DD	FL
Stream Bed						
Substrate (% of Transect Area) Organics	80	0	60	80	60	0
Fines	20	100	40	20	40	100
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.1	0.1	-	-	0.2	0.2	0.2	0.2	0.2	0.1	-	-
Bank Slope (°)	10	10	30	30	25	10	5	5	10	10	30	30
Bank Stability	MS	MS	US	US	MS	MS	US	MS	MS	MS	MS	MS
Dom. Bank Material	O	O	-	-	O	O	O	O	O	O	-	-
Subdom. Bank Material	F	F	-	-	F	F	F	F	F	F	-	-
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	M	M
Subdom. Riparian Veg.	G	G	G	G	G	G	G	C	G	G	C	C

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	10
Dom. Instream Cover:	WD	Dom. Overhead Cover:	C
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	S
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:28
Water Temperature (°C):	0.5
Dissolved Oxygen (mg/L):	9.45
Sp. Conductivity (µs/cm):	163
pH:	7.92
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	I
Bars:	N
Coupling:	PC
Confinement:	FC
Flow Stage:	Pooled

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None	None
Overwintering:	Moderate	Poor	Poor
Rearing:	Moderate-Good	Poor-Moderate	Poor
Passage:	Poor	Poor	Poor

Fish Sampling Data

Method	Effort
No Electrofishing	- (s)
No Trapping	- (hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

The upstream reach was mostly low shrubs and grasses as it was likely flooded in past due to downstream beaver dam, poorly defined channel. Some grasses instream at the crossing. There were two beaver dams, just upstream of the centerline crossing over the winter road. There was a smaller beaver dam at the winter road. Watercourse converged with larger channel approximately 130 m downstream. There were multiple beaver dams downstream as well. Could not assess parts of T2 and T6 locations because the water was frozen over and was unsafe to assess. Channel width for T6 was measured from aerial imagery. At 200 m downstream, the second channel was flooded and meandered around debris dams (likely from previous backflooding from impoundment). The downstream area would be more suitable fish habitat than in the channel that crosses the proposed highway alignment. No fishing conducted due to freezing conditions.



Photo 1: Site 857.4—Upstream of centerline, beaver dam impoundment.



Photo 2: Site 857.4—View of beaver dam at centerline.



Photo 3: Site 857.4— Downstream view of 200 m downstream from centerline.



Photo 4: Site 857.4— View of downstream watercourse 300 m downstream of centerline. Photo is downstream of confluence with larger watercourse and is of that water-course.



Photo 5: Site 857.4— View of the centerline looking south.

SITE 872.9



LEGEND

- Watercourse Crossing
- Minnow Trap
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2020)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 872.9

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:1,000
20 10 0 20
Metres

FILE NO.
WTRI03067-01_Figure18_Site8729.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 18

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TETRA TECH

Mackenzie Valley Highway

Site 872.9 Unnamed Watercourse

UTM Location: 10W 412679 7164554 **Survey Date:** 10/2/2021; 15:17

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	15:17
Water Temperature (°C):	0.1
Dissolved Oxygen (mg/L):	12.53
Sp. Conductivity (µs/cm):	435
pH:	7.74
Turbidity (NTU):	Clear

Habitat Inventory / Reach Data

Instream Cover (%):	60	Overhead Cover (%):	10
Dom. Instream Cover:	AQ	Dom. Overhead Cover:	-
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	1.0	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Wetland habitat, poor connectivity with rigmat over the crossing. Exposed pipe from a pipeline in the channel. One minnow trap was set but pulled after 1 hr when it was noted that there was no connectivity and no defined channel. The downstream area is flooded wetland with submerged aquatic vegetation. Substrate was all fines and organics. Not fish habitat.



Photo 1: Site 872.9—Facing upstream from centerline.



Photo 2: Site 872.9—Facing upstream from 50 m upstream of centerline.



Photo 3: Site 872.9—Facing upstream from aerial view.



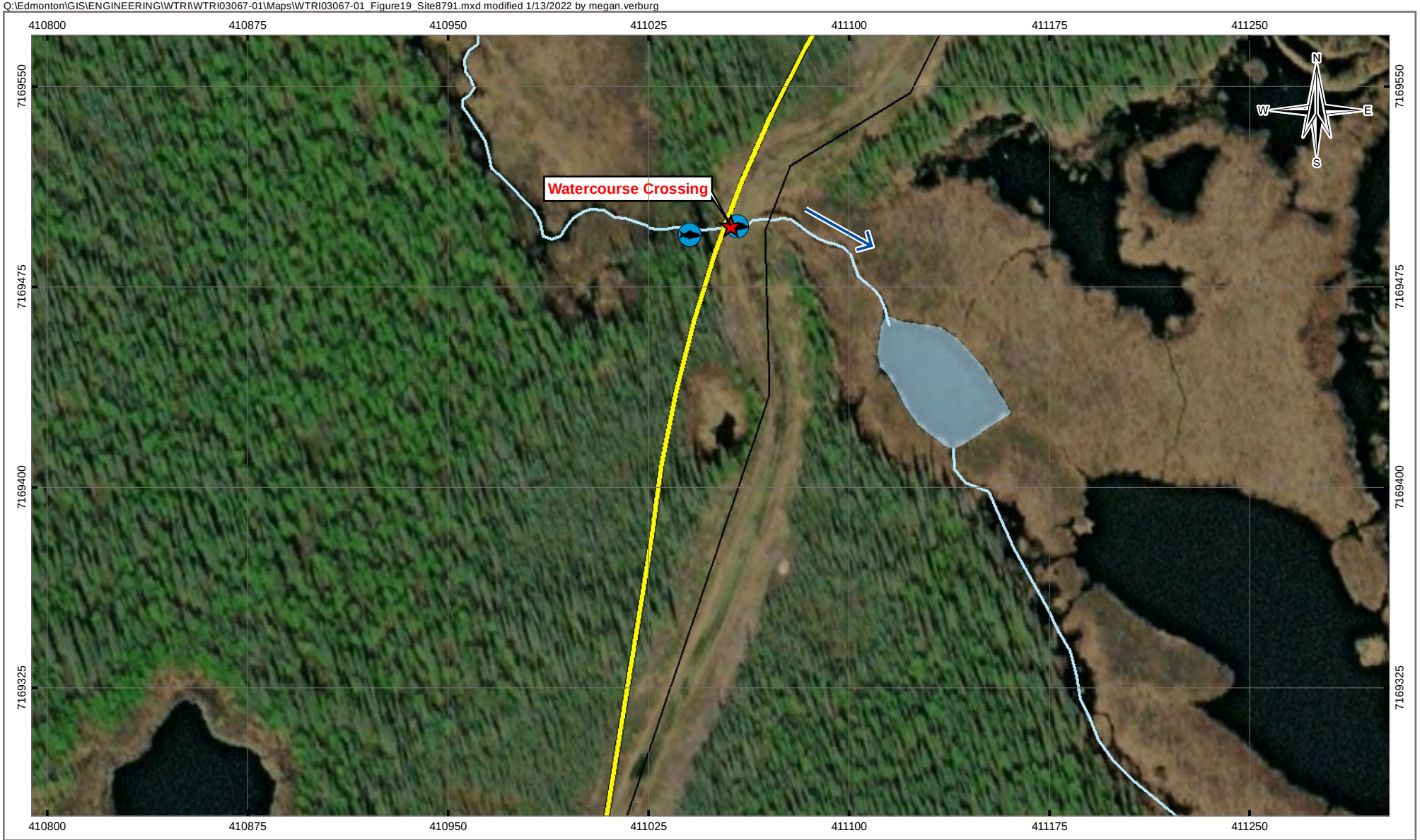
Photo 4: Site 872.9—Facing downstream at 100 m downstream from centerline.



Photo 5: Site 872.9— View of crossing from ground.

SITE 879.1

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LEGEND

- Watercourse Crossing
- Minnow Trap
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse
- Waterbody

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

Scale: 1:2,000
40 20 0 40
Metres

PROJECTION UTM Zone 10	**DATUM** NAD83
FILE NO. WTRI03067-01_Figure19_Site8791.mxd	

CLIENT Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 879.1

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0
DATE January 13, 2022	**PROJECT NO.** ENG.WTRI03067-01			

Figure 19

TETRA TECH

Mackenzie Valley Highway

Site 879.1 Unnamed Watercourse

UTM Location: 10W 411064 7169505 **Survey Date:** 10/9/2021; 16:16

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Water Quality Data

Time of Day (HH:MM):	16:16
Water Temperature (°C):	0.6
Dissolved Oxygen (mg/L):	0.68
Sp. Conductivity (µs/cm):	151
pH:	6.44
Turbidity (NTU):	Lightly Turbid

Habitat Inventory / Reach Data

Instream Cover (%):	0	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	G
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	C
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	36.5	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Very low dissolved oxygen - was measured multiple times in multiple locations and got same result. Frozen cover throughout, generally a marshy bog. This wetland was connected to the watercourse crossing at Site 879.4. Beaver activity in the upstream and a beaver lodge and impoundment downstream. Potential good habitat for forage fish but low DO levels may not make it suitable for larger bodied fish. No fishing conducted due to frozen conditions.



Photo 1: Site 879.1—Aerial view of upstream habitat.



Photo 2: Site 879.1—Aerial view of downstream habitat.



Photo 3: Site 879.1— Looking towards right bank 100 m upstream of centerline.

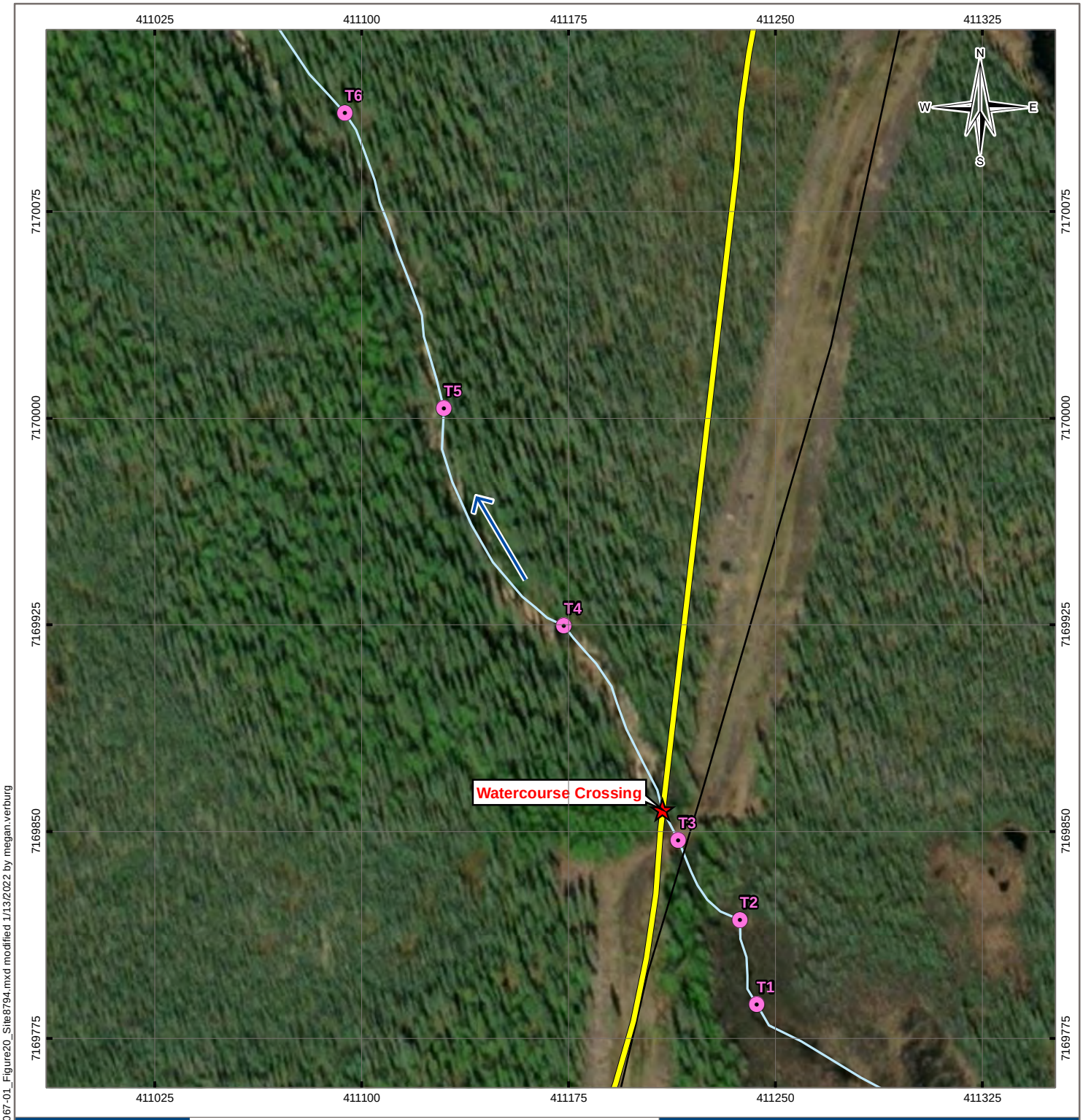


Photo 4: Site 879.1 —View of pond approximately 100 m downstream from centerline.



Photo 5: Site 879.1— View of crossing location, looking southwest.

SITE 879.4



LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 879.4

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure20_Site8794.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 20

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TETRA TECH

Mackenzie Valley Highway

Site 879.4 Unnamed Watercourse

UTM Location: 10W 411209 716858 **Survey Date:** 10/9/2021; 16:34

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.5	2.9	5.2	1.2	1.9	1.0
Wetted Width (m)	1.3	2.5	5.2	0.9	1.9	1.0
Depth at LDB + 25% (m)	0.3	0.5	0.2	0.2	0.1	0.0
Depth at LDB + 50% (m)	0.3	0.5	0.4	0.2	0.2	0.1
Depth at LDB + 75% (m)	0.3	0.4	0.5	0.2	0.1	0.2
Max.BankfullDepth (m)	0.31	0.54	0.46	0.39	0.56	0.59
Gradient (%)	1	1	2	3	1	1
Dominant Habitat Unit	IP1	IP1	IP1	R2	R1	R1
Stream Bed						
Substrate (% of Transect Area) – Organics	100	100	100	0	0	0
Substrate (% of Transect Area) – Fines	0	0	0	90	100	100
Substrate (% of Transect Area) – Small Gravel	0	0	0	10	0	0
Substrate (% of Transect Area) – Large Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Cobble	0	0	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	0	0	0	0	0	0

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.4	0.2	0.4	0.4
Bank Slope (°)	0	0	0	0	10	10	40	40	20	40	75	40
Bank Stability	S	S	S	S	S	S	US	US	MS	US	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	G	G	G	G	G	S	S	S	S	S	M
Subdom. Riparian Veg.	S	S	S	S	S	S	M	M	C	C	M	S

Habitat Inventory / Reach Data

Instream Cover (%):	50	Overhead Cover (%):	60
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	UC	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.5	Dom. Aquatic Veg. Type:	G

Water Quality Data

Time of Day (HH:MM):	16:36
Water Temperature (°C):	0.6
Dissolved Oxygen (mg/L):	10.81
Sp. Conductivity (µs/cm):	193
pH:	7.37
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	FC
Flow Stage:	Flood

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor-Moderate	None	None
Overwintering:	Poor-Moderate	Poor	Poor
Rearing:	Moderate	Poor-Moderate	Poor-Moderate
Passage:	Moderate-Good	Moderate	Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Some instream aquatic vegetation and grasses instream in upstream reach, within the flooded area. The upstream area is flooded throughout trees and downstream is confined to valley. Some undercut banks 300 m downstream. Aerial imagery of the area shows the watercourse is connected to Site 879.1 on the upstream side, and appears to have wetland characteristics upstream of T1 (100 m upstream) based on the aerial imagery. The area was snow covered at the time of the assessment. No fishing was conducted due to unsafe conditions for electrofishing and freezing conditions.



Photo 1: Site 879.4— Upstream view of 100 m upstream from centerline.



Photo 2: Site 879.4—Upstream view of 50 m upstream from centerline.



Photo 3: Site 879.4—Looking upstream at 200 m downstream from centerline.



Photo 4: Site 879.4—Looking upstream at 300 m downstream from centerline.

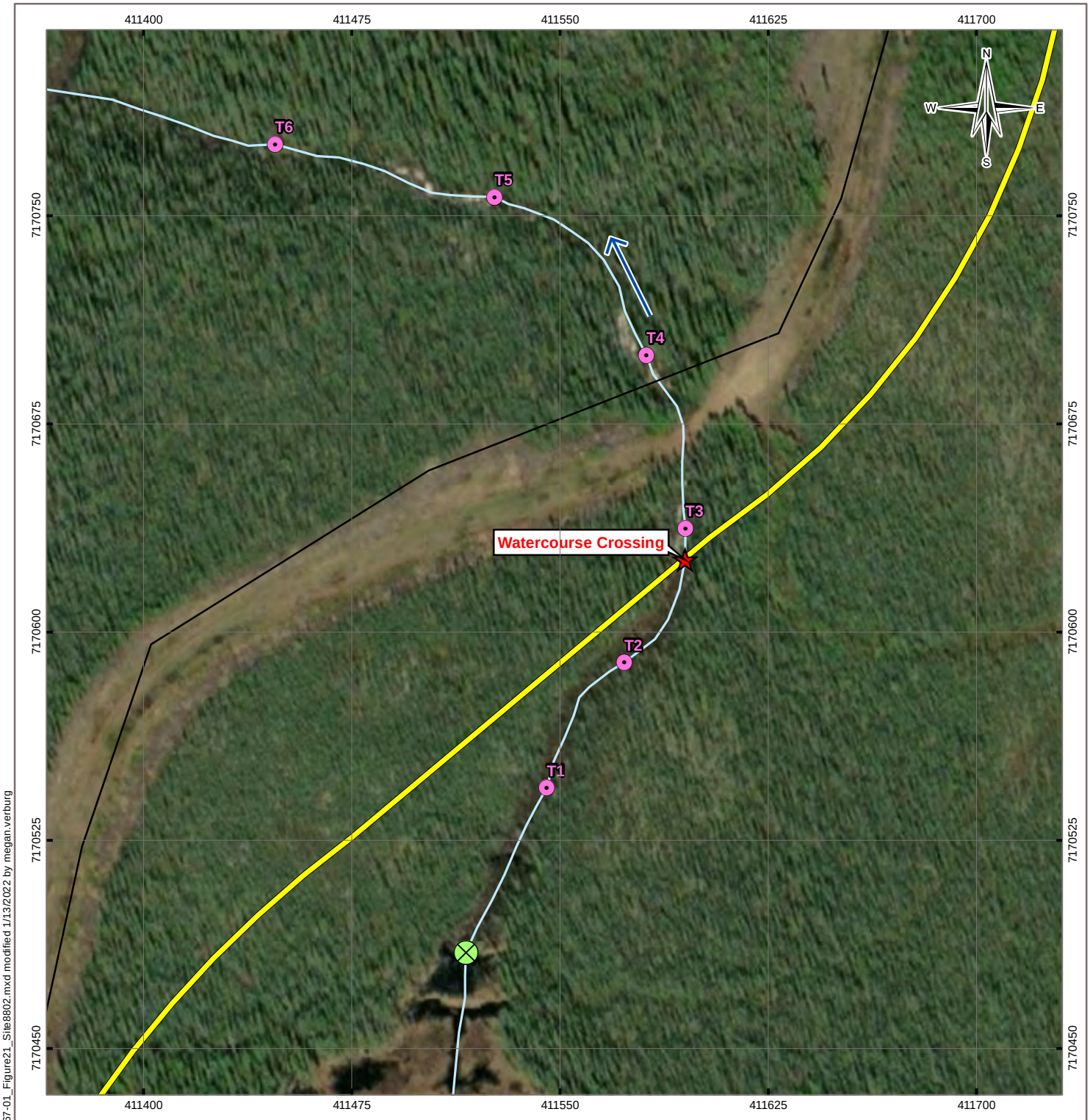


Photo 5: Site 879.4— View of crossing at centerline, looking north.



Photo 6: Site 879.4— Inlet side of centerline, snow covered.

SITE 880.2



LEGEND

- Watercourse Crossing
- Beaver Dam
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 880.2

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure21_Site8802.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 21

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Mackenzie Valley Highway

Site 880.2 Unnamed Watercourse

UTM Location: 10W 411595 7170626 **Survey Date:** 10/1/2021; 16:23

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	-	1.2	2.7	2.6	3.2	0.9
Wetted Width (m)	-	0.8	0.7	1.0	0.7	0.5
Depth at LDB + 25% (m)	-	0.1	0.1	0.1	0.1	0.1
Depth at LDB + 50% (m)	-	0.2	0.2	0.1	0.1	0.1
Depth at LDB + 75% (m)	-	0.1	0.2	0.1	0.1	0.1
Max.BankfullDepth (m)	-	0.4	1.0	0.5	0.5	0.6
Gradient (%)	-	1.0	2.0	2.0	8.0	8.0
Dominant Habitat Unit	WL	R2	R2	R2	R2	R2
Stream Bed						
Substrate (% of Transect Area) — Organics	-	90	0	60	10	10
Substrate (% of Transect Area) — Fines	-	10	100	40	80	90
Substrate (% of Transect Area) — Small Gravel	-	0	0	0	10	0
Substrate (% of Transect Area) — Large Gravel	-	0	0	0	0	0
Substrate (% of Transect Area) — Cobble	-	0	0	0	0	0
Substrate (% of Transect Area) — Boulder	-	0	0	0	0	0
Substrate (% of Transect Area) — Bedrock	-	0	0	0	0	0
Embeddedness	-	N	N	N	L	N

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bank Slope (°)	-	-	20	20	45	80	45	50	10	80	45	45
Bank Stability	-	-	MS	MS	S	MS	US	MS	US	US	MS	MS
Dom. Bank Material	-	-	O	O	O	O	O	O	F	F	O	O
Subdom. Bank Material	-	-	F	F	F	F	F	F	O	O	F	F
Dom. Riparian Veg.	-	-	S	S	S	S	S	S	S	S	C	C
Subdom. Riparian Veg.	-	-	C	C	C	C	C	C	C	C	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	20	Overhead Cover (%):	30
Dom. Instream Cover:	-	Dom. Overhead Cover:	-
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	-
Maximum Depth (m)	0.2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:23
Water Temperature (°C):	2.5
Dissolved Oxygen (mg/L):	9.47
Sp. Conductivity (µs/cm):	195
pH:	7.87
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	IR
Islands:	N
Bars:	N
Coupling:	DC
Confinement:	OC
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	None	None	None
Overwintering:	None	None	None
Rearing:	None	Poor	None
Passage:	None-Poor	None-Poor	None-Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

100 m upstream is a flooded area and no defined channel. Poor connectivity all the way to 100 m downstream of crossing. Abundant grasses instream and woody debris blocking channel. 100 m downstream of proposed alignment is just upstream of existing winter road. There is a soft organic bottom with minor undercuts. Some underground flow where banks have coupled previously. 200 m downstream looks like it was flooded a few years ago but has since had new growth. 300 m downstream is a narrow channel with steep grade and several logjams. Woody debris throughout. No fishing conducted due to shallow water depths.



Photo 1: Site 880.2—Upstream view of ponded area 150 m upstream from centreline.



Photo 2: Site 880.2— View of substrate at crossing location.



Photo 3: Site 880.2—Facing downstream from 100 m upstream from centerline.



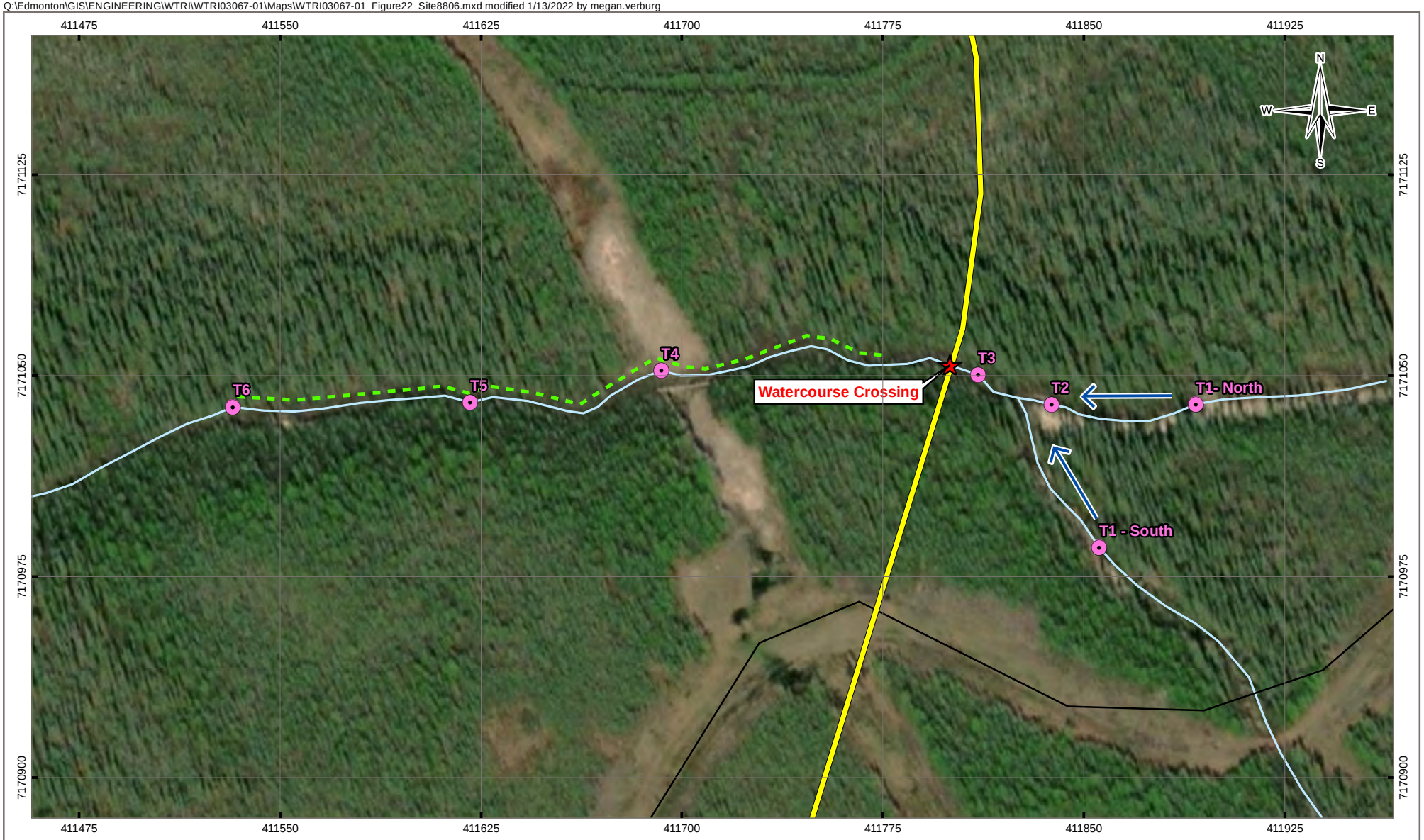
Photo 4: Site 880.2—Facing downstream at 100 m downstream from centerline.



Photo 5: Site 880.2—View of existing crossing along the winter road, approximately 60 m downstream of the proposed alignment. View looking southwest.

SITE 880.6

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LEGEND

- Watercourse Crossing
- Transect
- Electrofishing
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

Scale: 1:2,000
40 20 0 40
Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure22_Site8806.mxd

CLIENT Northwest Territories

TETRA TECH

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 880.6

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

Figure 22

Mackenzie Valley Highway

Site 880.6 Unnamed Watercourse

UTM Location: 10W411800 7171054 | **Survey Date:** 10/5/2021; 16:30

Legal Location: - | **Zone:**

Crew Initials: TM & MAN | **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	2.5	2.2	1.8	2.8	2.7	1.9
Wetted Width (m)	2.3	1.6	1.5	1.9	2.0	1.1
Depth at LDB + 25% (m)	0.2	0.3	0.2	0.3	0.3	0.5
Depth at LDB + 50% (m)	0.3	0.3	0.4	0.4	0.5	0.5
Depth at LDB + 75% (m)	0.4	0.2	0.6	0.3	0.2	0.4
Max.BankfullDepth (m)	0.67	0.65	0.78	0.66	0.83	1.1
Gradient (%)	1	1	2	4	5	5
Dominant Habitat Unit	FL	FL	R1	CA	R1	R1
Stream Bed						
Substrate (% of Transect Area) – Organics	0	10	30	10	10	10
Substrate (% of Transect Area) – Fines	100	90	70	80	70	90
Substrate (% of Transect Area) – Small Gravel	0	0	0	0	20	0
Substrate (% of Transect Area) – Large Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) – Cobble	0	0	0	0	0	0
Substrate (% of Transect Area) – Boulder	0	0	0	10	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	0	0	0	0	0	0

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.3	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.4	0.2	0.3	0.5
Bank Slope (°)	25	70	10	20	30	10	10	25	60	10	60	80
Bank Stability	MS	US	MS	MS	S	S	MS	MS	MS	MS	S	MS
Dom. Bank Material	O	F	F	O	O	O	F	F	F	F	F	O
Subdom. Bank Material	F	O	O	F	F	F	O	O	SG	O	O	F
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	C	C	G	G	D	G	S	S	M	M	D	C

Habitat Inventory / Reach Data

Instream Cover (%):	40	Overhead Cover (%):	80
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	C
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	16:30
Water Temperature (°C):	1.6
Dissolved Oxygen (mg/L):	13.61
Sp. Conductivity (µs/cm):	240
pH:	7.66
Turbidity (NTU):	Moderately Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	CO
Flow Stage:	High

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None-Poor	None-Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Good	Good	Good
Passage:	Good	Good	Good

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	246	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
200	30	12	200

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	tel. Abundanc (% of total)
BROOK STICKLEBACK	2	-	2.86	-	40.0%
FINESCALE DACE	1	-	1.43	-	20.0%
PEARL DACE	2	-	2.86	-	40.0%

General Comments

100 m downstream is located along pipeline, some large boulders in transect from riprap for wooden bank support that was in place. Some in stream grass throughout. Lots of woody debris in water. High flow rate wth occasional riffle sections. Occasional natural small debris dams.



Photo 1: Site 880.6—Looking downstream at 100 m downstream from centerline.



Photo 2: Site 880.6—Looking downstream at 200 m downstream from centerline.



Photo 3: Site 880.6—Looking downstream at 300 m downstream from centerline.



Photo 4: Site 880.6—Looking upstream at 50 m upstream from centerline.



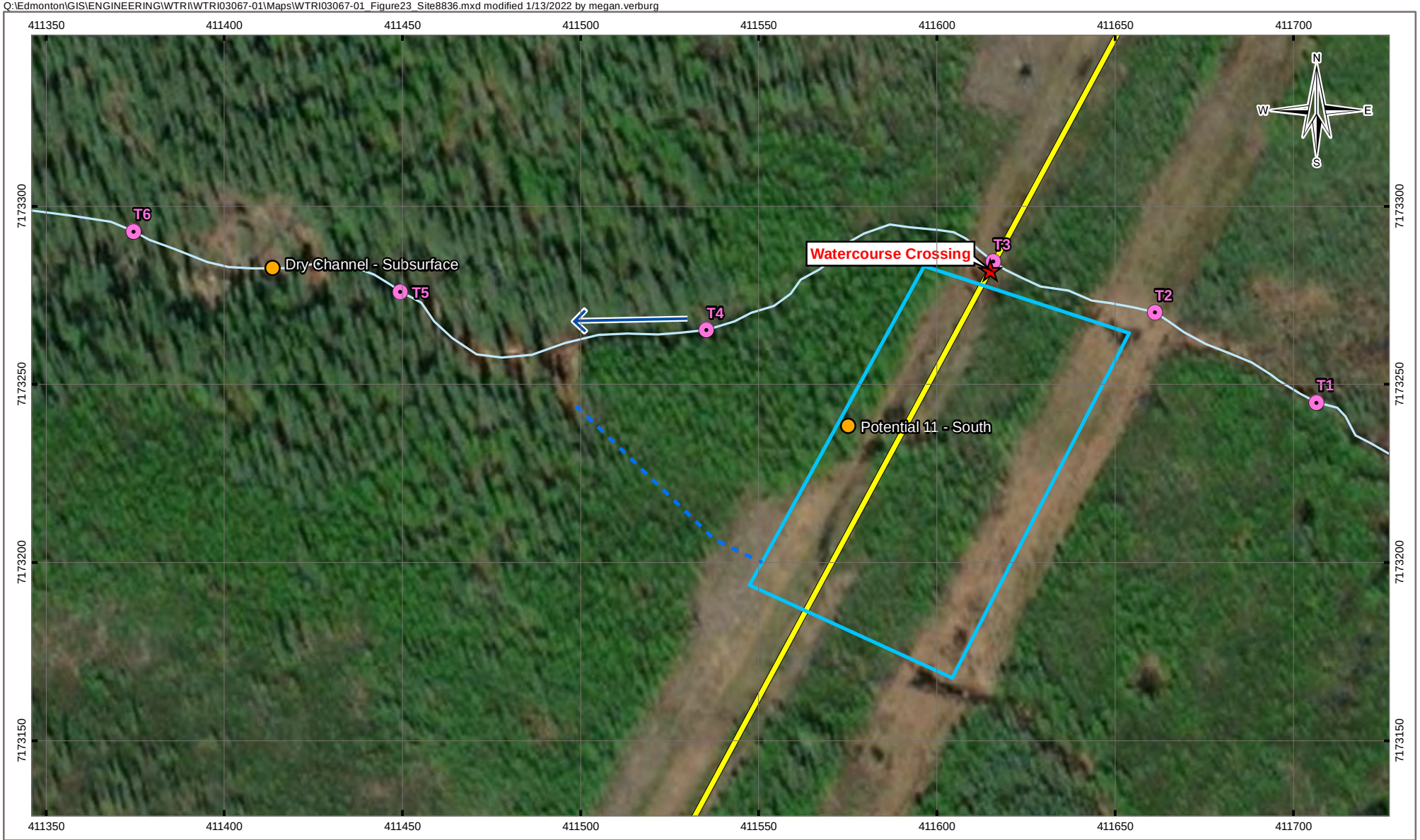
Photo 5: Site 880.6—Aerial view of watercourse crossing existing winter road.



Photo 6: Site 880.6—View of channel at the proposed centerline of the new alignment.

SITE 883.6

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LEGEND

- Watercourse Crossing
- Site Feature
- Transect
- Dry Channel
- Flow Direction
- Mackenzie Valley Highway Extension
- Wet Throughout

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

Scale: 1:1,500

30 15 0 30

Metres

PROJECTION	DATUM
UTM Zone 10	NAD83

FILE NO.
WTRI03067-01_Figure23_Site8836.mxd

CLIENT Northwest Territories

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 883.6

Figure 23

TETRA TECH

Mackenzie Valley Highway

Site 883.6 Unnamed Watercourse

UTM Location: 10W 411615 7173282 **Survey Date:** 10/5/2021; 11:53

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	2.4	-	1.3	2.1	3.1	3.4
Wetted Width (m)	2.0	-	1.3	1.3	0.5	1.1
Depth at LDB + 25% (m)	0.0	-	0.3	0.2	0.1	0.1
Depth at LDB + 50% (m)	0.1	-	0.3	0.1	0.1	0.1
Depth at LDB + 75% (m)	0.2	-	0.2	0.1	0.1	0.0
Max.BankfullDepth (m)	0.46	-	0.41	0.44	1.1	2.0
Gradient (%)	1	-	2	2	6	8
Dominant Habitat Unit	WL	-	R1	R1	RF	RF
Stream Bed						
Substrate (% of Transect Area) Organics	100	100	100	90	0	60
Fines	0	0	0	10	0	40
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.2	0.3	-	-	0.1	0.1	0.3	0.2	0.9	1.1	0.7	1.9
Bank Slope (°)	5	45	-	-	5	5	20	25	60	70	80	90
Bank Stability	MS	MS	-	-	MS	MS	MS	MS	US	US	US	US
Dom. Bank Material	O	O	-	-	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	-	-	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	G	D	-	-	S	S	S	S	S	S	C	C
Subdom. Riparian Veg.	S	S	-	-	C	D	M	M	C	D	S	S

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	70
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	M
Maximum Depth (m)	0.3	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	11:56
Water Temperature (°C):	2.8
Dissolved Oxygen (mg/L):	2.54
Sp. Conductivity (µs/cm):	355
pH:	7.16
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	O
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Poor	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Poor	Poor	Poor
Passage:	Poor	Poor	Poor

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

50 m upstream was the winter road and no defined channel was present (depths recorded at deep pools). The water was snow covered and had low flow upstream. Some overhanging vegetation and abundant downed woody debris. Orange copper look to water, flow is low with occasional pool pockets to the side, dominated by organic debris (leaves and sticks).Slope increased at 300 m downstrea, with steep slopes, riffles with minor cascades and organic islands. Abundant moss throughout. Flowing water, significant left bank erosion around 250 m downstream. No fishing conducted due to freezing conditions.



Photo 1: Site 883.6— Looking downstream at 100 m downstream from centerline.



Photo 2: Site 883.6—Looking downstream at centerline.



Photo 3: Site 883.6— Upstream view of 50 m upstream from centerline.



Photo 4: Site 883.6—View of existing winter road, 50 m upstream from centerline.

SITE 884.8



LEGEND

- Watercourse Crossing
- Transect
- Electrofishing
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 884.8

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:1,500
30 15 0 30
Metres

FILE NO.
WTRI03067-01_Figure24_Site8848.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 24

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Mackenzie Valley Highway

Site 884.8 Unnamed Watercourse

UTM Location: 10W 411300 7174635 **Survey Date:** 09/30/2021; 14:24

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	10.5	8.4	2.5	2.3	3.1	2.0
Wetted Width (m)	3.0	2.2	1.0	0.8	1.3	1.3
Depth at LDB + 25% (m)	0.5	0.1	0.3	0.3	0.2	0.2
Depth at LDB + 50% (m)	0.6	0.1	0.4	0.2	0.2	0.3
Depth at LDB + 75% (m)	0.3	0.1	0.2	0.2	0.2	0.3
Max.BankfullDepth (m)	2.0	2.1	0.82	0.97	0.72	1.0
Gradient (%)	-	-	-	-	-	-
Dominant Habitat Unit	IP1	FL	R2	R2	R1	R1
Stream Bed						
Substrate (% of Transect Area) — Organics	0	0	0	20	20	60
Substrate (% of Transect Area) — Fines	0	90	90	80	80	40
Substrate (% of Transect Area) — Small Gravel	0	10	10	0	0	0
Substrate (% of Transect Area) — Large Gravel	0	0	0	0	0	0
Substrate (% of Transect Area) — Cobble	0	0	0	0	0	0
Substrate (% of Transect Area) — Boulder	0	0	0	0	0	0
Substrate (% of Transect Area) — Bedrock	0	0	0	0	0	0
Embeddedness	VH	M	H	N	N	N

Bank Measurements	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Bank Height (m)	0.5	1.4	0.5	2.0	0.4	0.4	0.5	0.7	0.5	0.3	0.60	0.70
Bank Slope (°)	45	45	60	60	90	90	80	80	70	70	60	60
Bank Stability	US	US	US	US	MS	MS	MS	MS	MS	US	MS	MS
Dom. Bank Material	F	F	F	F	F	F	O	O	F	F	F	F
Subdom. Bank Material	O	O	O	O	O	O	F	F	O	O	O	O
Dom. Riparian Veg.	G	G	G	G	D	D	G	G	S	C	G	G
Subdom. Riparian Veg.	S	S	C	C	S	S	S	C	G	S	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	60	Overhead Cover (%):	30
Dom. Instream Cover:	WD	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	G
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	14:22
Water Temperature (°C):	3.2
Dissolved Oxygen (mg/L):	-
Sp. Conductivity (µs/cm):	338
pH:	7.70
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	IR
Islands:	O
Bars:	BR
Coupling:	CO
Confinement:	CO
Flow Stage:	Low

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	Poor	Poor
Overwintering:	Poor	Poor	Poor
Rearing:	Moderate-Good	Poor-Moderate	Poor
Passage:	Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	471	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
190	30	12	300

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
BROOK STICKLEBACK	3	-	0.64	-	9.4%
PEARL DACE	29	-	6.16	-	90.6%

General Comments

No crown cover from crossing to 100 m upstream, and no overhanging vegetation. Significant erosion on banks. Partially coupled. The wildlife monitor mentioned that a beaver dam approximately 50 m upstream of centerline was blown out a year ago. A lot of bank instability at that location. Ice scarring is 2 m high at 50 m upstream and at the crossing. Crown cover is 60% at crossing. In downstream reach, there are woody debris throughout.



Photo 1: Site 884.8—Aerial photo looking downstream.



Photo 2: Site 884.8—Facing upstream from 100 m upstream from centerline.



Photo 3: Site 884.8— View of existing culvert crossing on winter road, approximately 200 m upstream of proposed alignment centerline.



Photo 4: Site 884.8—Bank instability upstream approximately 60 m from centerline

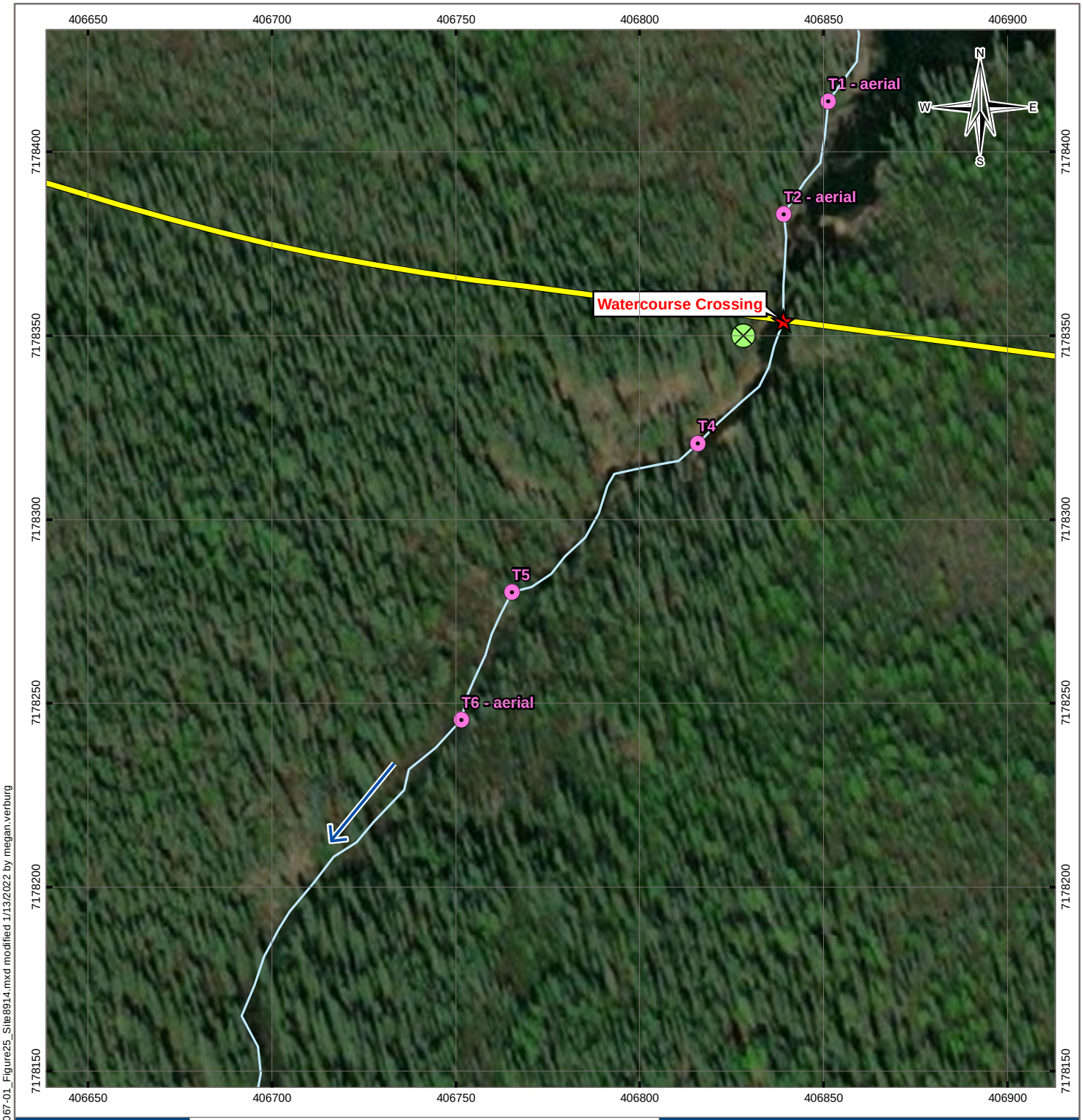


Photo 5: Site 884.8—Facing upstream at 200 m downstream from centerline.



Photo 6: Site 884.8—Facing upstream at 300 m downstream from centerline.

SITE 891.4



LEGEND

- Watercourse Crossing
- Beaver Dam
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2017)

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 891.4

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:1,500
30 15 0 30
Metres

FILE NO.
WTRI03067-01_Figure25_Site8914.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

TETRA TECH

Figure 25

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Mackenzie Valley Highway

Site 891.4 Unnamed Watercourse

UTM Location: 10W 406839 7178354 **Survey Date:** 10/11/2021; 11:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	17.0		15.0		12.5		5.5		5.8		6.0	
Wetted Width (m)	-		-		-		5.0		5.0		-	
Depth at LDB + 25% (m)	-		-		1.3		0.5		0.5		-	
Depth at LDB + 50% (m)	-		-		-		0.5		0.5		-	
Depth at LDB + 75% (m)	-		-		-		0.3		0.7		-	
Max.BankfullDepth (m)	-		-				0.52		0.65		-	
Gradient (%)	3		3		3		3		3		3	
Dominant Habitat Unit	R1		RF		BD		R1		R1		FL	
Stream Bed												
Substrate (% of Transect Area) Organics	-		-		0		30		30		-	
Fines	-		-		100		40		70		-	
Small Gravel	-		-		0		-		-		-	
Large Gravel	-		-		0		-		-		-	
Cobble	-		-		0		30		-		-	
Boulder	-		-		0		-		-		-	
Bedrock	-		-		0		-		-		-	
Embeddedness	-		-		N		M		M		-	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	-	-	-	-	1.3	-	-	-	-	-	-	-
Bank Slope (°)	80	80	70	70	65	65	50	50	50	50	50	50
Bank Stability	MS	MS	MS	US	US	US	US	US	US	US	US	US
Dom. Bank Material	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	C	C	C	C	C	C	C	C	C	C	C	C
Subdom. Riparian Veg.	G	G	G	G	G	G	G	G	G	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	10
Dom. Instream Cover:	WD	Dom. Overhead Cover:	C
Subdom. Instream Cover:	C	Subdom. Overhead Cover:	S
Maximum Depth (m)	>1	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	11:00
Water Temperature (°C):	3.3
Dissolved Oxygen (mg/L):	10.25
Sp. Conductivity (µs/cm):	340
pH:	8.04
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ST
Islands:	N
Bars:	N
Coupling:	CO
Confinement:	CO
Flow Stage:	High

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Poor	Poor
Overwintering:	Moderate	Moderate	Moderate
Rearing:	Good	Good	Good
Passage:	Moderate-Good	Moderate-Good	Moderate-Good

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Upstream of the centerline was a slightly impounded area as a result of the beaver dam at the centerline. The channel was wide providing moderate to good fish habitat. Steep banks on either side made access not possible for assessment of 100 m and 50 m upstream as well as 300 m downstream, therefore aerial assessments were completed instead. No barriers were observed with the exception of the beaver dam. Erosion of bank was more significant near the centerline and downstream, with increasing bank stability upstream. No fishing conducted due to freezing conditions an.d unsafe conditions for electrofishing due to high flows and water depth.

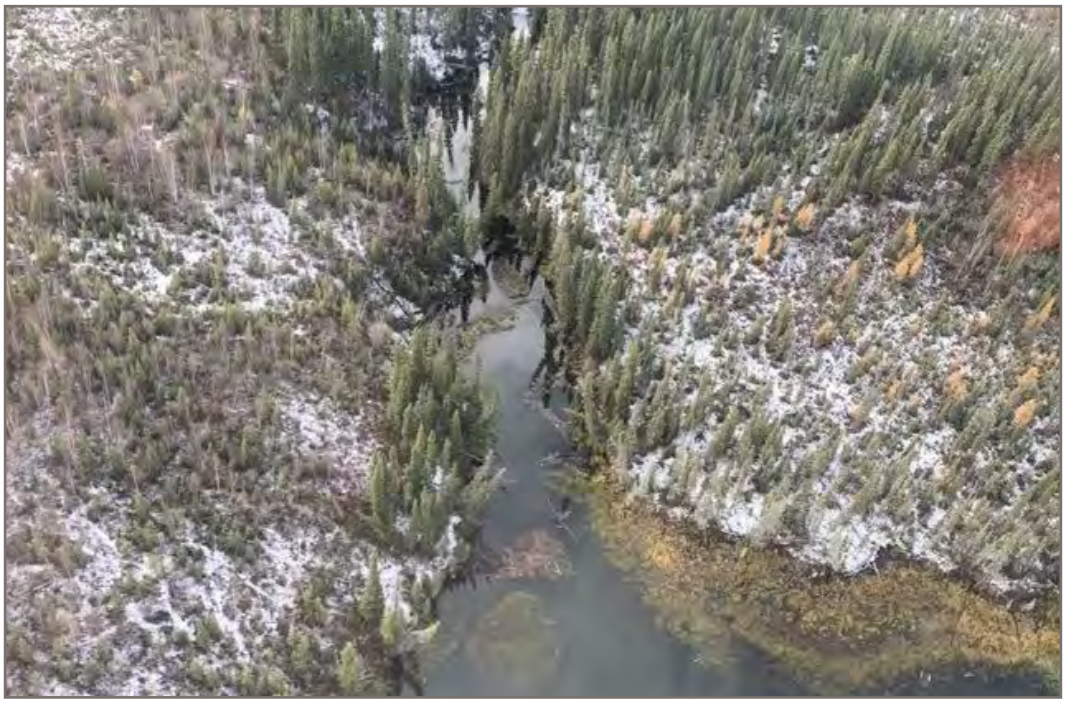


Photo 1: Site 891.4— Aerial view looking downstream at 100 m upstream to centerline.



Photo 2: Site 891.4— Looking upstream at the centerline.

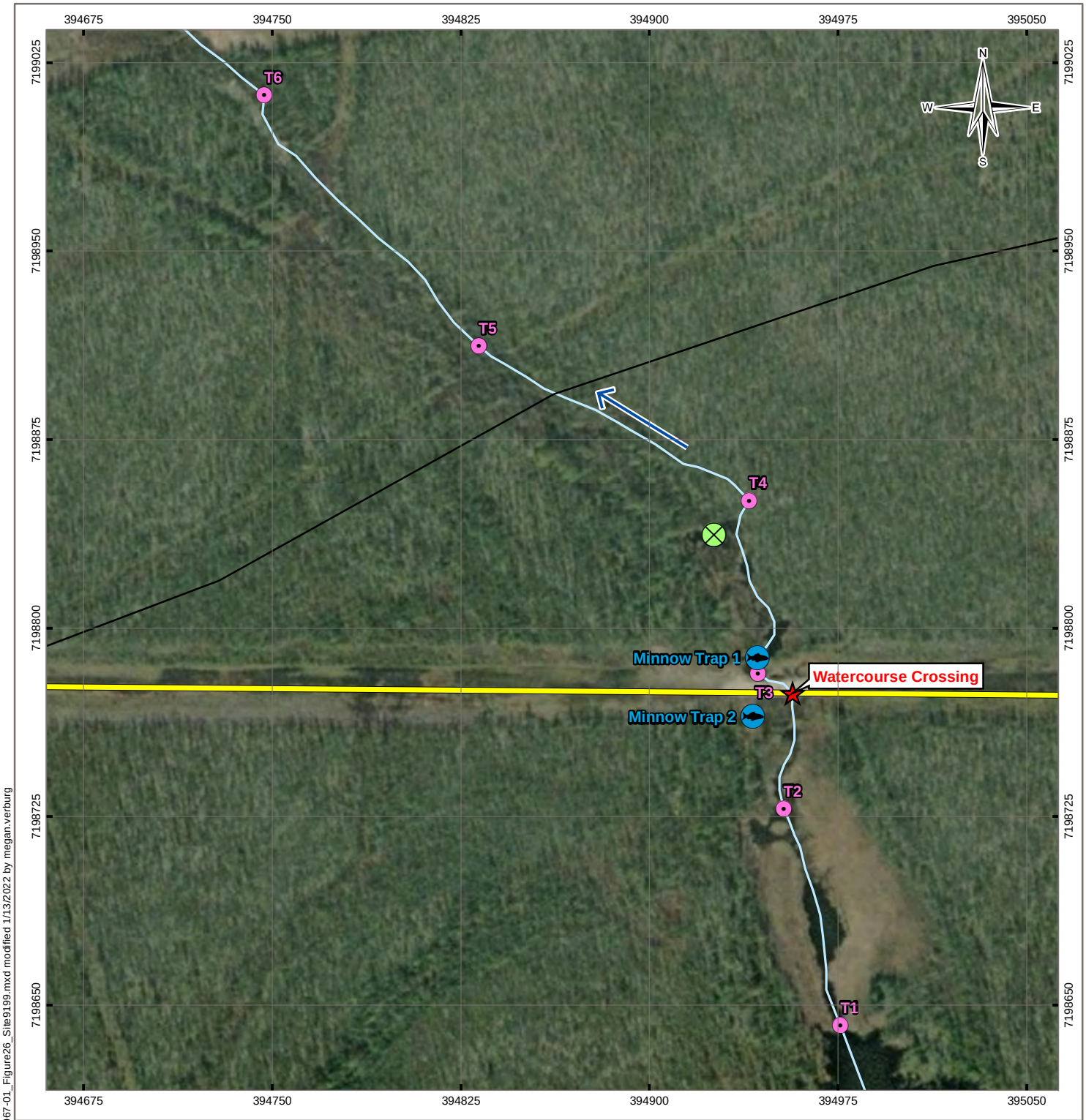


Photo 3: Site 891.4— Looking upstream at 50 m upstream from centerline.



Photo 4: Site 891.4— Upstream view at 100 m downstream from centerline.

SITE 919.9



LEGEND

- Watercourse Crossing
- Beaver Dam
- Minnow Trap
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2018)
CanVec 1:50,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 919.9

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,200
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure26_Site9199.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

TETRA TECH

Figure 26

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Mackenzie Valley Highway

Site 919.9 Unnamed Watercourse

UTM Location: 10W 394956 7198775 **Survey Date:** 9/30/2021; 10:27

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	43.0	44.0	37.0	18.0	3.1	1.3
Wetted Width (m)	27.0	44.0	37.0	18.0	1.8	0.6
Depth at LDB + 25% (m)	0.7	0.6	0.2	1.1	0.3	0.3
Depth at LDB + 50% (m)	1.1	1.4	0.2	1.2	0.3	0.4
Depth at LDB + 75% (m)	0.8	0.4	0.2	1.1	0.2	0.3
Max.BankfullDepth (m)	1.5	1.9	0.29	1.3	0.70	0.77
Gradient (%)	-	-	-	-	-	-
Dominant Habitat Unit	IP1	WL	WL	WL	WL	IP1
Stream Bed						
Substrate (% of Transect Area) Organics	100	100	30	30	60	60
Fines	0	0	60	70	40	40
Small Gravel	0	0	0	0	0	0
Large Gravel	0	0	0	0	0	0
Cobble	0	0	0	0	0	0
Boulder	0	0	10	0	0	0
Bedrock	0	0	0	0	0	0
Embeddedness	VH	VH	L	H	H	H

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	0.3	0.5	0.6	0.6	0.1	0.1	0.1	0.1	0.2	0.4	0.37	0.23
Bank Slope (°)	0	0	0	0	0	0	10	10	10	10	70	70
Bank Stability	S	S	S	S	S	S	S	S	MS	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	C	C	G	C	G	S	G	S	S	C	D	D
Subdom. Riparian Veg.	S	S	C	S	S	G	S	G	S	G	G	G

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	10
Dom. Instream Cover:	OHV	Dom. Overhead Cover:	G
Subdom. Instream Cover:	G	Subdom. Overhead Cover:	S
Maximum Depth (m)	>2	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	10:27
Water Temperature (°C):	2.9
Dissolved Oxygen (mg/L):	5.96
Sp. Conductivity (µs/cm):	182
pH:	6.50
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ME
Islands:	O
Bars:	BR
Coupling:	DC
Confinement:	UN
Flow Stage:	Flood

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Good	None	None
Overwintering:	Poor-Moderate	Poor	Poor
Rearing:	Good	Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
Minnow Trap (MT)	46.6	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

100 m upstream is the entrance of a deep pool flooded in floodplain. at 50 m upstream is a flooded area that crosses downstream of centerline. Downstream is braided with organic islands in the middle throughout to 100 m downstream, where beaver dam is present. An existing culvert is present at crossing with pooling on either side with vegetation islands. Entire reach had poorly defined channel taht was largely flooded.Two minnow traps were set on either side of the crossing.



Photo 1: Site 919.9—Upstream view at centreline.



Photo 2: Site 919.9—Looking upstream 100m upstream from centerline.



Photo 3: Site 919.9—Channel facing downstream at 300 m downstream from centerline.



Photo 4: Site 919.9— Beaver dam 100 m downstream of centerline.



Photo 5: Site 919.9—View of centerline looking down the existing winter road.



Photo 6: Site 919.9— Water pooling upstream of centerline gravel road.

SITE 940.1



LEGEND

- Watercourse Crossing
- Transect
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Other Road
- Watercourse

NOTES

Base data source: Imagery provided by ESRI; Maxar (2017)
Hydrology provided by Government of NT CanVec 1:50,000

STATUS
ISSUED FOR USE

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 940.1

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	Northwest Territories

Scale: 1:2,000
40 20 0 40
Metres

FILE NO.
WTRI03067-01_Figure27_Site9401.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE
January 13, 2022

PROJECT NO.
ENG.WTRI03067-01

TETRA TECH

Figure 27

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TETRA TECH

Mackenzie Valley Highway

Site 940.1 Unnamed Watercourse

UTM Location: 10W 375325 7203625 **Survey Date:** 10/8/2021; 18:00

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)		2 (↑50)		3 (CL)		4 (↓100)		5 (↓200)		6 (↓300)	
Channel Width (m)	1.9		2.2		1.5		1.4		1.0		1.3	
Wetted Width (m)	1.1		1.7		1.0		1.1		0.9		1.0	
Depth at LDB + 25% (m)	0.2		0.3		0.4		0.4		0.2		0.1	
Depth at LDB + 50% (m)	0.4		0.3		0.4		0.3		0.1		0.2	
Depth at LDB + 75% (m)	0.3		0.2		0.3		0.5		0.3		0.2	
Max.BankfullDepth (m)	0.51		0.47		0.93		0.68		0.40		0.32	
Gradient (%)	1		1		1		1		5		8	
Dominant Habitat Unit	R1		R1		R1		R1		P2		SP	
Stream Bed												
Substrate (% of Transect Area) Organics	40		40		60		100		30		60	
Substrate (% of Transect Area) Fines	60		60		40		0		70		30	
Substrate (% of Transect Area) Small Gravel	0		0		0		0				0	
Substrate (% of Transect Area) Large Gravel	0		0		0		0		0		10	
Substrate (% of Transect Area) Cobble	0		0		0		0		0		0	
Substrate (% of Transect Area) Boulder	0		0		0		0		0		0	
Substrate (% of Transect Area) Bedrock	0		0		0		0		0		0	
Embeddedness	N		N		N		N		N		N	
Bank Measurements	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Bank Height (m)	0.1	0.1	0.2	0.1	0.4	0.5	0.2	0.1	0.0	0.1	0.1	0.1
Bank Slope (°)	20	5	25	30	20	20	10	10	10	10	10	10
Bank Stability	MS	MS	MS	MS	MS	MS	US	MS	S	MS	MS	MS
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	D	D	S	S
Subdom. Riparian Veg.	G	G	G	G	G	G	D	D	S	S	D	D

Habitat Inventory / Reach Data

Instream Cover (%):	10	Overhead Cover (%):	90
Dom. Instream Cover:	UC	Dom. Overhead Cover:	S
Subdom. Instream Cover:	-	Subdom. Overhead Cover:	G
Maximum Depth (m)	0.6	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	18:09
Water Temperature (°C):	0.2
Dissolved Oxygen (mg/L):	12.54
Sp. Conductivity (µs/cm):	597
pH:	8.29
Turbidity (NTU):	Lightly Turbid

Channel Characteristics

Pattern:	ME
Islands:	N
Bars:	N
Coupling:	PC
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate	None	None
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Moderate-Good	Poor-Moderate	Poor-Moderate
Passage:	Poor-Moderate	Poor-Moderate	Poor-Moderate

Fish Sampling Data

Method	Effort	
No Electrofishing	-	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
-	-	-	-

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)

General Comments

Snow and ice cover throughout at time of assessment. Overhanging shrubs cover 90-100% of stream throughout. Grasses compressed by snow. Uplands show signs of fire in past, with abundant woody debris throughout. No instream vegetation. 200 DS: Significant flow with several cascades. Upstream passage, along with the increased gradient, would be difficult for all fish species.Step pools are present downstream 300 m and cascade drops 0.25m with 0.36m pool depth (i.e. natural barriers). No fishing conducted due to snow and ice conditions.



Photo 1: Site 940.1—Upstream view from new alignment centerline.



Photo 2: Site 940.1—Downstream view of 100 m downstream from centerline.



Photo 3: Site 940.1—Downstream view of 50 m upstream from centerline.



Photo 4: Site 940.1—upstream view of 300 m downstream from centerline.



Photo 5: Site 940.1—Aerial view of existing channel, looking northeast (upstream).

SITE 981.2

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LEGEND

- Watercourse Crossing
- Site Feature
- Transect
- Electrofishing
- Flow Direction
- Mackenzie Valley Highway Extension

Base Data

- Watercourse

NOTES
Base data source: Imagery provided by ESRI; Maxar (2017)
Hydrology provided by Government of NT

STATUS
ISSUED FOR USE

Scale: 1:2,000
40 20 0 40
Metres

PROJECTION	DATUM
UTM Zone 9	NAD83

FILE NO.
WTRI03067-01_Figure28_Site9812.mxd

CLIENT Northwest Territories

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-EDM	MRV	SL	TM	0

DATE	PROJECT NO.
January 13, 2022	ENG.WTRI03067-01

MACKENZIE VALLEY HIGHWAY FISHERIES ASSESSMENT

Site 981.2

Figure 28

TETRA TECH

Mackenzie Valley Highway

Site 981.2 Unnamed Watercourse

UTM Location: 10W 629352 7227768 **Survey Date:** 10/7/2021; 15:30

Legal Location: - **Zone:**

Crew Initials: TM & MAN **Restricted Activity Period:** -

Physical Channel Transect Data

Transect # (Location)	1 (↑100)	2 (↑50)	3 (CL)	4 (↓100)	5 (↓200)	6 (↓300)
Channel Width (m)	1.4	2.2	2.6	2.0	4.0	1.4
Wetted Width (m)	0.9	1.1	1.4	1.5	1.4	0.7
Depth at LDB + 25% (m)	0.1	0.1	0.0	0.2	0.5	0.2
Depth at LDB + 50% (m)	0.1	0.1	0.1	0.1	0.4	0.2
Depth at LDB + 75% (m)	0.1	0.1	0.2	0.1	0.4	0.2
Max.BankfullDepth (m)	0.45	0.71	1.0	0.52	0.86	0.57
Gradient (%)	4	4	4	2	2	2
Dominant Habitat Unit	RF	RF	RF	R1	R1	R2
Stream Bed						
Substrate (% of Transect Area) – Organics	0	0	0	0	0	0
Substrate (% of Transect Area) – Fines	10	10	0	0	30	20
Substrate (% of Transect Area) – Small Gravel	40	10	20	40	70	80
Substrate (% of Transect Area) – Large Gravel	30	25	40	50	0	0
Substrate (% of Transect Area) – Cobble	20	50	30	10	0	0
Substrate (% of Transect Area) – Boulder	0	5	10	0	0	0
Substrate (% of Transect Area) – Bedrock	0	0	0	0	0	0
Embeddedness	N	N	N	N	N	N

Bank Measurements	1 (↑100) Left	1 (↑100) Right	2 (↑50) Left	2 (↑50) Right	3 (CL) Left	3 (CL) Right	4 (↓100) Left	4 (↓100) Right	5 (↓200) Left	5 (↓200) Right	6 (↓300) Left	6 (↓300) Right
Bank Height (m)	0.3	0.3	0.6	0.5	0.9	0.7	0.3	0.3	0.3	0.4	0.3	0.4
Bank Slope (°)	70	90	50	90	90	90	35	50	20	30	90	70
Bank Stability	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	US	US
Dom. Bank Material	O	O	O	O	O	O	O	O	O	O	O	O
Subdom. Bank Material	F	F	F	F	F	F	F	F	F	F	F	F
Dom. Riparian Veg.	S	S	S	S	S	S	S	S	S	S	S	S
Subdom. Riparian Veg.	G	G	S	C	G	G	C	C	G	G	C	C

Habitat Inventory / Reach Data

Instream Cover (%):	25	Overhead Cover (%):	40
Dom. Instream Cover:	Co	Dom. Overhead Cover:	S
Subdom. Instream Cover:	Bo	Subdom. Overhead Cover:	C
Maximum Depth (m)	0.8	Dom. Aquatic Veg. Type:	-

Water Quality Data

Time of Day (HH:MM):	15:30
Water Temperature (°C):	0.2
Dissolved Oxygen (mg/L):	12.77
Sp. Conductivity (µs/cm):	961
pH:	8.54
Turbidity (NTU):	Clear

Channel Characteristics

Pattern:	ME
Islands:	I
Bars:	N
Coupling:	CO
Confinement:	OC
Flow Stage:	Moderate

Fish Habitat Assessment Ratings

	Forage Fish	Coarse Fish	Sport Fish
Spawning:	Moderate-Good	Moderate-Good	Moderate-Good
Overwintering:	None-Poor	None-Poor	None-Poor
Rearing:	Good	Good	Moderate
Passage:	Moderate	Moderate	Moderate

Fish Sampling Data

Method	Effort	
Backpack Electrofisher (EB)	485	(s)
No Trapping	-	(hr)

Electrofisher Settings

Volts	Freq. (Hz)	Duty Cycle (%)	Dist. (m)
235	30	12	100

Species	Efish Catch (n)	Trap Catch (n)	Efish CPUE (#fish/100s)	Trap CPUE (#fish/hr)	Rel. Abundance (% of total)
NO FISH CAPTURED					

General Comments

Assessment done in snow and 50% ice cover frozen. Upstream has some undercutbanks and large cobbles present under banks. There are riffle sections throughout with chutes abundant. Some step pools upstream from woody debris. Some logjams downstream that may be fish passage barriers. Good flow 300 m downstream, some woody debris causing riffling with minor undercutting and exposed roots on bank. Grasses covered in snow on bank.



Photo 1: Site 981.2—Downstream view of 100 m upstream from centerline.



Photo 2: Site 981.2— Looking upstream at 300 m downstream from centerline.



Photo 3: Site 981.2— Upstream view of 200 m downstream from centerline.



Photo 4: Site 981.2—Upstream view of 100 m downstream from centerline.



Photo 5: Site 981.2— Upstream view of from centerline of proposed alignment.

Topic: NRCan-05: Responsible Authority/Minister

Reviewer Preamble:

The Proponent has identified that the Project will require the manufacturing and storage of explosives. NRCan, through its role in the administration of the Explosives Act, may exercise a power or perform a duty or function that would enable the project to proceed.

Reviewer Request:

If the Project involves the manufacturing or storage of explosives, please provide details of the type and quantity of explosives to be stored, as well as the specific locations of the explosives facilities.

Response from the Government of the Northwest Territories:

It is not anticipated that explosives will be manufactured on site. It is more likely that pre-packaged ammonium-nitrate-fuel-oil (ANFO) emulsion explosives will be used, consistent with other Government of Northwest Territories (GNWT) highway and quarry development projects. Pre-packaged explosives are likely to be stored at one or more quarries or other designated areas, as was done during the construction of the Prohibition Creek Access Road (see Edie Lake Quarry –Quarry Operations Plan (https://registry.mvlwb.ca/Documents/S20E-005/S20E-005%20-%20PCAR%20Quarry%20Operations%20Plan%20Ver%201-%20Sep%2023_20.pdf).

The locations of explosives storage have not yet been determined. These will be determined by the contractor selected by the GNWT to construct the Project. The assessment assumes that explosives will be transported to quarries along constructed portions of the Project and quarry access roads, and that some quantity of explosives may be stored at the quarry during construction and/or operation of the quarry (see Developer's Assessment Report, Section 5.4.5.3).

An Explosives Management Plan will be developed for the Project prior to construction to support regulatory authorizations.

Topic: NRCan-04: Slope Stability in the Project Area and Project Design

Reviewer Preamble:

Slope instability related to ground warming has been discussed in the Developer's Assessment Report ([DAR] Section 14.4.4), and landslides have been identified on the terrain maps provided in Appendix 14A (Appendix B within). Creep (gradual downslope movement) has been observed to occur in warm permafrost on slopes along the Norman Wells pipeline and these movements have been monitored with slope inclinometers by Enbridge. NRCan notes that while there are a few references to creep in the DAR it is unclear whether it has been considered in the design of the approaches to water crossings and assessment of impacts on bridge abutments. It is not clear from the monitoring plans submitted whether instrumentation such as slope inclinometers will be installed to inform the need for mitigation at the water crossing approaches and bridge abutments. Any additional information regarding consideration of creep in the Project design and assessment of effects of the environment on the Project would help inform NRCan's review of the DAR.

Reviewer Request:

NRCan request from the Proponent:

Please provide clarification regarding how creep on warm permafrost slopes was considered in design of water crossing approaches and assessment of the effect of the environment on bridge abutments.

Please clarify if instrumentation to monitor creep, such as slope inclinometers, will be installed as part of environmental monitoring and management plans in order to determine the need for mitigation at water crossing approaches.

Response from the Government of the Northwest Territories:

Slope stability including creep in warm permafrost will be considered in the design of the roadway embankment and watercourse crossings. As the final engineering designs for the road and crossings have not been completed yet, we are unable to provide details about how creep and warm permafrost information has been considered. The engineering design will incorporate slope stability information along the route including near crossings.

Instrumentation to monitor creep, if required to ensure the integrity of the infrastructure, will be installed during construction, as experiences on the Tłı̨chǫ Highway have shown that instrumentation installed prior to construction within or near the Project footprint is subject to being damaged.

NRCan-03: Assessment of Long-Term Changes in Permafrost Condition and Associated Environmental Effects

Reviewer Preamble:

Knowledge of how permafrost conditions will change over time due to infrastructure construction and operation, climate change and other environmental disturbances is essential to inform project design and assessment of impacts of the project on the environment and also the impacts of the environment on the project. The expected changes in permafrost conditions including changes in thermal conditions has been assessed at a high level in the DAR. Similarly, a climate change risk assessment has been done at a high level with some aspects based on global or national scale assessments (including some inappropriate interpretation of results). Thermal modelling is usually done to quantitatively assess the evolution of the permafrost thermal regime over the project lifetime. However, this type of thermal analysis does not appear to be presented in the DAR. It is unclear if this type of analysis is included in the reports submitted to the Proponent by Tetra Tech in support of design of the Mount Gaudet Access Road and the Prohibition Creek Access Road, as these reports have not been provided. NRCan understands that more detailed site-specific thermal analysis is usually completed as design advances. However, information on any thermal modelling completed by the Proponent would be useful to NRCan's review of the DAR to better understand the anticipated changes in permafrost conditions and associated environmental impacts.

Reference for Tetra Tech reports cited in DAR:

Tetra Tech, 2020. *Mount Gaudet Access Road Thermal Assessment Report, MVWR km 687 to 708, Northwest Territories.* Issued for Review Report prepared for the Government of the Northwest Territories, Department of Infrastructure by Tetra Tech Canada Inc. November 24, 2020. Tetra Tech File: 704-ENG.YARC03354-02

Tetra Tech, 2020. *Prohibition Creek Access Road Thermal Assessment Report, MVWR km 995.3 to km 1009.3, Northwest Territories.* Issued for Review Report prepared for the Government of the Northwest Territories, Department of Infrastructure by Tetra Tech Canada Inc. November 24, 2020. Tetra Tech File: 704-ENG.YARC03354-02

Reviewer Request:

Please provide clarification on whether any thermal modelling has been done to assess the evolution of permafrost conditions and inform project design and assessment of environmental effects. If such analysis has been conducted, please provide any information (including reports) on the results of this analysis.

Response from the Government of the Northwest Territories:

The Government of the Northwest Territories has not conducted any Project-specific thermal modelling for the Project, and are not aware of any thermal modelling conducted by others in the Regional Assessment Area. The Tetra Tech reports referenced in the Technical Data Report for Terrain, Soils, and Permafrost (Appendix 14A) describe the soil and thermal conditions observed along the Mount Gaudet Access Road (Tetra Tech, 2021a) and the Prohibition Creek Access Road (Tetra Tech, 2021b) during the 2020 geotechnical investigation programs.

Thermal modelling may be considered for specific sections of the Project highway alignment where thaw-sensitive, ice-rich permafrost soils are identified. Data from thermal modelling studies, if undertaken, will inform the detailed design of the road embankment structure for specific sections of the Project. The GNWT does not expect to perform thermal modelling for the entire highway alignment.

References

Tetra Tech, 2021a. *Mount Gaudet Access Road Thermal Assessment Report, MVWR km 687 to km 708, Northwest Territories.* Issued for Use Report prepared for K'alo-Stantec Limited by Tetra Tech Canada Inc. June 18, 2021. Tetra Tech File: 704-ENG.YARC03354-02 (provided as attachment to the GNWT's response to IR CanNor-06)

Tetra Tech, 2021b. *Prohibition Creek Access Road Thermal Assessment Report, MVWR km 995.3 to km 1009.3, Northwest Territories.* Issued for Use Report prepared for K'alo-Stantec Limited by Tetra Tech Canada Inc. June 10, 2021. Tetra Tech File: 704-ENG.YARC03354-02 (provided as attachment to the GNWT's response to IR CanNor-06)

Mount Gaudet Access Road
Thermal Assessment Report

MVWR km 687 to 708, Northwest Territories



PRESENTED TO
Kãlo Stantec Limited

JUNE 18, 2021
ISSUED FOR USE
FILE: 704-ENG.YARC03354-02

Tetra Tech Canada Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was retained by Kãlo Stantec Limited (Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to provide thermal assessment support for advancing design and engineering of the Mount Gaudet Access Road (MGAR) north of Wrigley, Northwest Territories (NT). The MGAR is a section of the Mackenzie Valley Winter Road (MVWR) that is planned to be replaced with an all-season, two-lane, gravel highway as part of a future extension to the Mackenzie Valley Highway (MVH). The objective of this thermal assessment is to inform the MVH design of the geothermal and subsurface conditions expected along the MGAR alignment.

The MGAR alignment is located within a zone of extensive, discontinuous permafrost, indicating that permafrost is expected to be present in 50% to 90% of land cover (NRC 2009). Frozen soils were encountered along the MGAR alignment in 37 out of the 42 boreholes drilled during Tetra Tech's 2020 geotechnical and geophysical investigation. Frozen silts and clays, with visible ground ice and ice lenses, were observed at depth between MVWR km 693.0 and 703.5. Unfrozen silty clays were observed below the seasonal frost layer in five of the boreholes drilled.

During Tetra Tech's 2020 geotechnical investigation, PVC conduit pipes were installed in six boreholes along the MGAR alignment to depths of 8.0 m. These locations were selected based on subsurface and thermal conditions encountered during the investigation program and the pipes were installed to allow for the installation of ground temperature cables (GTCs). Tetra Tech returned to the MGAR in July 2020 and installed GTCs in five of the six boreholes. A partial set of ground temperature readings were collected in September 2020 and a complete set of readings were collected from all five GTCs in November 2020. Ground temperatures generally decrease with depth in all boreholes, except BH-01 where ground temperatures were the warmest. The active layer thickness within the instrumented boreholes is estimated to range from 0.5 m to 2.0 m and this will be confirmed by subsequent readings.

The MGAR was divided into three generalized sections based on thermal conditions: South, Middle, and North. The South Section is expected to be thaw-stable and permafrost was not encountered during the drill program. If permafrost is present, it is likely below 8.0 m depth and thaw settlement is not expected to be significant if impacted by the construction of the MGAR. The Middle Section of the MGAR is likely thaw-sensitive as it contains frequent ground ice within fine-grained soils and exhibits frozen ground temperatures indicative of warm permafrost. Thaw settlement is likely to occur in the Middle Section, should ground temperatures warm over time due to construction of the MGAR, and will be larger where visible ground ice is greater than 20% by volume, particularly between MVWR km 694.0 and 696.0. The North Section is expected to have ice-poor permafrost as low volumes of visible ground ice were observed below the active layer in all of the section's boreholes. This section is anticipated to be thaw-stable and is not likely to experience significant thaw settlement due to permafrost degradation.

Permafrost and thermal considerations for each section of the MGAR are provided based on Tetra Tech's experience on similar road projects and engineering judgement. Settlement along the MGAR alignment was estimated based on two mechanisms: thaw settlement and self-weight settlement of placed embankment fill during winter construction as well as thaw settlement and consolidation of the underlying subgrade. Significant thaw settlement is expected in the Middle Section of the MGAR where ice-rich permafrost has been identified in the subgrade. Embankment fill settlement is expected to be up to 0.3 m along the MGAR and consideration should be given to overbuilding the road embankments by 0.3 m to allow for this. Thaw settlement and consolidation of the subgrade due to permafrost warming and degradation over the service life of the road could be up to 0.6 m along the Middle Section of the MGAR.

Ground temperature monitoring should continue to better understand permafrost conditions at the MGAR site and all GTCs should be read two times each year, at a minimum. Readings should be taken in spring (early April) when ground temperatures are the coldest for the year and in the fall (late September) when ground temperatures are warmest for the year. Tetra Tech will continue to update and track ground temperatures as data is collected from the MGAR.

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APPENDICES

Appendix A Tetra Tech's Limitations on Use of this Document
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ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
CSA	Canadian Standards Association
GNWT	Government of the Northwest Territories, Department of Infrastructure
GTC	Ground Temperature Cable
km	Kilometres
m	Metres
mm	Millimetres
MGAR	Mount Gaudet Access Road
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NT	Northwest Territories
Stantec	Kãlo Stantec Limited
TAC	Transportation Association of Canada
Tetra Tech	Tetra Tech Canada Inc.

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Kãlo Stantec Limited, the Government of the Northwest Territories, and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Kãlo Stantec Limited and the Government of the Northwest Territories, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached in Appendix A.

1.0 INTRODUCTION

1.1 General

Tetra Tech Canada Inc. (Tetra Tech) was retained by Kãlo Stantec Limited (Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to provide thermal assessment support for advancing design and engineering of the Mount Gaudet Access Road (MGAR) near Wrigley, Northwest Territories (NT). The MGAR is a section of the Mackenzie Valley Winter Road (MVWR) that is expected to be replaced with an all-season, two-lane, gravel highway as part of a future extension to the Mackenzie Valley Highway (MVH). Tetra Tech completed geotechnical and geophysical investigations along the proposed MGAR alignment in February and March 2020.

The objective of this thermal assessment is to inform the MVH design of the geothermal and subsurface conditions expected along the MGAR alignment. This report includes an assessment of the site's thermal conditions based on data gathered from the investigation programs and subsequent ground temperature monitoring. It includes road construction considerations and recommendations on the MGAR design as well as future monitoring. This assessment report should be read in conjunction with the Tetra Tech geotechnical and geophysical evaluation report titled *Geotechnical and Geophysical Evaluation for Mount Gaudet Access Road, Wrigley, NT* (Tetra Tech 2020).

Tetra Tech was initially requested by the GNWT to conduct a thermal assessment of the MGAR via email on April 1, 2020. Authorization to proceed with this work was provided through a standing offer agreement in place between the GNWT and the team of Stantec and Tetra Tech, via a subconsultant agreement signed on August 11, 2020.

1.2 Project Description

The MVWR extends from Wrigley (km 690) to Fort Good Hope (km 1173), with supplementary access roads connecting to Déljne (106 km) and Colville Lake (165 km). The winter road is constructed and maintained by the GNWT on an annual basis and typically operates from late December to late March. The GNWT is currently advancing a project to replace the MVWR by extending the MVH from Wrigley to Norman Wells, connecting the Sahtu Region with an all-season, two-lane, gravel highway.

One section of the existing MVWR alignment to be upgraded between Wrigley (km 690) and Tulita (km 938) is the MGAR. It starts from the MVWR connection to the Mackenzie Highway (NT Highway 1, km 687) and extends northward to the proposed Mount Gaudet Quarry (km 707). The proposed MGAR alignment primarily follows the existing MVWR right-of-way and includes a by-pass around the community of Wrigley (Pehdzéh Kį). The project is located near Latitude 63°13'41" N and Longitude 123°28'12" W, as shown on Figure 1.

The proposed MGAR alignment traverses one bridge at Hodgson Creek (km 691.4). The GNWT is currently evaluating relocating the bridge and realigning the road between the crossing and Wrigley. Tetra Tech (2021) recently prepared five road realignment options, with four options assuming construction of a new bridge in the location of the existing bridge and a fifth option assuming construction of a new bridge approximately 25 m downstream. Options for relocating Hodgson Creek Bridge upstream of the current location were also previously considered and the proposed realignment is shown on Figures 2 and 3.

1.3 Scope of Work

Tetra Tech's scope of work, in accordance with the proposal submitted on July 7, 2020, included the following tasks:

- Conduct a site visit to the MGAR and install multi-bead ground temperature cables (GTCs) in existing boreholes with PVC conduit;
- Complete a thermal assessment based on the data collected during the geotechnical and geophysical investigation programs as well as recent ground temperature data; and
- Prepare a report summarizing the collected ground temperature data and provide an assessment of the thermal regime along the MGAR alignment, including a description of present permafrost conditions and thermal considerations for embankment design and engineering of the MVH.

2.0 SITE DESCRIPTION

2.1 Surface Conditions

Surface vegetation and organics are visible along portions of the MGAR alignment and were up to 1.5 m thick in Borehole BH-42. Forests border both sides of the road alignment, approximately 10 m to 20 m from the edge of the road surface, with occasional clearings present on the west side. The trees are predominantly Black Spruce with heights upwards of 10 m. Deciduous birch trees, estimated to be up to 15 m in height, are also prevalent along the MGAR alignment.

Surficial deposits along the MGAR alignment generally consist of glaciolacustrine silty clays and glacial till soils (ACS 1973). Glaciofluvial deposits of silty sands and sandy gravels frequent along the Mackenzie River and at watercourse crossings (Duk-Rodkin and Huntley 2009). Bedrock in the area comprises sedimentary Mud Shales and Siltstones from the Fort Simpson Formation (Douglas and Norris 1974).

2.2 Subsurface Conditions

Subsurface conditions were classified for the MGAR following Tetra Tech's 2020 geotechnical and geophysical investigations. A total of 42 boreholes (BH-01 to BH-42) were drilled along the access road alignment, spaced approximately 500 m apart from MVWR km 687 to 708. For reference, copies of the MGAR borehole logs are provided in Appendix B.

Drilling depths ranged from 0.9 m to 8.1 m and both unfrozen and frozen soils, including visible ground ice and ice lenses, were encountered. Groundwater was encountered in one borehole (BH-07) near MVWR km 690.5 at a depth of 1.5 m. The first six kilometres of the MGAR alignment (MVWR km 687 to 693) primarily consists of glaciofluvial sand and gravel deposits to depth and the remainder of the alignment from MVWR km 693 to 708 consists of lacustrine silt and clay deposits.

2.3 Climate

Environment and Climate Change Canada operates several meteorological stations at the nearby community of Wrigley with public records available from 1950 to the present (ECCC 2021). The mean annual air temperature for the period of record is -5.5°C, which has been gradually increasing from the start of data collection. The average rate of annual temperature increase has been 0.04°C/year over the period of record, with the biggest increase

occurring in the winter months between October to April. Over the past 10 years, the mean annual air temperature has averaged -4.2°C with an average rate of increase of 0.13°C/year.

Using published data from the Climate Atlas of Canada, it was determined that Wrigley has an annual average of 3,682 freezing degree days between 1950 and 2020 (CAC 2021). The number of freezing degree days has decreased by an average of 12 freezing degree days/year during that time. Over the past 10 years, the number of freezing degree days has averaged 3,362 with an average rate of decrease of 26 freezing degree days/year.

The mean annual precipitation over the period of record (1950 to 2020) was determined to be 311 mm/year. Over the past 10 years, the annual precipitation in Wrigley averaged 320 mm/year.

2.4 Permafrost Conditions

The MGAR alignment is located within a zone of extensive, discontinuous permafrost, indicating that permafrost is expected to be present in 50% to 90% of land cover (NRC 2009). Where present, the ground temperature of the permafrost is expected to be warmer than -0.5°C based on the ground temperature data collected by Tetra Tech to date, as detailed in Section 3.2.

It was previously estimated that permafrost exists along two-thirds of the MVWR alignment between Wrigley (km 690) and the Blackwater River Bridge at MVWR km 784 (ACS 1973). Frozen soils were encountered along the MGAR alignment in 37 out of the 42 overland boreholes during Tetra Tech's 2020 geotechnical and geophysical investigation. Frozen silts and clays, with visible ground ice and ice lenses, were observed at depth between MVWR km 693 and 703.5. Unfrozen silty clays were observed below the seasonal frost layer in five of the boreholes drilled.

3.0 THERMAL DATA

3.1 Ground Temperature Instrumentation

During Tetra Tech's 2020 geotechnical investigation, PVC conduit pipes (25 mm diameter) were installed in six select boreholes along the MGAR alignment to facilitate the installation of ground temperature instrumentation up to depths of 8.0 m. Borehole locations were selected based on subsurface and thermal conditions encountered during the investigation program to represent typical ground conditions along the alignment.

Tetra Tech returned to the MGAR in July 2020 to install GTCs in five of the six boreholes fitted with PVC conduit pipe (BH-01, BH-06, BH-17, BH-34, BH-42). A GTC could not be installed in one borehole (BH-22) due to ice blockage inside the conduit pipe, despite several attempts to clear it. The borehole locations with GTCs are presented on Figures 1 to 6. Table 3-1 summarizes the GTCs installed along the MGAR alignment.

Table 3-1: Ground Temperature Cables Installed

Borehole Number	MVWR Milepost (km)	Coordinates (m, UTM Zone 10: NAD83 [CSRS] Epoch 2010)		Ground Elevation (m)	Installation Depth (m)	Number of Thermistor Beads*	Date Installed
		Northing	Easting				
BH-01	686.4	7,008,935.5	479,114.4	143.0	8.0	8	July 23, 2020
BH-06	688.8	7,011,024.1	477,956.4	127.1	8.0	8	July 23, 2020
BH-17	694.8	7,014,599.4	474,066.2	181.3	7.7	8	July 23, 2020
BH-22^	697.3	7,016,547.7	472,562.1	206.6	-	-	-
BH-34	703.3	7,021,903.3	470,633.6	212.8	7.7	8	July 24, 2020
BH-42	707.3	7,025,844.5	471,382.1	201.0	8.0	8	July 24, 2020

^ GTC unable to be installed in Borehole BH-22 due to icing inside the conduit pipe.

** Depth below ground of each thermistor bead shown on Ground Temperature Profiles in Appendix C.*

Each GTC is manufactured with eight thermistor beads spaced along a total cable length of 8.0 m with a 2.0 m lead length. The upper four beads nearest the ground surface (Beads 1 to 4) are spaced in 0.5 m intervals. Two intermediate beads (Beads 5 and 6) are spaced at 1.0 m intervals. The bottom two beads (Beads 7 and 8) are spaced at 2.0 m intervals.

The five GTCs are all manual read installations and a multimeter with a switch box is needed to connect to the cables in the field to obtain readings. Resistances are recorded at the thermistor beads along each cable which are then converted to ground temperatures using an equation.

3.2 Ground Temperature Data

Ground temperature readings were initially collected in July 2020, following the installation of the GTCs, to confirm that they were all functioning. The ground temperatures from all boreholes, except BH-17, did not appear to have equilibrated to natural background temperatures at that time; therefore, July 2020 data for these installations are not presented. A second partial set of ground temperature readings were collected from Boreholes BH-01, BH-34, and BH-42 in September 2020. A third complete set of readings were collected from all five GTCs in November 2020. A summary of the November ground temperature data collected is presented in Table 3-2.

Table 3-2: Ground Temperature Data Summary

Borehole Number	BH-01	BH-06	BH-17	BH-34	BH-42
MVWR Milepost (km)	686.4	688.8	694.8	703.3	707.3
Permafrost Encountered	No	No	Yes	Yes	No
Estimated Thickness of Active Layer*	0.5 m	0.6 m	2.0 m	1.4 m	1.5 m
Minimum Temperature below Active Layer (November 2020)	1.3°C @ 1.0 m	0.1°C @ 8.0 m	-0.4°C @ 7.7 m	-0.2°C @ 7.7 m	1.9°C @ 6.0 m
Maximum Temperature below Active Layer (November 2020)	3.7°C @ 4.0 m	0.7°C @ 3.0 m	0.0°C @ 2.7 m	0.1°C @ 1.7 m	2.6°C @ 2.0 m

** Active layer is defined as the top layer of ground subject to annual thawing and freezing in areas underlain by permafrost.*

Ground temperature profiles for each GTC are presented in Appendix C. A combined ground temperature profile for all five GTC installations is also presented in the appendix.

Ground temperatures generally decreased with depth in all boreholes, except BH-01 where ground temperatures are the warmest. The active layer thickness in the boreholes is estimated to range from 0.5 m to 2.0 m and this will be confirmed by subsequent GTC readings. Boreholes BH-17 and BH-34 were frozen below depths of 2.7 m, ranging from -0.1°C to -0.4°C. Borehole BH-06 was unfrozen below the seasonal active layer to depth with temperatures varying from 0.1°C to 0.7°C. Boreholes BH-01 and BH-42 were also unfrozen below the estimated seasonal active layer; however, ground temperatures were much higher compared to the other boreholes with maximum readings of 3.7°C and 2.6°C, respectively.

4.0 THERMAL ASSESSMENT

The factors affecting the sensitivity of permafrost ground to thermal degradation are mainly based on soil type, ground ice content, and ground temperature. Ice-rich permafrost soils are generally described as soils where the amount of water contained in the soil in a frozen state is higher than would be retained in a thawed (unfrozen) state. When frozen ground contains excess ground ice, the soil is susceptible to significant settlement and loss of soil strength when thawed (i.e., thaw-sensitive). Ice-poor permafrost is described as frozen soil that contains little frozen water and when thawed will not experience significant settlement or loss of soil strength (i.e., thaw-stable).

The MGAR has been divided into three generalized sections based on thermal conditions observed during the 2020 investigation programs and supported by subsequent ground temperature monitoring. MGAR thermal characterization sections are presented in Table 4-1 and in the following subsections.

Table 4-1: MGAR Thermal Characterization Sections

MGAR Section	MVWR Milepost (km)		Permafrost Conditions	GTCs within Section	Boreholes within Section
	From	To			
South (Wrigley to MVWR km 692.5)	686.4	692.5	Unfrozen Frozen, No Excess Ice	2 (BH-01, BH-06)	12 (BH-01 to BH-12)
Middle (MVWR km 692.5 to 703.0)	692.5	703.0	Frozen, Ice-Poor Frozen, Ice-Rich	1 (BH-17)	21 (BH-13 to BH-33)
North (MVWR km 703.0 to Mount Gaudet)	703.0	707.3	Unfrozen Frozen, Ice-Poor	2 (BH-34, BH-42)	9 (BH-34 to BH-42)

Subsurface conditions are not uniform, and thermal conditions are expected to vary within each MGAR section; however, the data collected provides a good indication of the range of thermal conditions to be expected along the MGAR alignment.

4.1 South Section (Wrigley to MVWR km 692.5)

The South Section of the MGAR starts from the MVWR connection to the Mackenzie Highway near Wrigley and extends to MVWR km 692.5. A total of 12 geotechnical boreholes (BH-01 to BH-12) were drilled along this section. Two GTCs were installed within this portion of the alignment at MVWR km 686.4 (Borehole BH-01) and km 688.8 (Borehole BH-06), as shown on Figures 2 and 3.

Subsurface conditions along the South Section predominantly consist of unfrozen and frozen, coarse-grained materials (Tetra Tech 2020). Most of the section has an organic cover of less than 300 mm, except between km 689.5 to 690.5. Unfrozen gravels, sands, and occasional silt layers were observed below the estimated active layer in 5 of the 12 boreholes drilled. Visible ground ice below the estimated active layer was only observed in one borehole (BH-06) at a depth of 1.3 m. Moisture content test results ranged from dry to damp with an average moisture content of 9.8%.

Ground temperature readings from the South Section of the MGAR indicate the soils are unfrozen to depth below the seasonal active layer of 0.5 m to 0.6 m. Ground temperatures in Borehole BH-0, which are the warmest ground temperature readings collected along the MGAR alignment, warmed to 3.7°C at a depth of 4.0 m before decreasing to 2.3°C at depth. Readings at this location are likely influenced by the large body of water directly east of the intersection at the start of the MGAR. Readings collected from Borehole BH-06 generally decreased with depth below the estimated active layer, ranging from 0.7°C at 3.0 m to 0.1°C at depth.

The subgrade along the South Section of the MGAR is expected to be thaw-stable and does not appear to contain significant permafrost. If permafrost is present, it is likely below 8.0 m depth and thaw settlement will likely be minimal if thermally disturbed by construction of the MGAR.

4.2 Middle Section (MVWR km 692.5 to 703.0)

The MGAR's Middle Section extends from MVWR km 692.5 to 703.0, as shown on Figures 3, 4, and 5. Twenty-one geotechnical boreholes (BH-13 to BH-33) were drilled along this section and one GTC was installed at MVWR km 694.8 (Borehole BH-17).

Ground conditions primarily consist of frozen clays and silts from ground surface to depth, occasionally overlain by ice-rich, organic layers up to 0.6 m thick. Visible ice crystals (V_x), random ice formations (V_r), and stratified ice formations (V_s) were observed below the estimated active layer to depth in all boreholes, ranging from 2% to 40% by volume. Horizontal and oriented ice lenses up to 40 mm thick were also observed below the estimated active layer in 12 boreholes along the section. Moisture content test results for the Middle Section subgrade are damp to moist and had an average value of 26.2%.

Ground temperature measurements from Borehole BH-17 (km 694.8) indicate warm, discontinuous permafrost is present with an estimated active layer thickness of 2.0 m. Ground temperature readings indicate unfrozen materials below the estimated active layer between depths of 2.0 m to 2.7 m. The remainder of the borehole encountered permafrost conditions with ground temperatures decreasing with depth from -0.2°C to -0.4°C at depths of 3.7 m and 7.7 m, respectively. Based on this and the amount of visible ground ice encountered in the borehole, it is likely that frozen soils containing excess ice exist below depths of 8.0 m along the Middle Section.

The subgrade along the Middle Section of the MGAR is likely thaw-sensitive as it contains frequent ground ice within fine-grained subsurface materials. Thaw settlement is likely to occur in areas of the Middle Section during construction of the MGAR. Settlements will be greater where visible ground ice is more than 20% by volume, particularly between MVWR km 694.0 and 696.0 (Boreholes BH-15 to BH-19).

4.3 North Section (MVWR km 703.0 to Mount Gaudet)

The North Section of the MGAR spans from MVWR km 703.0 to the Mount Gaudet Quarry, as shown on Figures 5 and 6. Nine geotechnical boreholes (BH-34 to BH-42) were drilled along this section and two GTCs were installed at MVWR km 703.3 (Borehole BH-34) and km 707.3 (Borehole BH-42).

The North Section's subsurface primarily comprises frozen and unfrozen clay and silt layers. All boreholes encountered a thin layer of organics (less than 50 mm thick) at ground surface, except Borehole BH-42 where 1.5 m of peat was observed. Visible ice crystals (V_x), random ice formations (V_r), and stratified ice formations (V_s), up to 5% by volume, were observed below the active layer in all boreholes. Horizontal ice lenses up to 20 mm thick were also observed below the seasonal active layer in four boreholes along the section. Unfrozen layers were observed at depths from 1.3 m (Borehole BH-34) to 4.5 m (Boreholes BH-35 to BH-37) and extended to depth in 7 of the 9 boreholes. Moisture contents for the subgrade materials ranged from moist to wet, averaging 25.8%.

Measured ground temperatures along the North Section of the MGAR show warm, discontinuous permafrost near MVWR km 703.3 and unfrozen conditions at MVWR km 707.3. The active layer thickness is estimated to be between 1.4 m and 1.5 m along this section. Ground temperatures in Borehole BH-34 were frozen to depth with an unfrozen section at 1.7 m depth. The ground temperature readings collected from Borehole BH-42 were entirely unfrozen ranging from 1.9°C to 2.6°C below the seasonal active layer. Readings at this location were up to 2°C higher than other more southern sections of the MGAR, likely due to the significant layer of peat (1.5 m thick) overlying the location.

Although no frozen materials were identified from the recent ground temperature data, it is expected that ice-poor permafrost exists beneath the North Section of the MGAR. Visible ground ice was observed below the active layer in all of the section's boreholes indicating that permafrost is likely present albeit not ice-rich. Based on this, the North Section of the MGAR is expected to be thaw-stable and thaw settlement due to permafrost degradation is expected to be minor.

5.0 ROAD DESIGN CONSIDERATIONS

For road construction in areas of warm, discontinuous permafrost, any changes to the ground surface condition will unavoidably result in changes to the subgrade's thermal regime. This potentially activates permafrost degradation resulting in thaw settlement and consolidation of the subgrade. The thermal and mechanical response of the frozen subgrade to the construction of road embankments may be very slow (i.e., thaw consolidation). It is estimated that subgrade thermal regimes can take up to three years to equilibrate in the case of summer construction, or up to five years if constructed in winter conditions (Lingnau 1985). Considering this, thaw settlement and differential settlement of the MGAR road embankments and subgrade will occur and regular road maintenance should be expected, particularly in the first few years following construction.

The approach for embankment design is to protect the integrity of the structural core of the road where it is subject to traffic (TAC 2010). In thaw-sensitive permafrost areas, it is essential to anticipate thaw and to design the embankment to mitigate the effects of thaw. In thaw-stable permafrost areas, it may be possible to maintain permafrost with a suitable embankment design. The most common way to protect embankments against permafrost degradation is by increasing the thickness of the embankment fill. The objective is to use embankment fill as thermal resistance to slow the rate of heat flowing into the embankment foundation. Wide shoulders and flattened sideslopes should also be considered during the design of the MGAR as this provides an overall wider road configuration, which serves to move settlement away from the structural core of the embankment and reduces snow accumulation.

Permafrost and thermal considerations for the design of the MGAR should be based on guidance from the Transportation Association of Canada (TAC) *Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions* (TAC 2010) and the Canadian Standards Association (CSA) *Technical Guide: Infrastructure in permafrost: A guideline for climate change adaption* (CSA 2019).

Embankment design recommendations for the MGAR follow the generalized design approach outlined by TAC (2010). Three embankment designs are outlined in the following subsections based on the thermal conditions and

generalized road sections described in Section 4.0. Thermal considerations for design and engineering of the MGAR embankments are summarized in Section 5.4. Estimated magnitudes of embankment settlement for each section of the MGAR are provided in Section 5.5.

5.1 South Section (Wrigley to MVWR km 692.5)

The South Section of the proposed MGAR is expected to be thaw-stable and likely contains no permafrost. As a result, a minimum embankment thickness of 1.0 m is recommended; however, embankment thickness will likely be governed by conventional pavement structure considerations. Wide shoulders should be considered with sideslopes recommended to be 2H:1V or flatter. Cuts along this section of the MGAR can be considered, if necessary.

5.2 Middle Section (MVWR km 692.5 to 703.0)

The MGAR Middle Section likely contains thaw-sensitive permafrost soils as ground ice was frequently observed within the section, particularly between MVWR km 694.0 and 696.0. It is recommended that embankment fills be a minimum of 1.6 m thick with sideslope gradients of 3H:1V or flatter depending on the type of material used to construct the embankment. Woven geotextile is recommended to be installed between the road embankment and the subgrade from MVWR km 694.0 and 696.0 due to the increased potential for thaw settlement. Cuts in this section should be avoided; however, if cuts are required, a woven geotextile should be installed between the road embankment and the subgrade in these areas.

5.3 North Section (MVWR km 703.0 to Mount Gaudet)

The North Section of the MGAR is expected to be thaw-stable as the frozen soils observed were consistently ice-poor below the seasonal active layer; however, due to the presence of visible ground ice, permafrost is expected. Embankments along this section are recommended to have a minimum thickness of 1.4 m to maintain permafrost conditions, although the consequences of thaw settlement of the native subgrade are likely not severe. Sideslopes gradients are recommended to be 2.5H:1V along the North Section. If necessary, cuts along this section can be considered; however, if cuts are required, woven geotextile is recommended to be installed between the road embankment and the subgrade in these areas.

5.4 Embankment Design Summary

Embankment design parameters are developed for each MGAR section for consideration during design and engineering of the MVH. Table 5-1 summarizes the minimum recommended embankment design parameters for each section of the MGAR, based on previous recommendations for the MVH (EBA 2011).

Table 5-1: MGAR Minimum Embankment Design Parameters

MGAR Section	MVWR Milepost (km)		Embankment Thickness (m)	Sideslope Gradient	Cuts Allowed	Geotextile Over Subgrade?
	From	To				
South (Wrigley to MVWR km 692.5)	687.0	692.5	-	2H:1V	Yes	No
Middle (MVWR km 692.5 to 703.0)	692.5	703.0	1.6	3H:1V	No	Woven (km 694.0 to 696.0)
North (MVWR km 703.0 to Mount Gaudet)	703.0	707.5	1.4	2.5:1V	Yes	Woven (within cuts)

The above design parameters are the minimum recommended design parameters based on the MGAR's thermal conditions. The final design of embankment thicknesses and sideslope gradients along the MGAR may be governed by conventional pavement structure design, geometric design, or road safety requirements, which have not been considered in the recommendations provided. Final road embankment design should be done in accordance with TAC's *Geometric Design Guide for Canadian Roads* with consideration given to the above parameters.

Woven geotextile is recommended to be installed between the road embankment and the subgrade for a 2 km portion of the Middle Section, between MVWR km 694.0 to 696.0, where frequent ground ice within fine-grained soils was observed and there is a potential for increased thaw settlement. Widespread use of geotextile is generally not warranted; however, installing a woven geotextile along the MGAR subgrade would provide improved confinement, separation, and reinforcement for the road embankment.

5.5 Embankment Settlement

Settlement along the MGAR alignment was estimated based on two mechanisms:

1. Self-weight settlement and thaw settlement of placed embankment fills due to frozen fill placement during winter construction; and

2. Thaw settlement and consolidation of permafrost in the subgrade.

Estimated settlements for each MGAR section are summarized in Table 5-2.

Table 5-2: Estimated MGAR Embankment Settlement

MGAR Section	Estimated Range of Settlement (m)		
	Embankment Fill Settlement [1]	Thaw Settlement of Frozen Subgrade [2]	Total Settlement
South (Wrigley to MVWR km 692.5)	0.1 – 0.3	0.0 – 0.1	0.1 – 0.4
Middle (MVWR km 692.5 to 703.0)	0.1 – 0.3	0.1 – 0.6	0.2 – 0.9
North (MVWR km 703.0 to Mount Gaudet)	0.1 – 0.3	0.1 – 0.4	0.2 – 0.7

[1] Embankment Fill Settlement includes self-weight and thaw settlement of placed embankment fills due to frozen fill placement during winter construction. It was estimated to equal 5% of the road embankment height, assuming that embankment fill will consist of frozen, coarse-grained granular material placed in the winter.

[2] Thaw Settlement of Frozen Subgrade Soils estimated using the dry density method from Andersland and Ladanyi (2003).

The embankment settlements noted above represent the total estimated settlement for the range of road embankment heights in each MGAR section. Over the service life of the road, greater thaw settlement is expected in the Middle Section where ice-rich permafrost has been identified in the subgrade.

Embankment fill settlement is expected to occur primarily during the first few years of construction when winter placed frozen fill materials thaw and settle during the summer seasons. Initial fill settlement will likely be limited to the top 3 m of the embankment (due to the depth of thaw) and the core of the road structures will continue to thaw beyond the construction period (i.e., fill settlement for embankments with heights larger than 3 m is anticipated to take longer than two years). Based on this, the embankment fill settlement is expected to be between 0.1 m and 0.3 m along the MGAR. Consideration should be given to overbuilding the embankment fills by approximately 0.3 m to allow for this.

Thaw settlement and consolidation of the frozen subgrade could be up to 0.6 m over the service life of the road. Long-term embankment settlements are expected to occur while a new thermal equilibrium is established and in response to climate warming projections. Based on historical observations from other highway structures in the Northwest Territories, the majority of long-term settlement of the road embankment and native subgrade appears to occur within 10 years of construction.

Tetra Tech does not recommend undertaking quantitative geothermal modelling in an attempt to estimate the time for post-construction thaw settlement to occur in the road embankment and native subgrade as the results are unlikely to change the design basis, construction approach, or performance of the MGAR.

6.0 CLIMATE CHANGE

The anticipated rise in ground temperatures over time, due to climate change, will change the behaviour of permafrost soils and could lead to weather changes such as increased precipitation and runoff events that could impact infrastructure. The potential impacts due to climate change should be considered in the design of the MGAR. CSA (2019) provides technical guidance for screening the vulnerability of northern infrastructure to climate change.

The CSA guideline describes a risk-based approach to evaluate the sensitivity of the permafrost and the consequence of degradation due to climate change which is used to determine a level of risk. The level of risk guides the detail of the assessment and analysis that is warranted due to climate change impacts. Climate change

must be considered in all phases of permitting, design, operation, and closure planning of the MGAR as the project advances.

The sensitivity of a site to climate change is governed by the characteristics of the permafrost at the site. The MGAR site is in an area of extensive, discontinuous permafrost and frozen soils were encountered in 37 of the 42 overland boreholes drilled along the alignment. The permafrost is *warm* with a mean annual ground temperature above -2°C and subsurface materials were predominantly silts and clays. Accordingly, Tetra Tech characterizes the permafrost sensitivity of the MGAR site as *High* (Table 5.3, CSA 2019).

CSA provides guidance on the potential implications of climate change on ground temperature. Under a “high” (RCP8.5) greenhouse gas emission scenario, the mean annual air temperature for the MGAR site (located in Arctic Sector W1) is expected to warm 1.2°C by 2040, 3.1°C by 2070, and 5.2°C by 2100 (Table 4.3, CSA 2019). In the absence of modelling to indicate otherwise, the CSA recommends assuming that ground temperatures increase in step with air temperatures.

Considering the measured ground temperatures along the MGAR alignment and the noted climate warming projections, it is expected that the permafrost will warm and could begin to thaw during the design life of the road. The practical implications of this are that ground settlement and loss of soil strength are likely to occur; however, since this is a low volume gravel road, the consequences of climate change impacts on the performance of the MGAR are considered to be relatively *Minor*.

According to CSA, the level of risk related to climate change effects can be estimated by considering the sensitivity of the permafrost (i.e., likelihood of permafrost degradation) along with the associated consequences (i.e., effect to the structure if permafrost degradation occurs). Considering the permafrost sensitivity and the associated consequences together results in a climate change risk level of *B: Moderate Risk* (Table 5.1, CSA 2019). This risk level warrants a semi-quantitative analysis together with the application of expert judgement which should be employed during the design and engineering of the MGAR, provided that the embankment structures and foundation systems have been successfully used on similar sites. This is the level of effort that has been employed for estimating the amount of thaw settlement and consolidation expected along the MGAR (see Section 5.5).

7.0 MONITORING

Ground temperature readings from each GTC were collected in November 2020; however, additional data collection and ongoing monitoring is recommended to understand the annual temperature fluctuations and permafrost conditions along the MGAR alignment. Additional site visits by a trained environmental monitor from the nearby community of Wrigley are recommended so that ground temperature data can continue to be collected for the MGAR.

It is recommended that all GTCs be read a minimum of two times each year. Readings should be collected in spring (early April) when ground temperatures are the coldest for the year and in the fall (late September) when ground temperatures are warmest for the year. Readings in spring and fall provide ground temperature profiles that reasonably bound the range in ground temperatures produced by annual surface temperature variations. Ground temperature readings collected at other times of year provide intermediate temperature profiles.

Tetra Tech will continue to update and track ground temperatures as data is collected from the MGAR. The GNWT will be provided with the ground temperature data as it is collected and will be informed of any design and engineering considerations that arise in light of the ongoing monitoring.

8.0 CLOSURE

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

Respectfully submitted,
Tetra Tech Canada Inc.

REGISTERED PROFESSIONAL ENGINEER
T.A. BRADSHAW
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June 18, 2021

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18 June 2021

FILE: 704-ENG.YARC03354-02
FILE: 704-ENG.YARC03354-02
FILE: 704-ENG.YARC03354-02

PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature E.M. Grozic
Date 18 June 2021
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

Reviewed by:
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/jf

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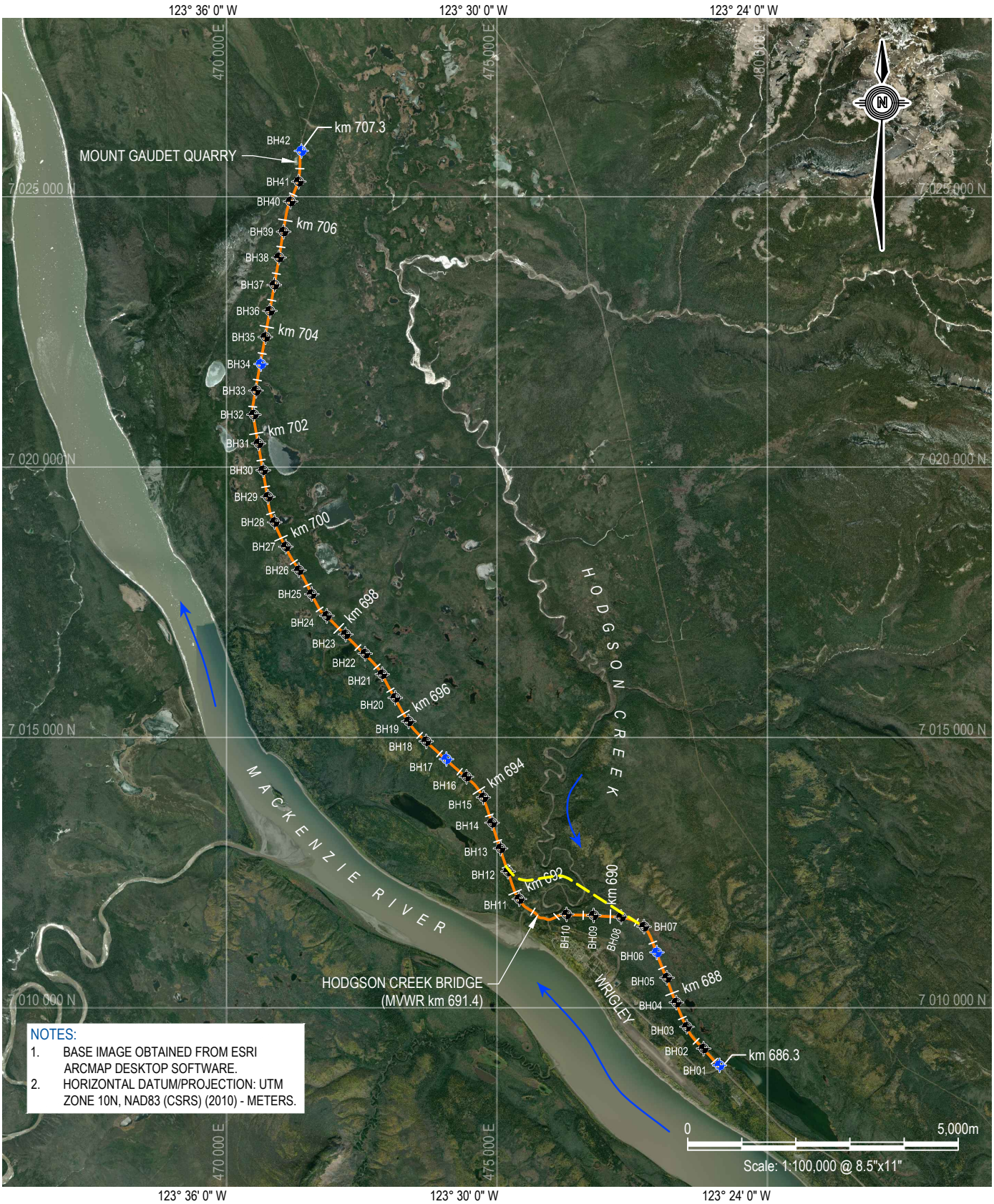
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FIGURES

Figure 1 Site Plan
Figure 2 MVWR km 687 to km 691
Figure 3 MVWR km 691 to km 696
Figure 4 MVWR km 696 to km 701
Figure 5 MVWR km 701 to km 704.5
Figure 6 MVWR km 704.5 to km 707.3



LEGEND:

- MOUNT GAUDET ACCESS ROAD (PROPOSED)
- ALTERNATE HODGSON CREEK BRIDGE REALIGNMENT (GNWT 2020)
- 2020 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)
- 2020 BOREHOLE (TETRA TECH)

CLIENT

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MOUNT GAUDET ACCESS ROAD THERMAL ASSESSMENT

SITE PLAN

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU
OFFICE	DATE		
EDMONTON	JUNE 2021		

FIGURE 1

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\MGAR\ENG.YARC03354-02_Figure 1.dwg [FIGURE 1] June 10, 2021 - 2:01:57 pm (BY: LEE, ELVIN)



LEGEND:

- MOUNT GAUDET ACCESS ROAD (PROPOSED)
- ALTERNATE HODGSON CREEK BRIDGE REALIGNMENT (GNWT 2020)
- 2020 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)
- 2020 BOREHOLE (TETRA TECH)

CLIENT

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MOUNT GAUDET ACCESS ROAD THERMAL ASSESSMENT

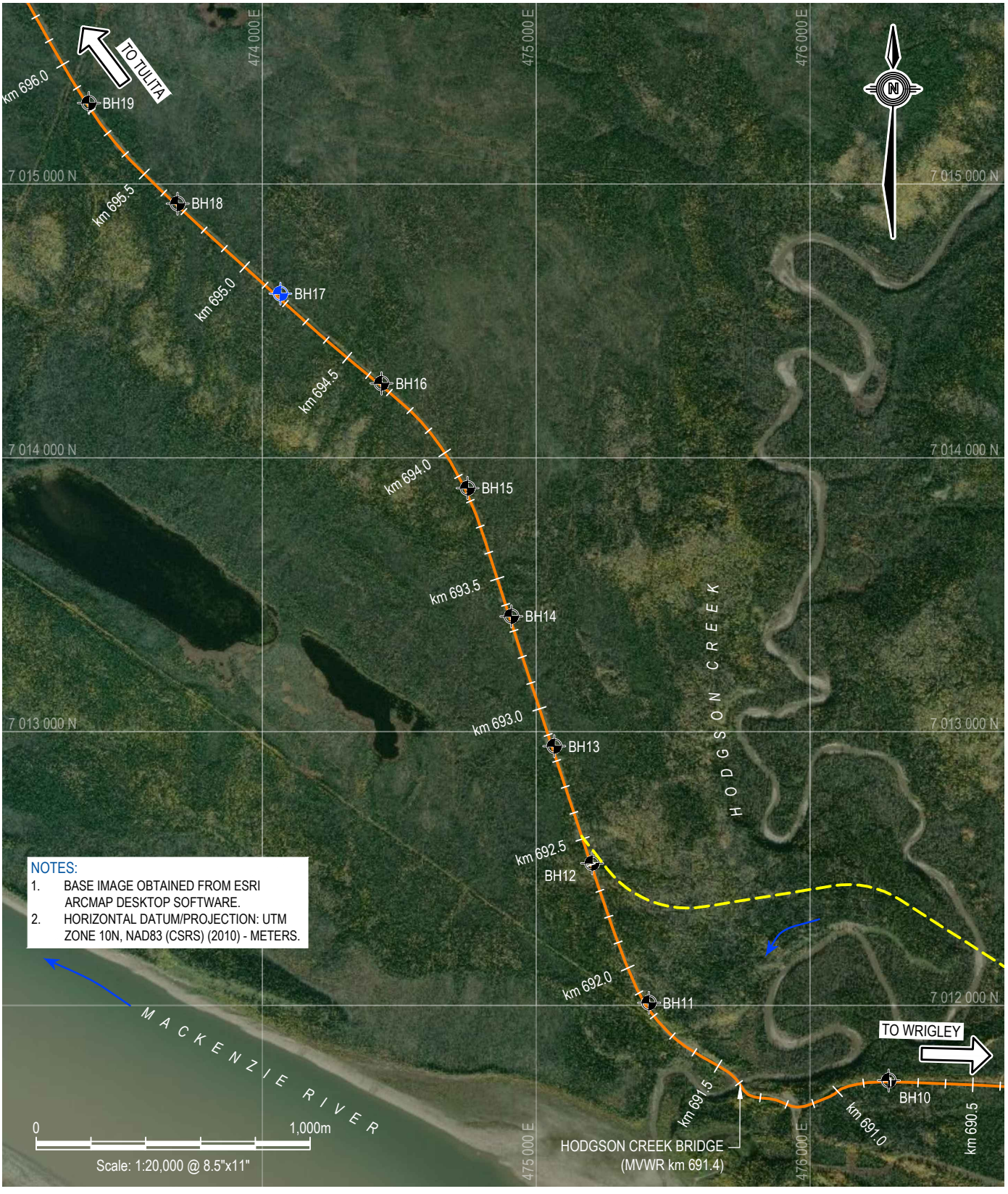
MVWR km 687 to km 691

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU

OFFICE	DATE
EDMONTON	JUNE 2021

FIGURE 2

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LEGEND:

- MOUNT GAUDET ACCESS ROAD (PROPOSED)
- ALTERNATE HODGSON CREEK BRIDGE REALIGNMENT (GNWT 2020)
- 2020 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)
- 2020 BOREHOLE (TETRA TECH)

CLIENT

Kãlo Stantec

TETRA TECH

MOUNT GAUDET ACCESS ROAD THERMAL ASSESSMENT

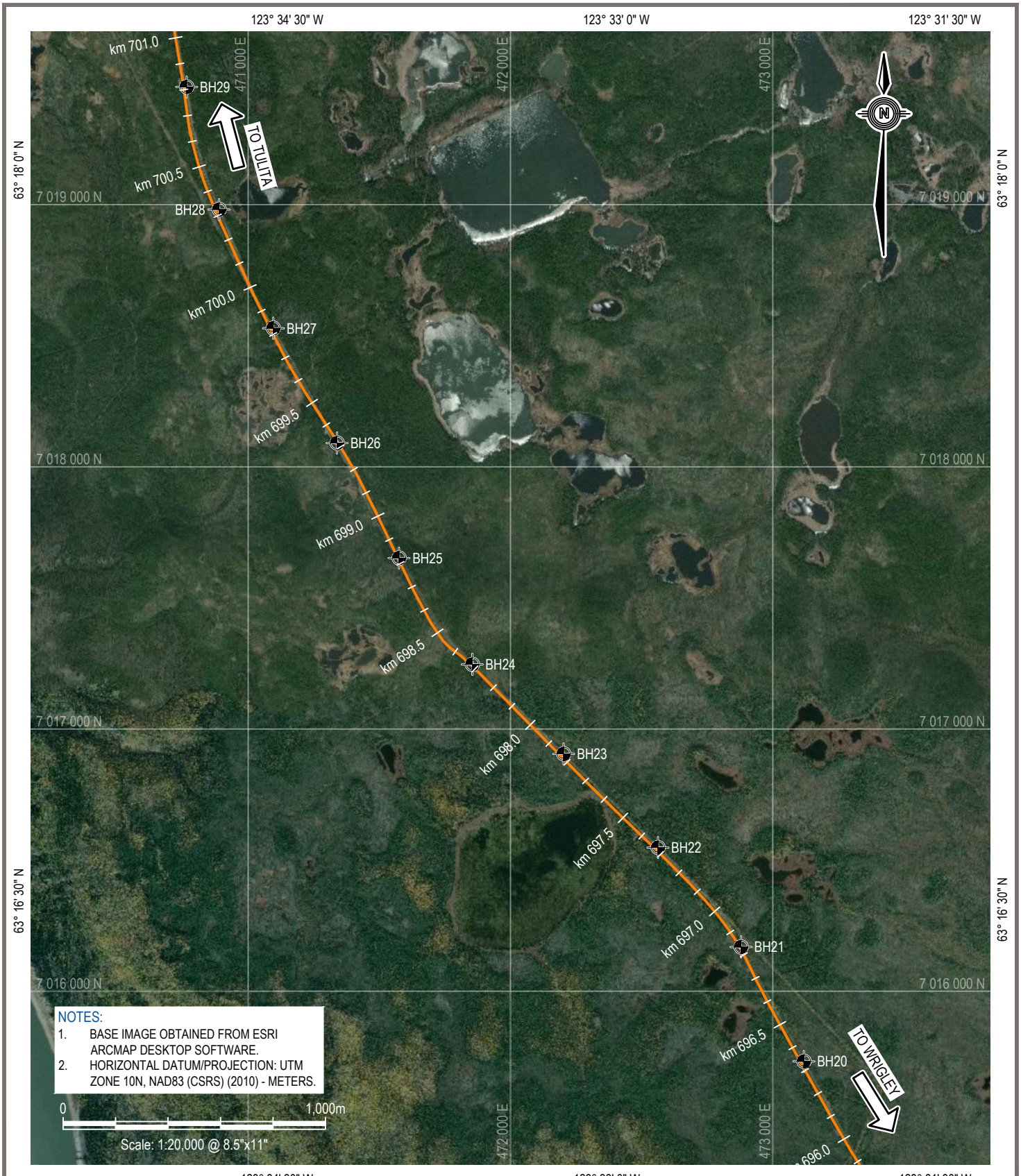
MVWR km 691 to km 696

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU

OFFICE	DATE
EDMONTON	JUNE 2021

FIGURE 3

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LEGEND:

MOUNT GAUDET ACCESS ROAD (PROPOSED)

2020 BOREHOLE (TETRA TECH)

CLIENT

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MOUNT GAUDET ACCESS ROAD THERMAL ASSESSMENT

MVWR km 696 to km 701

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU

OFFICE	DATE
EDMONTON	JUNE 2021

FIGURE 4

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\MGAR\ENG.YARC03354-02_Figure 2-6.dwg [FIGURE 4] June 10, 2021 - 2:01:49 pm (BY: LEE, ELVIN)



LEGEND:

- MOUNT GAUDET ACCESS ROAD (PROPOSED)
- 2020 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)
- 2020 BOREHOLE (TETRA TECH)

CLIENT

Kãlo Stantec

TETRA TECH

MOUNT GAUDET ACCESS ROAD THERMAL ASSESSMENT

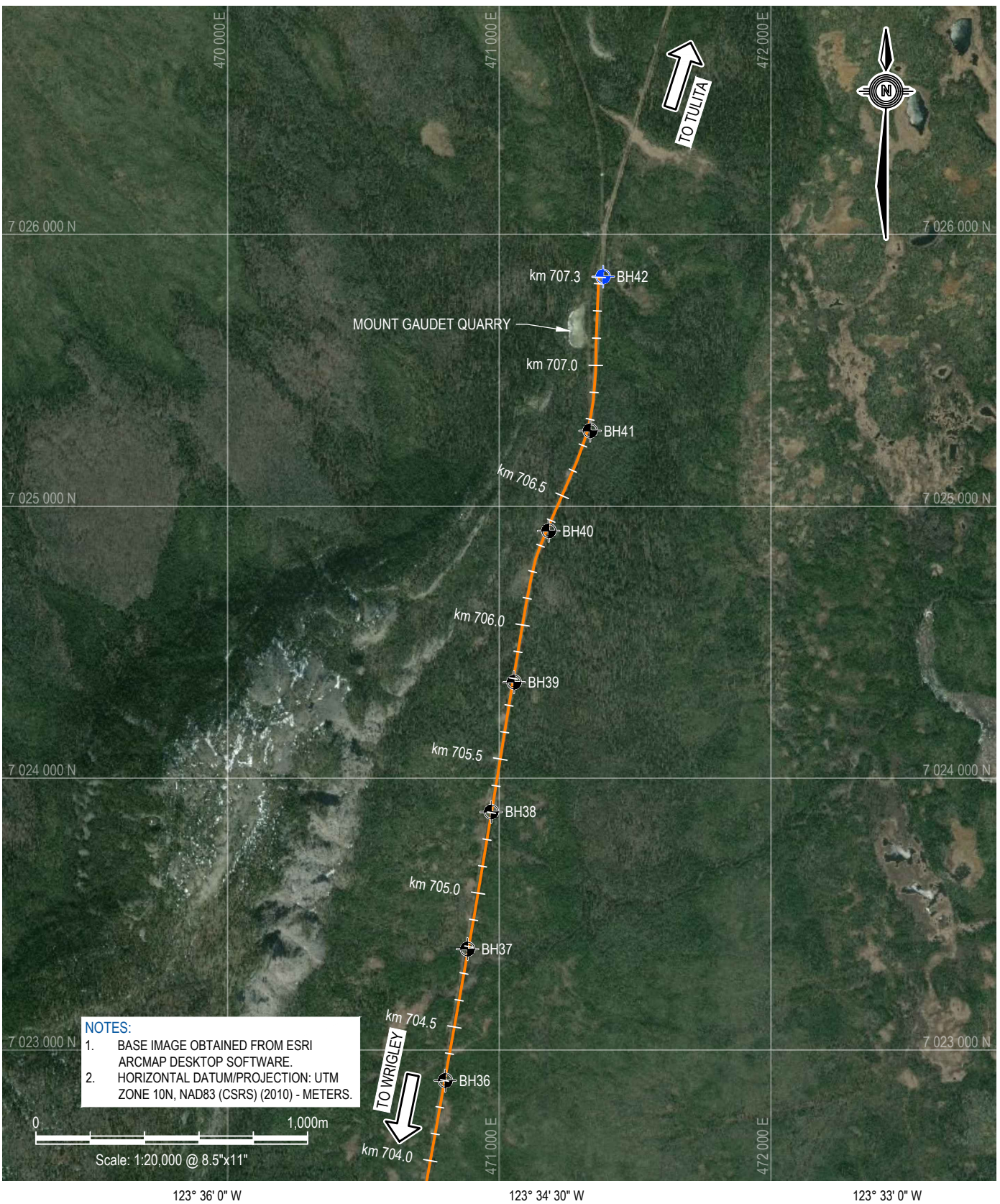
MVWR km 701 to km 704.5

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU

OFFICE	DATE
EDMONTON	JUNE 2021

FIGURE 5

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LEGEND:

- MOUNT GAUDET ACCESS ROAD (PROPOSED)
- 2020 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)
- 2020 BOREHOLE (TETRA TECH)

CLIENT

Kãlo Stantec

TETRA TECH

MOUNT GAUDET ACCESS ROAD THERMAL ASSESSMENT

MVWR km 704.5 to km 707.3

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU
OFFICE: EDMONTON	DATE: JUNE 2021		

FIGURE 6

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\MGAR\ENG.YARC03354-02_Figure 2-6.dwg [FIGURE 6] June 10, 2021 - 2:01:54 pm (BY: LEE, ELVIN)

APPENDIX A

TETRA TECH'S LIMITATIONS ON USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an "Authorized Party"), consideration for such authorization is the Authorized Party's acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the "Limitations on Liability"). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party's express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH's professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

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

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

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

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards 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. TETRA TECH 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.

1.9 LOGS OF TESTHOLES

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.

1.10 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 historical environment. TETRA TECH 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 exploration and review may be necessary.

1.11 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.

1.12 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.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact 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, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and 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.

1.15 DRAINAGE SYSTEMS

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. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters 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 used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH 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.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

APPENDIX B

2020 BOREHOLE LOGS

Borehole No: **BH01**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 143.033 m
Wrigley, Northwest Territories	UTM: 479114.43 E; 7008935.534 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit Moisture Content Liquid Limit 20 40 60 80	PVC pipe	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice							143
		SAND AND GRAVEL - trace silt, beige, multicoloured gravel, rounded to subrounded gravel to 25 mm diameter								
1										142
		- (Gravel - 40%; Sand - 53%; Silt & Clay - 7%)			1	37	3			
2	Solid stem auger									141
					2		2			
3										140
		GRAVEL AND SAND - trace silt, multicoloured gravel, beige sand and silt, rounded to subrounded gravel to 75 mm diameter								
4										139
		- (Gravel - 54%; Sand - 39%; Silt & Clay - 7%)			3		2			
5										138
6		END OF BOREHOLE (6.0 metres) PVC pipe installed to 8.0 metres on March 8, 2020								137
7										136
8										135
9										134
10										

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 3
Logged By: DY	Completion Date: 2020 March 3
Reviewed By: EG	Page 1 of 1

Borehole No: **BH02**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 140.75 m
Wrigley, Northwest Territories	UTM: 478819.823 E; 7009245.909 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice						
		SAND - some silt/clay, trace gravel, beige, fine sand							
1									140
		- (Gravel - 0%; Sand - 81%; Silt & Clay - 19%)			4	63	6		
2									139
									138
3	Solid stem auger	- silty, loose to compact - (Gravel - 0%; Sand - 74%; Silt & Clay - 26%)			5	16	8		
4									137
		- some silt - (Gravel - 5%; Sand - 79%; Silt & Clay - 16%)			6		7		136
5		SAND AND GRAVEL - trace silt, rounded to subrounded gravel to 40 mm diameter							
									135
6		- (Gravel - 44%; Sand - 47%; Silt & Clay - 9%)			7	50/ 75mm	4		
		END OF BOREHOLE (6.2 metres)							
7									134
8									133
									132
9									
10									131

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.2 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 3
Logged By: DY	Completion Date: 2020 March 3
Reviewed By: EG	Page 1 of 1

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Borehole No: **BH03**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 134.024 m
Wrigley, Northwest Territories	UTM: 478512.032 E; 7009649.516 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					134
		GRAVEL - sandy, some silt, brown, rounded to subrounded gravel to 40 mm diameter						
		- (Gravel - 55%; Sand - 32%; Silt & Clay - 13%)			8	3	●	
1		END OF BOREHOLE (0.9 metres) Note: Auger refusal at 0.9 metres, producing loud grinding sound. Three attempts made spaced approximately 5.0 m apart.						133
2								132
3								131
4								130
5								129
6								128
7								127
8								126
9								125
10								

TETRA TECH

Contractor: Geotech Drilling Ltd.	Completion Depth: 0.9 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 3
Logged By: DY	Completion Date: 2020 March 3
Reviewed By: EG	Page 1 of 1

Borehole No: **BH04**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 132.196 m
Wrigley, Northwest Territories	UTM: 478316.33 E; 7010096.241 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					132
		GRAVEL AND SAND - some silt, brown, rounded to subrounded gravel to 25 mm diameter						
1		- (Gravel - 42%; Sand - 40%; Silt & Clay - 18%)			9	5	●	131
		- gravel to 40 mm diameter						
		END OF BOREHOLE (1.2 metres)						
		Note: Auger refusal at 1.2 metres, producing loud grinding sound. Three attempts made spaced approximately 5.0 m apart.						
2								130
3								129
4								128
5								127
6								126
7								125
8								124
9								123
10								

Contractor: Geotech Drilling Ltd.	Completion Depth: 1.2 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 2
Logged By: DY	Completion Date: 2020 March 2
Reviewed By: EG	Page 1 of 1

Borehole No: **BH05**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 128.442 m
Wrigley, Northwest Territories	UTM: 478142.919 E; 7010553.402 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick) PEAT - dark brown, (180 mm thick) SILT - sandy, some clay, low plastic, olive brown, fine sand	Frozen, Vr, 30% ice by volume, random ice Nbn, no visible ice					128
1		- (Gravel - 0%; Sand - 21%; Silt - 65%; Clay - 14%)			10	23		127
2		END OF BOREHOLE (2.0 metres) Note: Auger refusal at 2.0 metres, producing loud grinding sound.Three attempts made spaced approximately 5.0 m apart.						126
3								125
4								124
5								123
6								122
7								121
8								120
9								119
10								

Contractor: Geotech Drilling Ltd.	Completion Depth: 2 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 2
Logged By: DY	Completion Date: 2020 March 2
Reviewed By: EG	Page 1 of 1

Borehole No: **BH06**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 127.106 m
Wrigley, Northwest Territories	UTM: 477956.366 E; 7011024.052 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	PVC pipe	Elevation (m)
0	Solid stem auger	ORGANICS - moss, roots, brown, (300 mm thick)	Frozen, Vr, 20% ice by volume, random ice						127
		CLAY - silty, trace sand, hard, medium plastic, olive green, (200 mm thick)	Nbn, no visible ice						
		ORGANICS - muskeg, brown							
1		SILT - some clay, some sand, low plastic, dark brown							126
		- (Gravel - 0%; Sand - 15%; Silt - 67%; Clay - 18%)	Vr, 20% ice by volume		11	22			
		PEAT - dark brown, faint organic odour	Nbn						
		SAND AND GRAVEL - some silt, loose to compact, brown, multicoloured gravel, rounded to subrounded gravel to 75 mm diameter							
2									125
3					12	8			124
4		- (Gravel - 35%; Sand - 50%; Silt & Clay - 15%)			13	10			123
5									122
		- (Gravel - 41%; Sand - 49%; Silt & Clay - 10%)			14	8			
6		END OF BOREHOLE (6.0 metres) PVC pipe installed to 8.0 metres on March 8, 2020							121
7									120
8									119
9									118
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 2
Logged By: DY	Completion Date: 2020 March 2
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH07**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 123.066 m
Wrigley, Northwest Territories	UTM: 477720.036 E; 7011499.34 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Vr, 30% ice by volume, random ice					123
		PEAT - dark brown						
		SAND - some silt, wet, olive brown, fine sand						
1			Unfrozen				22	122
		- trace gravel			15			
0 hrs.		- (Gravel - 7%; Sand - 79%; Silt & Clay - 14%)			16	49/ 75mm	22	0 hrs.
2		- some gravel, rounded to subrounded gravel to 20 mm diameter	Frozen, Nbn, no visible ice					121
	Solid stem auger	- silty, trace clay			17		20	
3		- (Gravel - 0%; Sand - 62%; Silt - 33%; Clay - 5%)						120
4		- (Gravel - 14%; Sand - 63%; Silt & Clay - 23%)			18		18	119
		SILT - sandy, some gravel, trace clay, soft, low plastic, greyish brown, rounded gravel to 10 mm diameter	Unfrozen					
5								118
		- (Gravel - 13%; Sand - 37%; Silt - 41%; Clay - 9%)			19		15	
6		END OF BOREHOLE (6.0 metres) water - 1.5 metres at 0 hrs.						117
7								116
8								115
9								114
10								

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 2
Logged By: DY	Completion Date: 2020 March 2
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH08**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 124.717 m
Wrigley, Northwest Territories	UTM: 477295.808 E; 7011678.041 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice						124
		SAND - silty, trace clay, brown							
1		- moist, loose							
		- (Gravel - 0%; Sand - 65%; Silt & Clay - 35%)		⊠	20	50/ 100mm	21		123
2			Unfrozen						
		GRAVEL - sandy, trace silt, multicoloured gravel, rounded to subrounded gravel to 50 mm diameter							
		- moist to wet							122
3		- (Gravel - 63%; Sand - 32%; Silt & Clay - 5%)			21		7		
									121
4		- sandier							
		- (Gravel - 52%; Sand - 41%; Silt & Clay - 7%)			22		9		120
5									
		SAND - gravelly, trace silt, wet							119
6		- (Gravel - 36%; Sand - 60%; Silt & Clay - 4%)			23		11		
		END OF BOREHOLE (6.0 metres)							118
7									
									117
8									
									116
9									
									115
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 February 29
Logged By: DY	Completion Date: 2020 February 29
Reviewed By: EG	Page 1 of 1

Borehole No: **BH09**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 126.012 m
Wrigley, Northwest Territories	UTM: 476788.089 E; 7011709.815 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					126
		SAND - silty, trace clay, trace gravel, brown with light brown						
1								125
		- (Gravel - 2%; Sand - 61%; Silt & Clay - 37%)			24	45/ 100mm	23	
2		- some gravel, multicoloured gravel, rounded to subrounded gravel to 25 mm diameter						124
		- (Gravel - 18%; Sand - 53%; Silt - 22%; Clay - 7%)			25		5	
3								123
			Unfrozen					
4		- trace gravel, multicoloured gravel, rounded to subrounded gravel to 25 mm diameter						122
		SILT - sandy, trace to some clay, trace gravel, stiff, low plastic, grey			26	12	14	
5		- (Gravel - 6%; Sand - 30%; Silt & Clay - 64%)						121
6		- some gravel to 40 mm diameter	Frozen, Nbn, no visible ice					120
		- (Gravel - 17%; Sand - 38%; Silt - 35%; Clay - 11%)			27	31	8	
		END OF BOREHOLE (6.6 metres)						
7								119
8								118
9								117
10								

Solid stem auger

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 February 29
Logged By: DY	Completion Date: 2020 February 29
Reviewed By: EG	Page 1 of 1

Borehole No: **BH10**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 122.226 m
Wrigley, Northwest Territories	UTM: 476287.832 E; 7011725.827 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					122
		SILT - trace clay, trace gravel, loose, brown, rounded to subrounded gravel to 20 mm diameter						
1								121
		- (Gravel - 2%; Sand - 52%; Silt & Clay - 46%)			28	52/ 75mm	10	
2								120
		CLAY - silty, sandy, trace gravel, light brown						
3		- (Gravel - 5%; Sand - 39%; Silt & Clay - 56%)			29		5	119
4		END OF BOREHOLE (3.9 metres) Note: Auger refusal at 3.9 metres. Stopped drilling due to excessive bit wear and risk of damage to the augers and fishtail bit.						118
5								117
6								116
7								115
8								114
9								113
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit

20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 3.9 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 February 29
Logged By: DY	Completion Date: 2020 February 29
Reviewed By: EG	Page 1 of 1

Borehole No: **BH11**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 124.263 m
Wrigley, Northwest Territories	UTM: 475412.202 E; 7012009.352 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					124
1	Solid stem auger	SAND - some silt, trace gravel, damp, loose, brown, rounded to subrounded gravel to 20 mm diameter - gravelly, light brown						123
					30	50/ 75mm	8	
2		GRAVEL AND SAND - some silt, trace clay, brown, rounded to subrounded gravel to 40 mm diameter	Unfrozen					122
		- (Gravel - 42%; Sand - 40%; Silt & Clay - 18%)			31		3	
3								121
					32		3	
4		- gravel to 50 mm diameter						120
		SAND - gravelly, trace silt, trace clay						
5		- (Gravel - 22%; Sand - 65%; Silt & Clay - 13%)			33		2	119
6		END OF BOREHOLE (6.0 metres) Note: Loud grinding sound and drill bit wear while augering at 2.0 metres						118
7								117
8								116
9								115
10								

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit

20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 3
Logged By: DY	Completion Date: 2020 March 3
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH12**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 130.794 m
Wrigley, Northwest Territories	UTM: 475204.187 E; 7012519.173 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					130
1	Solid stem auger	SAND - gravelly, silty, trace clay, loose, light brown, rounded to subrounded gravel to 20 mm diameter - gravel to 50 mm diameter						
		- (Gravel - 25%; Sand - 50%; Silt & Clay - 25%)			34	5	●	
2			Unfrozen					129
3		- trace to some silt, gravel to 75 mm diameter			35			128
			Frozen, Nbn, no visible ice					127
4		- (Gravel - 31%; Sand - 57%; Silt & Clay - 12%)			36	3	●	
5								126
					37			125
6		END OF BOREHOLE (6.0 metres) Note: Loud grinding sound and drill bit wear while augering						
7								124
8								123
9								122
10								121

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 3
Logged By: DY	Completion Date: 2020 March 3
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH13**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 138.921 m
Wrigley, Northwest Territories	UTM: 475066.272 E; 7012946.524 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit – Moisture Content – Liquid Limit 20 40 60 80	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice						138
		SILT - some sand, trace to some clay, non plastic, brown							
1		- (Gravel - 0%; Sand - 13%; Silt & Clay - 87%)	Ice lens, Vr, 1 mm thick, <2% ice by volume	X	38	50/ 150mm	31		137
2		- sandy							
3		- (Gravel - 0%; Sand - 28%; Silt - 70%; Clay - 2%)		X	39	74	26		136
		- 200 mm thick silty sand seam							
		SILT AND SAND - trace clay, wet, loose, non plastic, brown, coarse sand	Unfrozen						
4									135
		- silty, olive brown, fine sand	Frozen, Nbn, no visible ice	X	40	90/ 225mm	16		
5		- (Gravel - 0%; Sand - 45%; Silt - 51%; Clay - 4%)							134
		SILT sandy, trace gravel, trace clay, non plastic, dark grey, rounded to subrounded gravel to 20 mm diameter	Ice crystals, Vx, <1% ice by volume						
6		- (Gravel - 8%; Sand - 29%; Silt & Clay - 63%)		X	41	50/ 150mm	16		133
		END OF BOREHOLE (6.2 metres)							
7									132
8									131
9									130
10									129

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.2 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 4
Logged By: DY	Completion Date: 2020 March 4
Reviewed By: EG	Page 1 of 1

Borehole No: **BH14**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 146.533 m
Wrigley, Northwest Territories	UTM: 474909.394 E; 7013420.922 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit Moisture Content Liquid Limit 20 40 60 80	Elevation (m)
0	Solid stem auger	ICE AND PEAT - dark brown, organic odour	Frozen, 60% ice by volume						146
		CLAY - silty, trace sand, medium plastic, brown - (Gravel - 0%; Sand - 3%; Silt - 55%; Clay - 42%)	Nbn, no visible ice		42		22		
1		SAND - silty, some gravel, trace clay, light brown to black, fine sand, rounded to subrounded gravel to 20 mm diameter - (Gravel - 11%; Sand - 52%; Silt & Clay - 37%)	Ice crystals, Vx, 2% ice by volume		43	70	18		145
2		END OF BOREHOLE (1.7 metres) Note: Stopped due to auger refusal. Auger produces a loud, grinding sound. Three attempts made spaced approximately 5.0 m apart.							144
3									143
4									142
5									141
6									140
7									139
8									138
9									137
10									

TETRA TECH

Contractor: Geotech Drilling Ltd.	Completion Depth: 1.7 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 4
Logged By: DY	Completion Date: 2020 March 5
Reviewed By: EG	Page 1 of 1

Borehole No: **BH15**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 167.627 m
Wrigley, Northwest Territories	UTM: 474749.695 E; 7013889.289 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - dark brown, (20 mm thick)	Frozen, Vr, 30% ice by volume, random ice						167
		CLAY - silty, trace sand, trace gravel, very stiff, low to medium plastic, greyish brown	Nbn, no visible ice						
1		- (Gravel - 1%; Sand - 5%; Silt & Clay - 94%)	Stratified ice, Vs, 20% ice by volume		44	100	35		166
2			Ice crystals, Vx, 2% ice by volume						165
3		SILT - some clay, low to medium plastic, greyish brown							
		- (Gravel - 0%; Sand - 0%; Silt - 81%; Clay - 19%)			45	57	35		
		CLAY - silty, trace sand, medium plastic, greyish brown	Vx, 1% ice by volume						164
4									
		- (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)	Vx, 25% ice by volume		46	48	27		163
5			Vx, 1% ice by volume						
									162
6		- some sand, trace gravel, brown							
		- (Gravel - 8%; Sand - 12%; Silt - 60%; Clay - 21%)	Vx, 40% ice by volume		47	26/ 150mm	17		
		END OF BOREHOLE (6.3 metres)							161
7									
									160
8									
									159
9									
									158
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.3 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 4
Logged By: DY	Completion Date: 2020 March 4
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH16**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 176.711 m
Wrigley, Northwest Territories	UTM: 474435.301 E; 7014271.509 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ICE AND ORGANICS - dark brown, (100 mm thick)	Frozen, 50% ice by volume					176
		CLAY - silty, some sand, medium to high plastic, brown	Ice crystals, Vx, 1% ice by volume					
1								
		- (Gravel - 0%; Sand - 0%; Silt - 51%; Clay - 49%)	Vx, 15% ice by volume		48	51	26	175
2		- dark greyish brown	Vx, 1% ice by volume					
								174
3	Solid stem auger	- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	Vx, 20% ice by volume		49	25	29	
			Vx, 1% ice by volume					173
4								
		- (Gravel - 0%; Sand - 0%; Silt - 52%; Clay - 48%)	Vx, 20% ice by volume		50	32	25	172
5			Vx, 1% ice by volume					
			Nbn, no visible ice					171
6		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)						
			Ice strata, Vs, 10% ice by volume		51	32	28	
		END OF BOREHOLE (6.4 metres)						170
7								
								169
8								
								168
9								
								167
10								

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.4 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 5
Logged By: DY	Completion Date: 2020 March 5
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH17**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 181.298 m
Wrigley, Northwest Territories	UTM: 474066.173 E; 7014599.445 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	PVC pipe	Elevation (m)
0	Solid stem auger	ICE AND PEAT - dark brown, (200 mm thick)	Frozen, 50% ice by volume						181
		CLAY - silty, trace sand, firm, medium plastic, dark greyish brown	Nbn, no visible ice						
1		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)			52	4	26		180
2			Ice lens, Vs, 10% ice by volume Nbn, no visible ice						179
3		SILT - some clay, trace sand, dark greyish brown - (Gravel - 0%; Sand - 3%; Silt - 84%; Clay - 13%)			53	6	28		178
			Unfrozen						
4		CLAY - silty, trace sand, medium plastic, dark greyish brown	Frozen ice crystals, Vx, <1% ice by volume						177
5		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%) - grey	Ice lens, Vs, 5% ice by volume ice crystals, Vx, <1% ice by volume		54	33	30		176
6			Ice crystals, Vx, 1% ice by volume 2 mm thick ice lens, Vs, 10% ice by volume Sporadic ice crystals, Vx, <1% ice by volume		55	28	29		175
7									174
8		- (Gravel - 0%; Sand - 1%; Silt - 59%; Clay - 40%)	10 mm thick ice lens - Vs, 40% ice by volume		56	26	28		173
		END OF BOREHOLE (8.0 metres) PVC pipe installed to 8.0 metres to support future ground temperature cable installation							
9									172
10									

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 8 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 5
Logged By: DY	Completion Date: 2020 March 5
Reviewed By: EG	Page 1 of 1

Borehole No: **BH18**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 187.824 m
Wrigley, Northwest Territories	UTM: 473690.602 E; 7014927.92 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ICE AND PEAT - brown, (200 mm thick)	Frozen, 50% ice by volume					187
		CLAY - silty, trace sand, medium plastic, brown	Nbn, no visible ice					
1								
		- (Gravel - 0%; Sand - 5%; Silt - 50%; Clay - 45%)	Sporadic ice crystals, Vx, <1% ice by volume		57	33/ 150mm	21	186
2								
3		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Vs, 2% ice by volume		58	39	26	185
		- no visible sand	Vx, <1% ice by volume					
4								184
		- (Gravel - 0%; Sand - 0%; Silt - 56%; Clay - 44%)	Vs, 5% ice by volume		59	33	22	
5			Vx, <1% ice by volume					183
6		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	10 mm thick ice lens, Vr, various ice strata, Vs, 20% ice by volume		60	32	27	182
		END OF BOREHOLE (6.4 metres)						
7								181
8								180
9								179
10								178

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.4 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 5
Logged By: DY	Completion Date: 2020 March 5
Reviewed By: EG	Page 1 of 1

Borehole No: **BH19**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 193.033 m
Wrigley, Northwest Territories	UTM: 473366.538 E; 7015295.198 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen						193
		MUSKEG - brown, slight organic odour							
		CLAY - silty, trace sand, low plastic, brown to grey							
1									192
		- (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)	Vs, 5% ice by volume		61	59	24		
2			Nbn, no visible ice						191
3		- some sand	Vs, 5% ice by volume						
		- (Gravel - 0%; Sand - 11%; Silt - 64%; Clay - 25%)	Nbn, no visible ice		62	47	28		190
4									189
		- sandy, dark brown							
		- (Gravel - 0%; Sand - 28%; Silt & Clay - 72%)			63	52	28		
5		- medium plastic, grey	Vx, <5% ice by volume						188
6		- (Gravel - 0%; Sand - 0%; Silt - 58%; Clay - 42%)	Vs, 40% ice by volume		64	31	34		187
		END OF BOREHOLE (6.4 metres)							
7									186
8									185
9									184
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.4 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 5
Logged By: DY	Completion Date: 2020 March 5
Reviewed By: EG	Page 1 of 1

Borehole No: **BH20**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 199.578 m
Wrigley, Northwest Territories	UTM: 473118.331 E; 7015732.246 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ICE AND PEAT - dark brown, (200 mm thick)	Frozen, 50% ice by volume					199
		SILT - some clay, trace sand, low to medium plastic, mottled light to dark brown	Nbn, no visible ice					
1		- (Gravel - 0%; Sand - 2%; Silt - 81%; Clay - 17%)	Various ice strata, Vs, 5% ice by volume		65	70	28	198
2			Ice crystals, Vx, <1% ice by volume					
		CLAY - silty, trace sand, medium plastic, dark brownish grey						197
3		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	5% ice by volume		66	32	29	
			<1% ice by volume					196
4								
		- (Gravel - 0%; Sand - 1%; Silt - 59%; Clay - 40%)	2 mm thick vertical ice lens, Vr		67	30	26	195
5		- dark grey						
								194
6		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	Ice lens (Vr) and ice strata (Vs), 10% ice by volume		68	30	24	
		END OF BOREHOLE (6.4 metres)						193
7								
								192
8								
								191
9								
								190
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.4 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 6
Logged By: DY	Completion Date: 2020 March 6
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH21**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 202.949 m
Wrigley, Northwest Territories	UTM: 472878.591 E; 7016168.903 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80	Elevation (m)
0		ICE AND PEAT - dark brown, (200 mm thick)	Frozen, 50% ice by volume						202.949
		CLAY - silty, medium plastic, dark brownish grey	Nbn, no visible ice						
1	Solid stem auger								202
		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	Ice crystals, Vx, 1% ice by volume		69	58	25		
2			Nbn, no visible ice						201
3		- dark grey - (Gravel - 0%; Sand - 0%; Silt - 64%; Clay - 36%)	Ice crystals, Vx, 1% ice by volume		70	50	20		200
4									199
		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	5% ice by volume		71	35	26		
5			Nbn, no visible ice						198
			Single ice crystal, Vx						
6		- (Gravel - 0%; Sand - 0%; Silt - 65%; Clay - 35%)	Ice crystals, Vx, 5% ice by volume 5 mm thick ice lens, Vr		72	32	26		197
		END OF BOREHOLE (6.4 metres)	5 mm thick ice lens, Vr						
7									196
8									195
9									194
10									193

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.4 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 7
Logged By: DY	Completion Date: 2020 March 7
Reviewed By: EG	Page 1 of 1

Borehole No: **BH22**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 206.617 m
Wrigley, Northwest Territories	UTM: 472562.086 E; 7016547.72 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	PVC pipe	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice						206
		CLAY - silty, trace sand, medium plastic, dark greyish brown							
1			Ice crystals, Vx, <1% ice by volume		73	17	21		205
2			Nbn, no visible ice Ice crystals, Vx, <1% ice by volume						204
3		- mottled dark and light brown - (Gravel - 0%; Sand - 3%; Silt & Clay - 97%)	5% ice by volume		74	29	29		
			Nbn, no visible ice		75		26		
		- dark grey	Ice crystals, Vx, <1% ice by volume						203
4									
		- (Gravel - 0%; Sand - 0%; Silt - 62%; Clay - 38%)	2% ice by volume		76	26	24		202
5			<1% ice by volume						
									201
6		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)			77	27	27		
			10% ice by volume 2% ice by volume						200
7		SILT - some clay, grey							
		- (Gravel - 0%; Sand - 0%; Silt - 85%; Clay - 15%)							199
			20% ice by volume		78	32	27		
8		END OF BOREHOLE (8.0 metres) PVC pipe installed to 8.0 metres							198
9									197
10									

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit

20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 8 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 6
Logged By: DY	Completion Date: 2020 March 6
Reviewed By: EG	Page 1 of 1

Borehole No: **BH23**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 206.909 m
Wrigley, Northwest Territories	UTM: 472202.296 E; 7016904.786 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit – Moisture Content – Liquid Limit 20 40 60 80	Elevation (m)
0		ICE AND PEAT - dark brown, organic odour, (100 mm thick)	Frozen, 50% ice by volume						
		CLAY - silty, medium plastic, greyish brown	Nbn, no visible ice						
1			Ice crystals, Vx, 1% ice by volume						206
			5% ice by volume						
		- (Gravel - 0%; Sand - 0%; Silt - 59%; Clay - 41%)			79	29/ 150mm	30		
2			Nbn, no visible ice						205
	Solid stem auger	- trace sand							
3		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)			80	30/ 150mm	29		204
			Ice crystals, Vx, 2% ice by volume						
4									203
		- (Gravel - 0%; Sand - 0%; Silt - 71%; Clay - 29%)	10-40 mm thick ice lenses, Vs		81	33	47		
5			Ice crystals, Vx, 5% ice by volume						202
6		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Ice lenses, Vr, 45° orientation		82	48	34		201
		END OF BOREHOLE (6.5 metres)							
7									200
8									199
9									198
10									197

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 6
Logged By: DY	Completion Date: 2020 March 6
Reviewed By: EG	Page 1 of 1

Borehole No: **BH24**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 210.661 m
Wrigley, Northwest Territories	UTM: 471854.123 E; 7017246.677 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ICE AND PEAT - dark brown, (200 mm thick)	Frozen, 50% ice by volume						210
		CLAY - silty, trace sand, medium plastic, olive brown	Nbn, no visible ice						
1		- (Gravel - 0%; Sand - 3%; Silt & Clay - 97%)	Single ice crystal, Vx		83	35/ 150mm	32		209
2									208
3		- greyish brown - (Gravel - 0%; Sand - 1%; Silt - 56%; Clay - 43%)	Ice crystals, Vx, 5% ice by volume		84	30	26		207
4		- no visible sand	<1% ice by volume						
5		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	10% ice by volume		85	31	24		206
		- grey	2% ice by volume						205
6		- (Gravel - 0%; Sand - 0%; Silt - 65%; Clay - 35%)			86		24		
		END OF BOREHOLE (6.0 metres)							204
7									203
8									202
9									201
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 6
Logged By: DY	Completion Date: 2020 March 6
Reviewed By: EG	Page 1 of 1

Borehole No: **BH25**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 211.194 m
Wrigley, Northwest Territories	UTM: 471574.987 E; 7017652.01 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ICE AND PEAT - dark brown, (100 mm thick)	Frozen, 50% ice by volume					211
		CLAY - silty, trace sand, low to medium plastic, olive brown	Nbn, no visible ice					
1								210
		- (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)		X	87	44/ 150mm	24	
2			Ice crystals, Vx, 1% ice by volume					209
		- medium plastic, mottled olive brown with orange	Nbn, no visible ice					
			Ice crystals, Vx, 1% ice by volume					
			1% ice by volume					
3		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	5% ice by volume	X	88	40	29	208
			1% ice by volume					
4		- no visible sand, medium plastic, grey						207
		- (Gravel - 0%; Sand - 0%; Silt - 62%; Clay - 38%)	5% ice by volume	X	89	33	24	
5								206
		- medium to high plastic						
6		- (Gravel - 0%; Sand - 0%; Silt - 51%; Clay - 49%)	10% ice by volume	X	90	34	39	205
		END OF BOREHOLE (6.5 metres)						
7								204
8								203
9								202
10								

SPT (N) 20 40 60 80

Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 6
Logged By: DY	Completion Date: 2020 March 6
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH26**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 211.082 m
Wrigley, Northwest Territories	UTM: 471338.662 E; 7018090.813 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		PEAT - brown, (100 mm thick)	Frozen, Vr, 30% ice by volume, random ice					211
		CLAY - silty, trace sand, low to medium plastic, olive brown	Nbn, no visible ice					
1								210
		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Ice crystals, Vx, 1% ice by volume		91	35/ 150mm	27	
2								209
3	Solid stem auger	- olive brown, mottled orange - (Gravel - 0%; Sand - 2%; Silt - 80%; Clay - 18%)	2% ice by volume		92	38	28	208
		- medium plastic, grey	Nbn, no visible ice					
4								207
		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	Ice crystals, Vx, 5% ice by volume		93	21	26	
5			2% ice by volume					206
6		- (Gravel - 0%; Sand - 0%; Silt - 69%; Clay - 31%)	1% ice by volume		94	22	26	205
			100 mm thick ice strata, Vs, 10% ice by volume					
		END OF BOREHOLE (6.5 metres)						
7								204
8								203
9								202
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit
20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 7
Logged By: DY	Completion Date: 2020 March 7
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH27**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 211.329 m
Wrigley, Northwest Territories	UTM: 471096.014 E; 7018528.539 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice						211
		CLAY - silty, medium plastic, olive brown							
1									210
		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	Ice crystals, Vx, 5% ice by volume		95	45	26		
2			Nbn, no visible ice						209
	Solid stem auger	- trace sand, olive brown, mottled orange	Ice crystal, Vx, 2% ice by volume						
3		- (Gravel - 0%; Sand - 1%; Silt - 74%; Clay - 25%)			96	28	25		208
4			Nbn, no visible ice						
		- greyish brown							207
		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Ice crystals, Vx, 10% ice by volume		97	31	26		
5		- medium plastic, grey	1% ice by volume						206
6		- (Gravel - 0%; Sand - 0%; Silt - 66%; Clay - 34%)	5% ice by volume		98	22	24		205
		END OF BOREHOLE (6.5 metres)							
7									204
8									203
9									202
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 7
Logged By: DY	Completion Date: 2020 March 7
Reviewed By: EG	Page 1 of 1

Borehole No: **BH28**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 209.03 m
Wrigley, Northwest Territories	UTM: 470888.689 E; 7018980.862 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					209
		SILT - trace clay, trace sand, non plastic, olive brown, mottled orange						
1								208
		- (Gravel - 0%; Sand - 10%; Silt - 80%; Clay - 10%)			99	44/ 150mm	26	
2			Ice crystals, Vx, <1% ice by volume					207
		CLAY - silty, trace sand, medium plastic, olive brown, mottled orange						
3		- (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)	Nbn, no visible ice					206
			Ice crystals, Vx, 5% ice by volume		100	39	25	
		- no visible sand, grey	Nbn, no visible ice					
4								205
		- (Gravel - 0%; Sand - 0%; Silt - 57%; Clay - 43%)	Ice crystals, Vx, 1% ice by volume 2 mm thick vertical ice lens, Vr		101	26	25	
5								204
6		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	5% ice by volume 10 mm thick ice lens, Vr 10 mm thick ice lens, Vr		102	27	27	203
		END OF BOREHOLE (6.5 metres)						
7								202
8								201
9								200
10								

SPT (N) 20 40 60 80

Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 9
Logged By: DY	Completion Date: 2020 March 9
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH29**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 212.698 m
Wrigley, Northwest Territories	UTM: 470765.032 E; 7019448.675 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick) CLAY - silty, trace sand, low plastic, olive brown	Frozen, Nbn, no visible ice					212
1		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Ice crystals, Vx, 1% ice by volume		103	47	22	
2								211
3		- low to medium plastic - (Gravel - 0%; Sand - 1%; Silt - 79%; Clay - 20%)	Nbn, no visible ice Single ice crystal, Vx Ice coating on particles, Vc		104	25	25	210
4								209
5		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Ice crystals, Vx, 5% ice by volume Nbn, no visible ice		105	28	24	208
6		- medium to high plastic, grey - (Gravel - 0%; Sand - 1%; Silt - 52%; Clay - 47%)	1 mm thick ice lens, Vr, 2% ice by volume		106	20	24	207
7		END OF BOREHOLE (6.5 metres)						206
8								205
9								204
10								203

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 7
Logged By: DY	Completion Date: 2020 March 7
Reviewed By: EG	Page 1 of 1

Borehole No: **BH30**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 212.052 m
Wrigley, Northwest Territories	UTM: 470677.739 E; 7019940.779 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					212
		CLAY - silty, medium plastic, olive brown						
1								211
		- (Gravel - 0%; Sand - 0%; Silt - 68%; Clay - 32%)	Ice crystals, Vx, <1% ice by volume		107	53	22	
2								210
	Solid stem auger	- trace sand, grey with orange silty nodules						
3		- (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)	2% ice by volume		108	22	24	209
			<1% ice by volume					
4								208
		- medium to high plastic, greyish brown	2% ice by volume					
		- (Gravel - 0%; Sand - 0%; Silt - 53%; Clay - 47%)	3 mm thick ice lens, Vr 3 mm thick ice lens, Vr		109	30	24	
5			1% ice by volume					207
		- grey						
6		- (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)	Nbn, no visible ice		110	26	24	206
		END OF BOREHOLE (6.5 metres)						
7								205
8								204
9								203
10								

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 8
Logged By: DY	Completion Date: 2020 March 8
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH31**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 209.859 m
Wrigley, Northwest Territories	UTM: 470590.781 E; 7020436.158 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					
		CLAY - silty, trace sand, low plastic, olive brown						
1								209
		- (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)	Ice crystals (Vx) and ice lens (Vs), 1% ice by volume ~1 mm thick		111	51	20	
2			Ice crystals, Vx, <1% ice by volume					208
3	Solid stem auger	- olive brown, mottled orange	1% ice by volume					207
		- (Gravel - 0%; Sand - 5%; Silt - 72%; Clay - 23%)			112	34	25	
		- medium plastic, grey	2% ice by volume					
4								206
		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)			113		23	
5						29		205
6		- (Gravel - 0%; Sand - 0%; Silt - 72%; Clay - 28%)	20 mm thick ice lens, Vs		114	32	33	204
			50 mm thick ice lens, Vs					
		END OF BOREHOLE (6.5 metres)						
7								203
8								202
9								201
10								200

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 8
Logged By: DY	Completion Date: 2020 March 8
Reviewed By: EG	Page 1 of 1

Borehole No: **BH32**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 213.85 m
Wrigley, Northwest Territories	UTM: 470505.468 E; 7020970.921 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					213
		CLAY - silty, some sand, low plastic, dark brown						
1								
		- (Gravel - 0%; Sand - 14%; Silt - 55%; Clay - 31%)	Ice strata, Vs, 2% ice by volume		115	65	26	212
2			Ice crystals, Vx, 1% ice by volume					
		- trace sand, grey, mottled orange						211
3	Solid stem auger	- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	5% ice by volume		116	28	27	
		- medium plastic, grey	2% ice by volume		117		26	
4								210
		- (Gravel - 0%; Sand - 1%; Silt - 72%; Clay - 27%)	Random ice, Vr, 10% ice by volume		118	27	22	
5			2 mm thick vertical ice lens, Vr					209
			Ice crystals, Vx, 2% ice by volume					
6								208
		- (Gravel - 0%; Sand - 6%; Silt & Clay - 94%)	1-10 mm thick vertical ice lens, Vr		119	45	36	
7		END OF BOREHOLE (6.5 metres)						207
8								206
9								205
10								204

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 8
Logged By: DY	Completion Date: 2020 March 8
Reviewed By: EG	Page 1 of 1

Borehole No: **BH33**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 215.675 m
Wrigley, Northwest Territories	UTM: 470544.045 E; 7021412.232 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice						215
		CLAY - silty, trace sand, low to medium plastic, olive brown							
1									
		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%)	Ice crystals, Vx, 1% ice by volume		120	41	22		214
2									
		SILT - trace clay, trace sand, low plastic, olive brown							213
3		- (Gravel - 0%; Sand - 6%; Silt - 84%; Clay - 10%)	Nbn, no visible ice		121	32	26		
		CLAY - silty, trace sand, medium plastic, greyish brown	Ice crystal, Vx, 1% ice by volume						212
4									
		- (Gravel - 0%; Sand - 3%; Silt & Clay - 97%)	Nbn, no visible ice		122	23	24		211
5			10 mm thick vertical ice lens, Vr Sporadic ice crystals, Vx, <1% ice by volume						
									210
6			Nbn, no visible ice		123	16	24		
		- (Gravel - 0%; Sand - 1%; Silt - 69%; Clay - 30%)	Ice crystals, Vx, <1% ice by volume		124		26		
		END OF BOREHOLE (6.5 metres)							209
7									
									208
8									
									207
9									
									206
10									

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 8
Logged By: DY	Completion Date: 2020 March 8
Reviewed By: EG	Page 1 of 1

Borehole No: **BH34**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 212.847 m
Wrigley, Northwest Territories	UTM: 470633.642 E; 7021903.295 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit – Moisture Content – Liquid Limit 20 40 60 80	PVC pipe	Elevation (m)
0		ORGANICS - dark brown, (50 mm thick)	Frozen, random ice, Vr, 30% ice by volume							212
		CLAY - silty, trace sand, low plastic, olive brown	Nbn, no visible ice							
1		- firm	Unfrozen							
		- (Gravel - 0%; Sand - 5%; Silt & Clay - 95%)			125	4	21			211
2			Frozen, ice crystals, Vx, 4% ice by volume							
		SILT - trace clay, trace sand, non plastic, olive brown								210
3		- (Gravel - 0%; Sand - 9%; Silt - 81%; Clay - 10%)	Nbn, no visible ice		126	22	27			
			Single ice crystal							
	Solid stem auger	CLAY - silty, trace sand, medium to high plastic, grey	Ice crystals, Vx, 1% ice by volume							209
4			10 mm thick ice lenses, Vr							
			10 mm thick ice lenses, Vr		127	16	24			208
5			Ice crystals, Vx, 2% ice by volume							
										207
6		- (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)	Ice crystal concentrations for 100 mm, Vx		128	19	26			
			1% ice by volume							
7										206
		- trace gravel, high plastic	5% ice by volume							
		- (Gravel - 2%; Sand - 1%; Silt - 55%; Clay - 42%)			129	21	31			205
8		END OF BOREHOLE (8.0 metres)								
		PVC pipe installed to 8.0 metres to support future ground temperature cable installation								204
9										
										203
10										

Contractor: Geotech Drilling Ltd.	Completion Depth: 8 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 10
Logged By: DY	Completion Date: 2020 March 10
Reviewed By: EG	Page 1 of 1

Borehole No: **BH35**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 212.441 m
Wrigley, Northwest Territories	UTM: 470717.81 E; 7022404.222 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	CLAY - silty, trace sand, medium to high plastic, olive brown	Frozen, Nbn, no visible ice					212
1		- (Gravel - 0%; Sand - 3%; Silt & Clay - 97%)	Ice crystals, Vx, 2% ice by volume		130	33	36	211
2			Nbn, no visible ice					210
3		- olive brown - (Gravel - 0%; Sand - 0%; Silt - 51%; Clay - 49%)	Marginally frozen Random ice, Vr, 5% ice by volume		131	8	27	209
4			Ice crystals, Vx, 2% ice by volume					208
5		- damp to moist, firm to stiff, grey - (Gravel - 0%; Sand - 0%; Silt - 78%; Clay - 22%)	Unfrozen		132	9	23	207
6		- trace sand - (Gravel - 0%; Sand - 1%; Silt & Clay - 99%) - 2 mm thick sandy seam			133	9	25	206
7		END OF BOREHOLE (6.5 metres)						205
8								204
9								203
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 8
Logged By: DY	Completion Date: 2020 March 8
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH36**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 211.021 m
Wrigley, Northwest Territories	UTM: 470801.198 E; 7022886.831 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					211
		CLAY - silty, trace sand, low plastic, olive brown						
1								210
		- (Gravel - 0%; Sand - 5%; Silt & Clay - 95%)	Ice crystals, Vx, 2% ice by volume		134	50	27	
2			1% ice by volume					209
		SILT - some clay, trace sand, low plastic, olive brown						
3	Solid stem auger	- (Gravel - 0%; Sand - 2%; Silt - 81%; Clay - 17%)	<1% ice by volume		135	19	27	208
		CLAY - silty, trace sand, medium plastic, olive brown	2% ice by volume					
4								207
		- (Gravel - 0%; Sand - 6%; Silt & Clay - 94%)	Unfrozen		136	11	24	
5		- firm to stiff, grey						206
		- firm						
6		- (Gravel - 0%; Sand - 2%; Silt - 60%; Clay - 38%)			137	13	24	205
		END OF BOREHOLE (6.4 metres)						
7								204
8								203
9								202
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.4 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 8
Logged By: DY	Completion Date: 2020 March 8
Reviewed By: EG	Page 1 of 1

Borehole No: **BH37**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 207.98 m
Wrigley, Northwest Territories	UTM: 470883.101 E; 7023370.995 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					207.98
		CLAY - silty, trace sand, medium plastic, olive brown						
1								207
		- (Gravel - 0%; Sand - 1%; Silt - 68%; Clay - 31%)	Ice crystals, Vx, 2% ice by volume		138	37	22	
2			<1% ice by volume					206
	Solid stem auger							
3		- (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)	Random 1 mm thick ice crystals (Vx) and lenses (Vr), 1% ice by volume		139	14	25	205
			Ice crystals, Vx, 2% ice by volume					
4		- no visible sand, grey						204
		- firm	Unfrozen					
		- (Gravel - 0%; Sand - 0%; Silt - 71%; Clay - 29%)			140	9	22	
5								203
6		- trace sand, stiff						202
		- (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)			141	13	25	
		END OF BOREHOLE (6.5 metres)						
7								201
8								200
9								199
10								198

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 9
Logged By: DY	Completion Date: 2020 March 9
Reviewed By: EG	Page 1 of 1

Borehole No: **BH38**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 208.289 m
Wrigley, Northwest Territories	UTM: 470970.23 E; 7023875.074 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick) CLAY - silty, trace sand, medium plastic, olive brown	Frozen, Nbn, no visible ice					208
1			Ice crystals, Vx					207
2		- (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)	Ice strata, Vs, 1% ice by volume Nbn, no visible ice		142	32	25	206
3		- soft to firm, greyish brown - (Gravel - 0%; Sand - 1%; Silt - 65%; Clay - 34%)	Unfrozen		143	7	23	205
4								204
5		- stiff, grey - (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)			144	9	19	203
6		- trace gravel - (Gravel - 1%; Sand - 1%; Silt - 55%; Clay - 43%)			145	11	25	202
7		END OF BOREHOLE (6.5 metres)						201
8								200
9								199
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 9
Logged By: DY	Completion Date: 2020 March 9
Reviewed By: EG	Page 1 of 1

Borehole No: **BH39**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 209.987 m
Wrigley, Northwest Territories	UTM: 471054.501 E; 7024352.554 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick) CLAY - silty, medium to high plastic, olive brown	Frozen, Nbn, no visible ice					209
1		- (Gravel - 0%; Sand - 0%; Silt - 53%; Clay - 47%)	Ice crystals, Vx, 2% ice by volume		146	41	24	
2			<1% ice by volume					208
3		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)	Random 2 mm thick ice crystals (Vx) and ice lenses (Vr), <1% ice by volume Unfrozen		147	10	27	207
4		- trace sand, firm, medium plastic						206
5		- (Gravel - 0%; Sand - 4%; Silt - 63%; Clay - 33%) - grey			148	7	24	205
6		- stiff, (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)			149	10	25	204
7		END OF BOREHOLE (6.5 metres)						203
8								202
9								201
10								200

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 9
Logged By: DY	Completion Date: 2020 March 9
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH40**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 209.475 m
Wrigley, Northwest Territories	UTM: 471181.699 E; 7024909.11 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick) PEAT - dark brown, (180 mm thick) CLAY - silty, trace gravel, medium plastic, olive brown	Frozen, random ice, Vr, 30% ice by volume Nbn, no visible ice					209
1								
		- (Gravel - 1%; Sand - 0%; Silt & Clay - 99%)	Ice crystals, Vx, 2% ice by volume		150	49	27	208
2			1% ice by volume					
								207
3	Solid stem auger	- trace sand, light brown - (Gravel - 0%; Sand - 1%; Silt - 55%; Clay - 44%)	10-20 mm thick ice lenses (Vs) at 3.2, 3.3 and 3.5 metres		151	14	46	
			Unfrozen					206
4		- no visible sand, brown						
		- (Gravel - 0%; Sand - 0%; Silt & Clay - 100%)			152	6	28	205
5								
		- trace sand, trace gravel, firm, grey						204
6		- (Gravel - 1%; Sand - 3%; Silt - 65%; Clay - 31%)			153	5	26	
		END OF BOREHOLE (6.5 metres)						203
7								
								202
8								
								201
9								
								200
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 10
Logged By: DY	Completion Date: 2020 March 10
Reviewed By: EG	Page 1 of 1

Borehole No: **BH41**

Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 207.717 m
Wrigley, Northwest Territories	UTM: 471334.31 E; 7025277.288 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, Nbn, no visible ice					207
		CLAY - silty, some sand, medium plastic, olive brown						
1								
		- (Gravel - 0%; Sand - 16%; Silt - 55%; Clay - 29%)	Ice crystal, Vs, <1% ice by volume Nbn, no visible ice		154	44	22	206
2								
		- trace sand, firm, light brown	Unfrozen					205
3		- (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)			155	6	27	
								204
4		- orange oxidation						
		- stiff, (Gravel - 0%; Sand - 1%; Silt - 67%; Clay - 32%)			156	11	22	203
5								
			Frozen, Ice crystals, Vx, <1% ice by volume. Despite presence of ice, soil conditions are unfrozen					202
6		- brown - (Gravel - 0%; Sand - 4%; Silt & Clay - 96%)			157	17	28	
		END OF BOREHOLE (6.5 metres)						201
7								
								200
8								
								199
9								
								198
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit 20 40 60 80

Contractor: Geotech Drilling Ltd.	Completion Depth: 6.5 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 10
Logged By: DY	Completion Date: 2020 March 10
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH42**

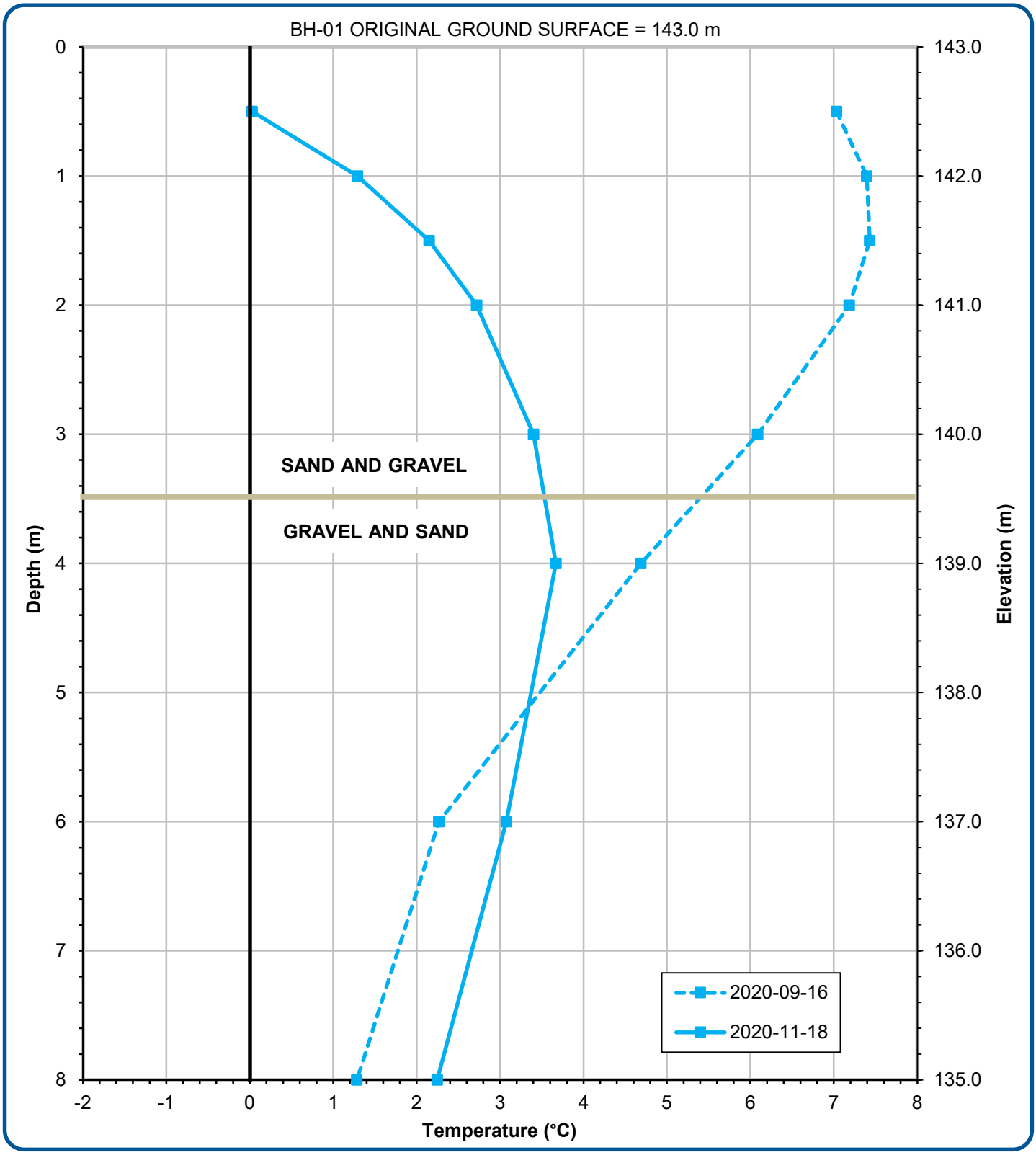
Project: Geotechnical Evaluation for MGAR	Project No: ENG.YARC03329-01
Location: Mount Gaudet Access Road	Ground Elev: 201.017 m
Wrigley, Northwest Territories	UTM: 471382.143 E; 7025844.45 N; Z 10

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit Moisture Content Liquid Limit 20 40 60 80	PVC pipe	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, random ice, Vr, 30% ice by volume							201
		PEAT - brown								
1										200
		CLAY - silty, trace sand, soft to firm, medium plastic, brown	Unfrozen							
2					158	4	24			199
3										198
		- firm				7				
	Solid stem auger	- (Gravel - 0%; Sand - 3%; Silt & Clay - 97%) - greyish brown			159		28			
4										197
		- (Gravel - 1%; Sand - 2%; Silt - 63%; Clay - 35%)			160	9	27			
5										196
6		- (Gravel - 0%; Sand - 1%; Silt & Clay - 99%) - soft			161	3	28			195
7										194
		- trace gravel, stiff, grey, rounded to subrounded gravel to 20 mm diameter								
		- (Gravel - 9%; Sand - 2%; Silt - 63%; Clay - 26%)			162	12	21			
8										193
		END OF BOREHOLE (8.1 metres) PVC pipe installed to 8.1 metres to support future ground temperature cable installation								
9										192
10										

Contractor: Geotech Drilling Ltd.	Completion Depth: 8.1 m
Drilling Rig Type: Truck Mounted M5T	Start Date: 2020 March 10
Logged By: DY	Completion Date: 2020 March 10
Reviewed By: EG	Page 1 of 1

APPENDIX C

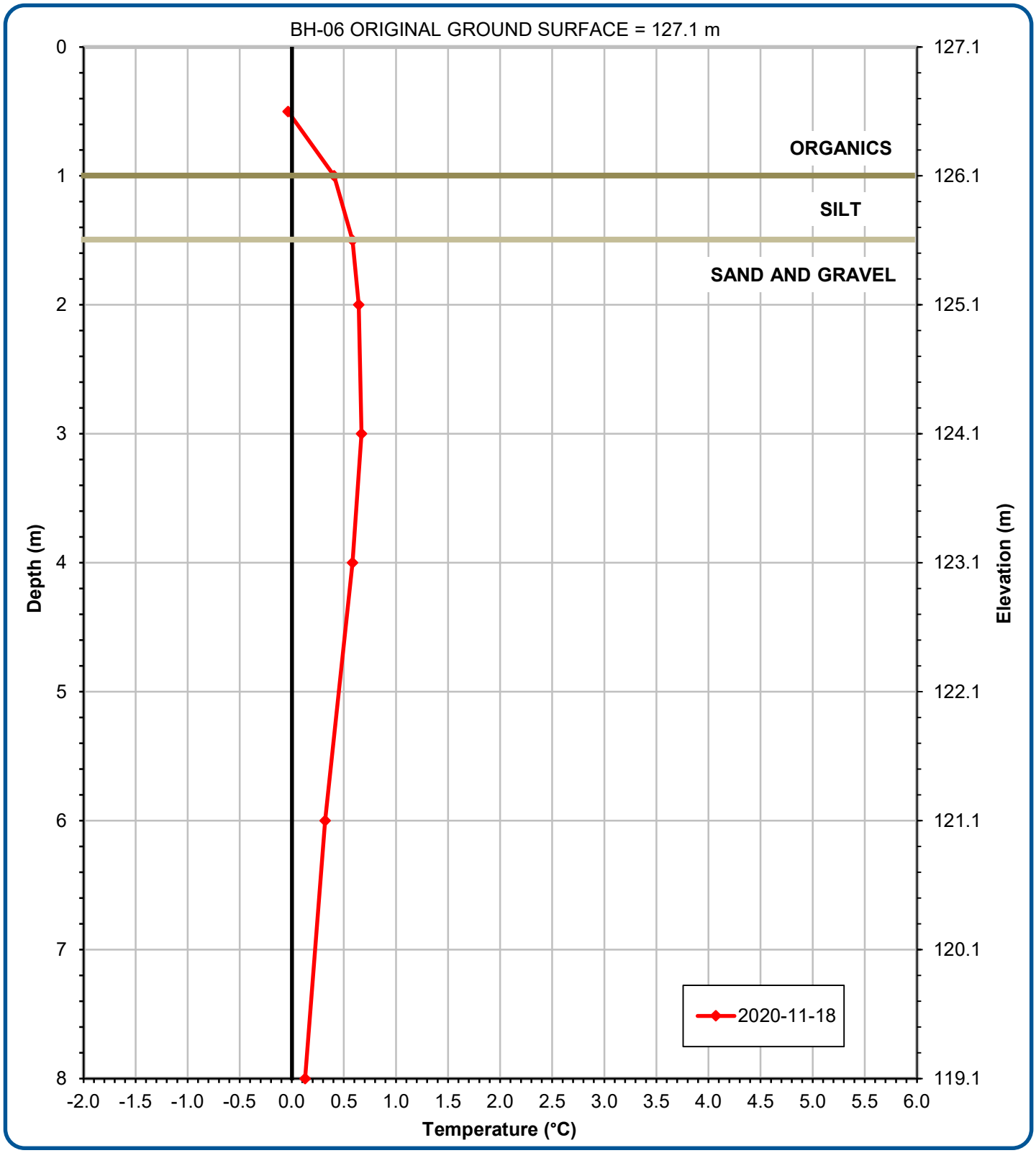
GROUND TEMPERATURE PROFILES



GTC Serial No. 2736
Date Drilled: March 3, 2020
Date Installed: July 23, 2020

Borehole BH-01 (MVWR km 686.4)
Ground Temperature Profile

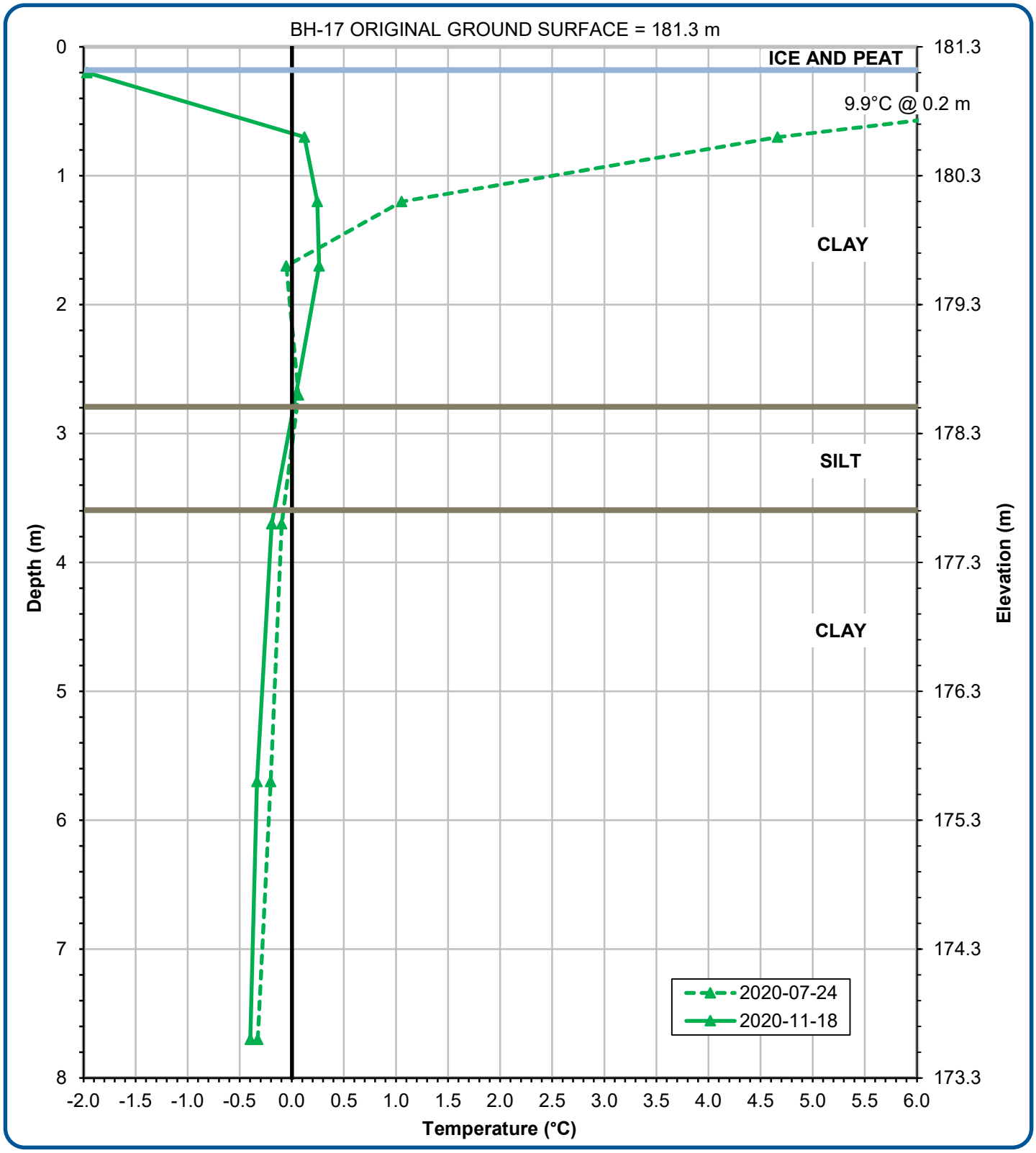
TETRA TECH



GTC Serial No. 2735
Date Drilled: March 2, 2020
Date Installed: July 23, 2020

Borehole BH-06 (MVWR km 688.8)
Ground Temperature Profile

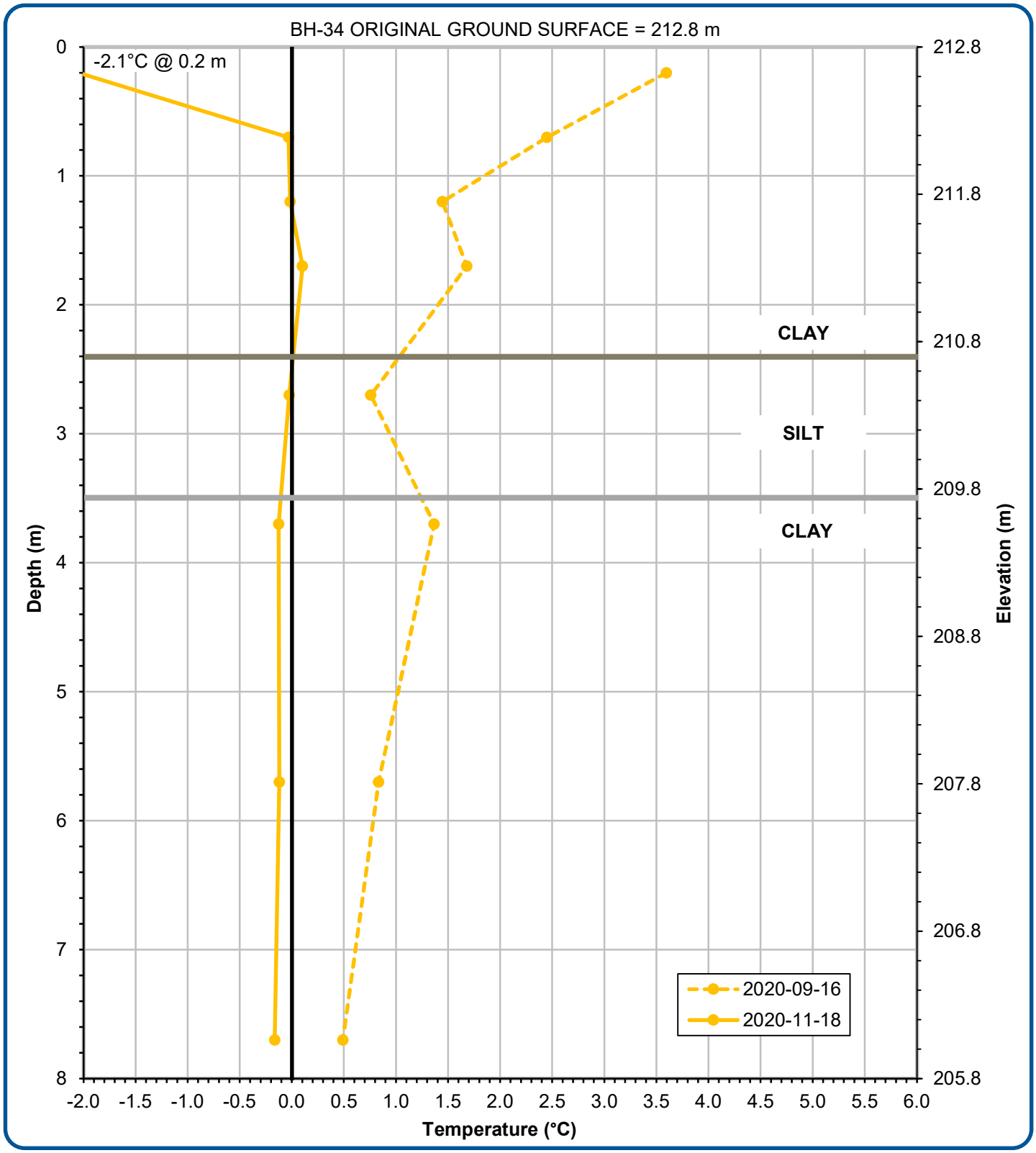
TETRA TECH



GTC Serial No. 2731
Date Drilled: March 5, 2020
Date Installed: July 23, 2020

Borehole BH-17 (MVWR km 694.8)
Ground Temperature Profile

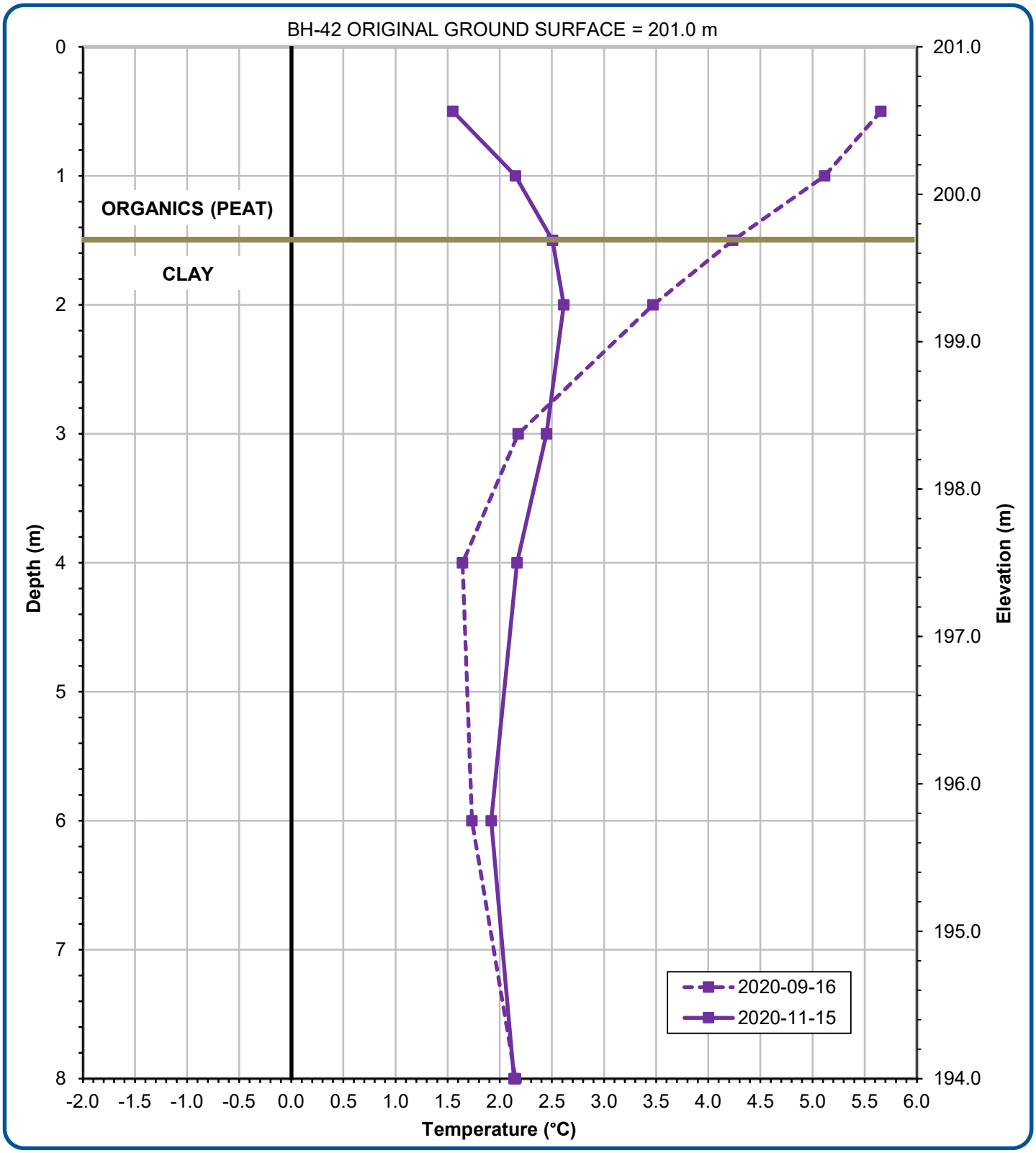
TETRA TECH



GTC Serial No. 2732
Date Drilled: March 6, 2020
Date Installed: July 24, 2020

Borehole BH-34 (MVWR km 703.3)
Ground Temperature Profile

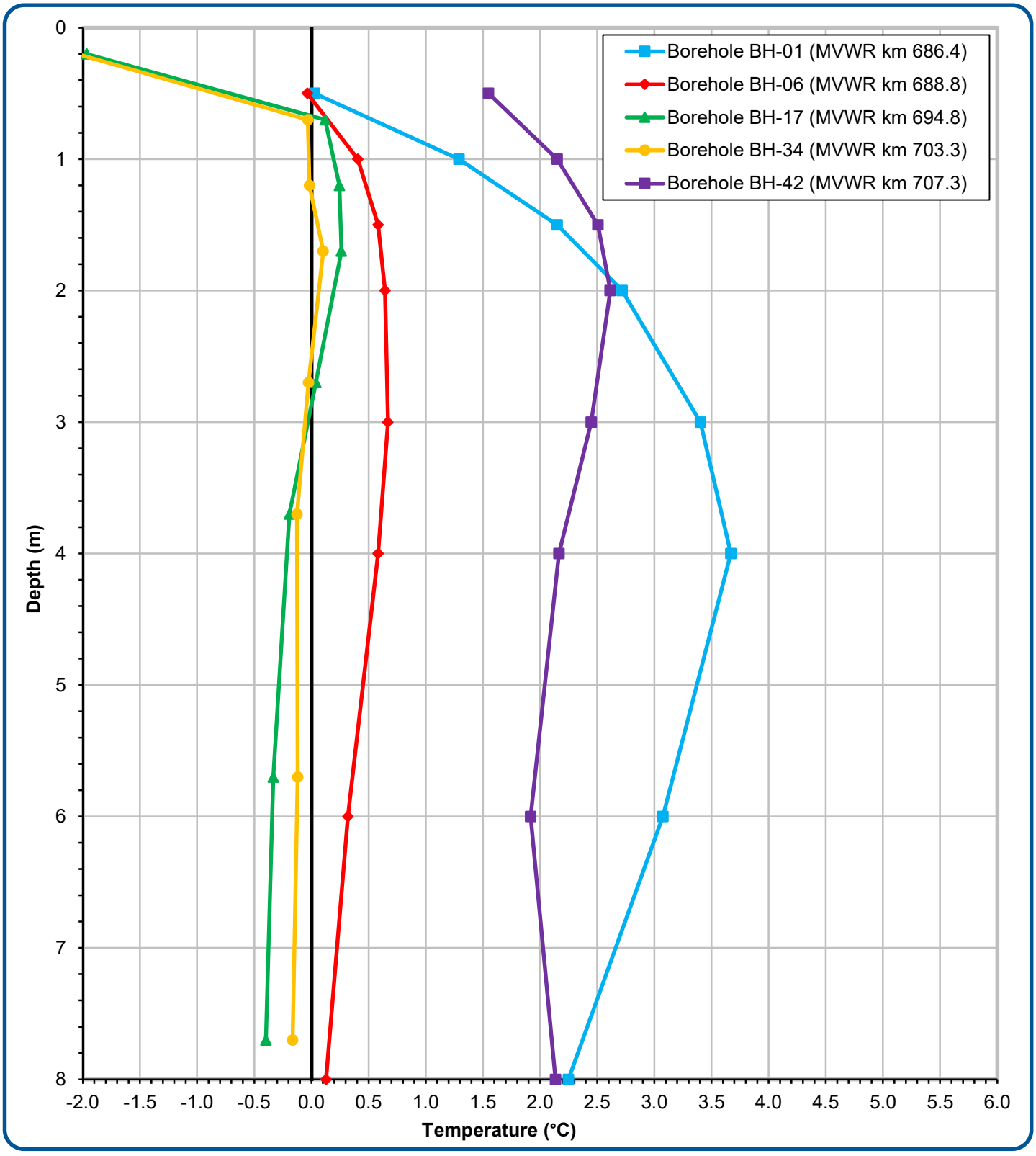
TETRA TECH



GTC Serial No. 2733
Date Drilled: March 10, 2020
Date Installed: July 24, 2020

Borehole BH-42 (MVWR km 707.3)
Ground Temperature Profile

TETRA TECH



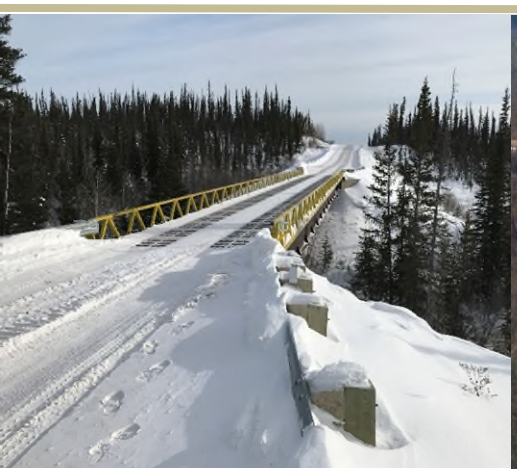
Dates Drilled: March 2 - 10, 2020
Dates Installed: July 23 - 24, 2020
Dates Read: November 15 - 18, 2020

Boreholes BH-01, BH-06, BH-17, BH-34, BH-42
Combined Ground Temperature Profile

TETRA TECH

Canyon Creek Bridge Thermal Investigation Data Report

MVWR km 1009.3, Northwest Territories





PRESENTED TO
Kãlo Stantec Limited

JUNE 24, 2021
ISSUED FOR USE
FILE: 704-ENG.YARC03354-05.002

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Figure 2 Site Plan
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Photo 1 Canyon Creek Bridge, North Abutment.
Photo 2 Canyon Creek Bridge, South Approach.
Photo 3 Drilling Borehole CCBH-05 (North Abutment).
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Photo 6 Drilling Borehole CCBH-06 (South Abutment).
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APPENDICES

Appendix A Borehole Logs
Appendix B Ground Temperature Instrumentation Installation Diagrams
Appendix C Ground Temperature Profiles
Appendix D Tetra Tech's Limitations on Use of this Document

ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
CCB	Canyon Creek Bridge
GNWT	Government of the Northwest Territories, Department of Infrastructure
GPS	Global Positioning System
GTC	Ground Temperature Cable
km	Kilometres
m	Metres
mm	Millimetres
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NAD83	North American Datum of 1983
NT	Northwest Territories
Ollerhead	Ollerhead & Associates Ltd.
SMSD	Sahtu Midnight Sun Drilling Inc.
SPT	Standard Penetration Testing
Stantec	Kãlo Stantec Limited
Tetra Tech	Tetra Tech Canada Inc.
UTM	Universal Transverse Mercator

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Kãlo Stantec Limited, the Government of the Northwest Territories, and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Kãlo Stantec Limited and the Government of the Northwest Territories, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached in Appendix D.

1.0 INTRODUCTION

1.1 General

Tetra Tech Canada Inc. (Tetra Tech) was retained by Kãlo Stantec Limited (Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to undertake a thermal investigation and install ground temperature cables (GTCs) at the Canyon Creek Bridge (CCB) located southeast of Norman Wells, Northwest Territories (NT). The CCB is an existing bridge at km 1009.3 of the Mackenzie Valley Winter Road (MVWR) that is expected to be replaced or rehabilitated as part of the proposed extension to the Mackenzie Valley Highway (MVH). Authorization to proceed with this work was granted by Warren McLeod of Stantec via a signed subconsultant agreement dated March 5, 2021.

The objective of the thermal investigation was to install GTCs for ground temperature monitoring of the CCB and collect geotechnical and permafrost information from the drill holes. This report presents data collected during the thermal investigation including borehole logs, ground temperature data, and a summary of the thermal conditions encountered.

In 2020, Tetra Tech completed a geotechnical investigation and evaluation of the CCB. This report should be read in conjunction with the results and findings from that program which are presented in a separate report titled *Canyon Creek Bridge Geotechnical Evaluation Report* (Tetra Tech 2020).

1.2 Project Description

The MVWR extends from Wrigley (MVWR km 690) to Fort Good Hope (MVWR km 1173), with supplementary access roads connecting to Déljne (106 km) and Colville Lake (165 km). The winter road is constructed and maintained by the GNWT on an annual basis and typically operates from late December to late March. The GNWT is currently advancing a project to replace the MVWR by extending the MVH from Wrigley to Norman Wells, connecting the Sahtu Region with an all-season, two-lane, gravel highway. One of the major watercourse crossings along the proposed MVH extension between Tulita (MVWR km 938) and Norman Wells (MVWR km 1026) is at Canyon Creek located at km 1009.3 of the MVWR, approximately 17 km southeast of Norman Wells, NT. The existing CCB was constructed in 1999 and is a 42 m long, single-span structure with open steel grid decking (Photos 1 and 2). A plan view showing the project location is presented in Figure 1.

The coordinate system referenced for the project is the Universal Transverse Mercator (UTM) Zone 9 using the following datums:

- Horizontal: North American Datum of 1983 (NAD83) [CSRS] Epoch 2010.0
- Vertical: CGVD2013 (CGG2013a)

The thermal investigation was completed on March 12 and 13, 2021. Geotechnical logging and permafrost classification was conducted onsite by Thomas Bradshaw, P.Eng. of Tetra Tech. Drilling was completed by Sahtu Midnight Sun Drilling Inc. (SMSD) from Norman Wells, NT. Snow clearing, site access, and traffic control support were provided by HRN Contracting Ltd. from Norman Wells, NT. Survey support for the project was provided by Ollerhead & Associates Ltd. (Ollerhead) from Yellowknife, NT. Onsite environmental and wildlife monitoring was provided by the Norman Wells Renewable Resource Council. All of these services were subcontracted by Tetra Tech for the project.

1.3 Scope of Work

Tetra Tech's scope of work, in accordance with the proposal submitted on March 2, 2021, included the following:

- Acting as the Prime Contractor, assemble a team of local subcontractors to provide geotechnical drilling, surveying, environmental monitoring, and site access clearing for the project;
- Prepare a site-specific Health and Safety Plan, including a traffic management component, and conduct site orientations for all project personnel;
- Undertake geotechnical drilling and install multi-bead GTCs in one borehole at each CCB abutment; and
- Prepare a report summarizing the collected ground temperature data and present the findings of the thermal investigation at each CCB abutment.

The GNWT requested that no field sampling or laboratory testing be undertaken for the thermal investigation.

2.0 SITE DESCRIPTION

Canyon Creek is a meandering stream that originates in the Franklin Mountains, approximately 7 km northeast of the MVWR, and receives inflow from nearby Bandy Lake. The creek flows from northeast to southwest at the CCB location (Latitude 65° 13' 36.0", Longitude -126° 31' 25.0") and connects with the Mackenzie River approximately 2 km downstream of the CCB. Trees in the area of the thermal investigation were generally black spruce with occasional birch up to 9 m in height and 0.2 m in diameter (Associated 1974). A site plan of Canyon Creek at the bridge location is shown on Figure 2.

The valley walls of Canyon Creek are relatively low on the southern bank but quite steep on the northern bank (RMH 1973). The northern bank of the valley rises from the creek at an approximate 3H:1V gradient to an elevation of 88.8 m. The southern bank is flat for approximately 92 m before sloping at approximately 7H:1V to an elevation of 86.3 m. Canyon Creek is approximately 15 m wide at the crossing location. The CCB abutments and bridge deck sit at an elevation of 89.2 m, approximately 7 m above Canyon Creek, as illustrated on Figure 3.

2.1 Geological Setting

Glacial till veneer and blanket deposits are the predominant surficial materials around Canyon Creek based on surficial geology mapping for the Norman Wells area (Duk-Rodkin 2002). The till deposits typically consist of unsorted silt and clay with sand and coarser clasts, ranging from 2 m to 6 m thick. Alluvial deposits are noted to the south of the CCB, occurring as terraces, and comprise of sands and silts underlain by gravels. Alluvial materials range from 2 m to 5 m thick and are deposited following modern drainage regimes. Two localized glaciofluvial deposits were noted directly north of the CCB, deposited by glacial meltwater as proglacial or ice contact sediments. The glaciofluvial materials are described as gentle sloping fans ranging from 2 m to 30 m in thickness, comprised of sands and gravels locally with occasional veneers of eolian silts.

Geological mapping indicates that the bedrock for CCB and most of the proposed MVH alignment consists of sedimentary rocks from the Devonian geologic period (Fallas and MacNaughton 2013). Based on mapping for areas southeast of Norman Wells, the CCB area appears to be underlain by greenish-grey to purplish-brown, laminated Siltstone of the Imperial Formation. The material is expected to be interbedded with locally silty, fissile, dark grey to greenish-grey Mud Shale as well as grey to greenish-grey, very thin- to medium-bedded, laminated and cross-laminated sandstone. Mapping shows that material boundaries between formations tend to run parallel to the

proposed MVH alignment, between the Mackenzie River and the Norman Range. Bedrock encountered during the geotechnical thermal investigation was interpreted as Siltstone.

2.2 Climate

Environment and Climate Change Canada operates several meteorological stations at the nearby town of Norman Wells with records available from 1950 to the present (Environment and Climate Change Canada 2021). The mean annual air temperature for the period of record is -6.6°C, which has been gradually increasing from the start of data collection. The average rate of annual temperature increase has been 0.04°C/year over the period of record, with the biggest increase occurring in the winter months between October to April. Over the past 10 years, the mean annual air temperature has averaged -5.6°C with an average rate of increase of 0.15°C/year.

Using published data from the Climate Atlas of Canada, it was determined that Norman Wells has an average number of freezing degree days of 3,996 from 1950 to the present (Climate Atlas of Canada 2021). The number of freezing degree days has decreased by an average of 11 freezing degree days/year during that time. Over the past 10 years, the number of freezing degree days has averaged 3,737 with an average rate of decrease of 35 freezing degree days/year.

The mean annual precipitation over the period of record (1950 to 2020) was determined to be 341 mm/year. Over the past 10 years, the annual precipitation in Norman Wells averaged 350 mm/year.

2.3 Permafrost Conditions

The CCB is located within a zone of extensive, discontinuous permafrost, meaning permafrost is expected to be present in 50% to 90% of land cover (NRC 2009). Permafrost is typically present in muskeg terrain and heavily treed areas that are not free draining. Ground temperature readings collected from the nearby Canyon Creek All-Season Access Road range between 0°C and -2.0°C, indicating warm permafrost (Tetra Tech 2016).

During the 2020 geotechnical investigation of CCB, frozen ground conditions were observed at varying depths in both abutments (Tetra Tech 2020). Unfrozen layers, up to 9 m thick, were observed below the road embankment fill in the south abutment (Boreholes CCBH-03 and CCBH-04). Frozen soils with ground ice, up to 15% in volume, were observed above the bedrock in the north abutment (Boreholes CCBH-01 and CCBH-02).

3.0 THERMAL INVESTIGATION

3.1 Borehole Locations

Two boreholes were drilled as part of the CCB thermal investigation, one at each bridge abutment, to install GTCs. The North Abutment drilling and GTC installation took place on March 13, 2021 (Photos 3 and 4) and the South Abutment drilling and GTC installation occurred on March 12, 2021 (Photos 5 and 6). As-drilled borehole coordinates and elevations are summarized in Table 3-1.

Table 3-1: Borehole Coordinates and Elevations

Borehole Number	Bridge Abutment	Coordinates (m, UTM Zone 9: NAD83 [CSRS] Epoch 2010)				Ground Elevation (m)	Depth Drilled (m)
		Northing	Easting	Latitude	Longitude		
CCBH-05	North	7,235,986.6	615,765.6	65° 13’ 35.9”	126° 31’ 24.9”	90.3	16.8
CCBH-06	South	7,235,930.1	615,843.0	65° 13’ 34.0”	126° 31’ 19.1”	89.3	18.3

Tetra Tech flagged the borehole locations in the field using a handheld Garmin GPSMAP 64S global positioning system (GPS) receiver before drilling. Following the completion of drilling, the as-drilled borehole locations were surveyed by Ollerhead on March 15, 2021. The borehole coordinates and elevations are presented on the borehole logs in Appendix A.

3.2 Drilling Methodology

The CCB thermal investigation was completed using a Locust Geotechnical air rotary, tracked drill rig (Photo A), owned and operated by SMSD of Norman Wells, NT. The drill rig was equipped for solid stem and hollow stem augering as well as NQ-sized diamond rock coring. The drill rig was also equipped for Standard Penetration Testing (SPT); however, this was not undertaken during the thermal investigation at the request of the GNWT. Both boreholes were drilled with 152 mm (6 inch) diameter solid stem augers in 1.5 m (5 feet) runs to completion depth.



Photo A: Locust Geotechnical Drill Rig used for Thermal Investigation.

3.3 Geotechnical Logging

All recovered soils were logged and photographed at the drilling locations, allowing for accurate classification of the materials and ground ice encountered.

Soils were classified according to the Modified Unified Soil Classification system and Tetra Tech's Work Method *WM4400 – Geotechnical Soil Classification*. The frozen state of the soils was described according to the NRCC Ground Ice Classification system and Tetra Tech's Work Method *WM4102 – Logging of Perennially Frozen Soils and Ground Ice for Engineering Purposes*. Soil logging consisted of identifying the following parameters:

- Soil Composition;
- Particle Size;
- Angularity/Shape;
- Moisture;
- Consistency;
- Plasticity;
- Colour;
- Odour;
- Frozen/Unfrozen State; and
- Ground Ice Description.

Borehole logs and a summary of the classification system are presented in Appendix A.

3.4 Field Samples and Laboratory Testing

No field sampling (i.e., auger or split spoon soil sampling), field testing (i.e., SPTs), and laboratory testing were undertaken as instructed by the GNWT.

3.5 Ground Temperature Instrumentation

Ground temperature cables were manufactured in Tetra Tech's Edmonton laboratory. Two GTCs, one for each CCB abutment, were fabricated with 16 thermistor beads over a cable length of 15 m. The GTCs had an additional 2 m of lead length for a total cable length of 17 m.

Both GTCs were installed in the CCB abutments to the depth drilled. Sections of 25 mm (1 inch) diameter, threaded PVC conduit pipe were placed down each borehole and the GTCs were installed down the conduit. The PVC conduit pipe was backfilled with *Target Filter Sand (10-20)* while the remainder of the borehole (i.e., outside of the PVC) was backfilled with drill cuttings.

Each GTC was tested after installation and a set of ground temperature readings were taken at the end of each shift (Photo 7). GTC installation diagrams showing the thermistor bead depths for each installation are presented in Appendix B. Table 3-2 summarizes the ground temperature instrumentation installed at CCB.

Table 3-2: Ground Temperature Cables Installed

Borehole Number	GTC Serial Number	Total Cable Length (m)	Number of Thermistor Beads*	Ground Elevation (m)	Thermistor Bead Elevations (m)		Date Installed
					Top	Bottom	
CCBH-05	2726	17.0	16	90.3	89.8	75.3	March 13, 2021
CCBH-06	2727			89.3	87.8	73.3	March 12, 2021

** Depth below ground of each thermistor bead shown on Ground Temperature Instrumentation Installation Diagrams in Appendix B.*

The GTCs are manual read installations. A switch box and multimeter need to be connected to the cables in the field to obtain readings. Resistances are recorded at the thermistor beads spaced along each cable which are then converted to ground temperatures using the following equation:

$$T_g = (333.5 \times R^{-0.07168}) + (2.5 \times (\log R/16.325)^2 - 273 + T_c)$$

Where:

T_g = ground temperature at depth of thermistor bead (°C)
R = resistance measured from thermistor bead (kΩ)
T_c = temperature calibration correction for thermistor bead (°C)

4.0 THERMAL CONDITIONS

Subsurface conditions for the CCB are shown on the applicable borehole logs in Appendix A. The interpreted stratigraphy is generally consistent with the findings from the 2020 geotechnical investigation. Figure 3 illustrates the interpreted subsurface conditions on a profile view of the CCB crossing. Thermal conditions for the CCB are summarized herein based on findings from the thermal investigation.

4.1 Ground Temperature Data

An initial set of ground temperature readings were collected on March 15, 2021 following the installation of the GTCs to confirm that they were functioning (Photo 8), and a second set of ground temperature readings were collected on March 18, 2021. The ground temperature data collected is presented in Table 4-1. The ground temperature profiles are presented in Appendix C and noted on the borehole logs in Appendix A.

Table 4-1: Ground Temperature Data Summary

Thermistor Bead No.	North Abutment (Borehole CCBH-05)			South Abutment (Borehole CCBH-06)		
	Depth Below Ground (m)	Calibration Correction (°C)	Ground Temperature* (°C)	Depth Below Ground (m)	Calibration Correction (°C)	Ground Temperature* (°C)
1	0.5	-0.01	-14.2	1.5	0.00	-11.7
2	1.0	0.05	-11.0	2.0	-0.02	-9.1
3	1.5	0.02	-8.6	2.5	-0.02	-6.3
4	2.0	0.00	-6.5	3.0	-0.01	-3.9
5	2.5	-0.03	-4.2	3.5	0.05	-1.7
6	3.0	0.00	-2.1	4.0	0.00	-0.2
7	3.5	-0.02	-0.3	4.5	0.09	-0.1
8	4.0	0.03	-0.1	5.0	-0.03	-0.1
9	4.5	0.02	-0.1	5.5	0.03	-0.1
10	5.5	-0.01	-0.1	6.5	0.02	0.3
11	6.5	0.02	-0.1	7.5	0.15	0.4
12	7.5	0.03	-0.1	8.5	0.04	0.3
13	9.0	0.02	-0.1	10.0	0.05	0.3
14	10.5	-0.02	-0.2	11.5	0.11	0.5
15	12.5	0.14	-0.2	13.5	-0.03	0.8
16	15.0	0.04	-0.2	16.0	0.05	0.8

** Calibration-corrected ground temperatures measured on March 18, 2021.*

4.2 North Abutment

Three geotechnical boreholes have been drilled at the North Abutment of the CCB: two boreholes from the 2020 geotechnical investigation (CCBH-01 and CCBH-02) and one borehole from the 2021 thermal investigation (CCBH-05), as shown on Figure 3. One GTC was installed in Borehole CCBH-05 during the 2021 thermal investigation.

The subsurface soil conditions at the North Abutment consist of frozen silts and clays with some sand layers. These overburden materials are overlain with road fill (sands and gravels) that is consistently 1.5 m thick. In 2020, visible ice crystals (V_x) up to 15% by volume were observed at depths of 6.0 m in Boreholes CCBH-01 and CCBH-02. Further visible ice crystals (V_x) were noted at a depth of 13.5 m in Borehole CCBH-01.

Measured ground temperatures from the North Abutment of the CCB indicate permafrost is present. The thickness of the active layer is not known at this time as further ground temperature readings are required in warmer months to define this. Ground temperatures in Borehole CCBH-05 were frozen and warmed with depth to 4.0 m before stabilizing at a temperature of -0.1°C at 9.0 m depth. Temperatures then slightly cooled from 9.0 m to an ultimate depth of 15.0 m.

Unfrozen conditions were previously recorded in 2020 between depths of 4.5 m and 6.0 m in both boreholes; however, current ground temperature readings indicate that these zones are frozen, not unfrozen. Further ground temperature readings will confirm the presence of any discontinuous permafrost in this section.

4.3 South Abutment

Three geotechnical boreholes have been drilled in the South Abutment of the CCB: two boreholes from the 2020 geotechnical investigation (CCBH-03 and CCBH-04) and one borehole from the 2021 thermal investigation (CCBH-06), as shown on Figure 3. One GTC was installed in Borehole CCBH-06 during the 2021 thermal investigation.

The subsurface soil conditions at the South Abutment consist of frozen road embankment fill, ranging from ground surface up to 5.0 m thick, underlain by silty clays and sandy silts. Visible ice crystals (V_x) up to 10% by volume were observed in the road embankment fill in both 2020 boreholes. Ground ice (V_x) up to 3% by volume was also noted at a depth of 12.0 m in Borehole CCBH-03 with a frozen section identified from 12.0 m to 15.0 m; however, recent ground temperatures suggest this section is likely unfrozen. Inferred groundwater conditions were encountered in all three South Abutment boreholes at depths ranging from 7.3 m to 10.5 m below ground surface.

Measured ground temperatures from the South Abutment of the CCB (Borehole CCBH-06) were frozen to approximately 5.8 m depth and unfrozen the remainder of the borehole. Ground temperatures were frozen from the surface and warmed with depth to 4.5 m before stabilizing at -0.1°C to a depth of 5.8 m. Unfrozen ground temperatures were then measured in the remainder of the borehole. Unfrozen conditions below depths of 3 m were previously noted in 2020 in both boreholes. Future ground temperature readings are required to determine the active layer thickness.

5.0 MONITORING

Ground temperature readings were collected from both installations on March 18, 2021; however, additional data collection is necessary to understand the annual temperature fluctuations and confirm the permafrost conditions at each installation. Future site visits to continue collecting ground temperature readings could be undertaken by Tetra Tech or a trained environmental monitor from the town of Norman Wells.

It is recommended that both GTCs be read a minimum of two times each year. Readings should be collected in spring (early April) when ground temperatures are the coldest for the year and in the fall (late September) when ground temperatures are warmest for the year. Readings in spring and fall provide ground temperature profiles that reasonably bound the range in ground temperatures produced by annual surface temperature variations. Ground temperature readings collected at other times of year provide intermediate temperature profiles.

6.0 CLOSURE

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

Respectfully submitted,
Tetra Tech Canada Inc.

REGISTERED PROFESSIONAL ENGINEER
T.A. BRADSHAW
LICENSEE
NT/NU
June 24, 2021

FILE 704-ENG.YARC03354-05.002
FILE 704-ENG.YARC03354-05.002
FILE 704-ENG.YARC03354-05.002

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FILE 704-ENG.YARC03354-05.002
FILE 704-ENG.YARC03354-05.002

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PERMIT NUMBER: P 018
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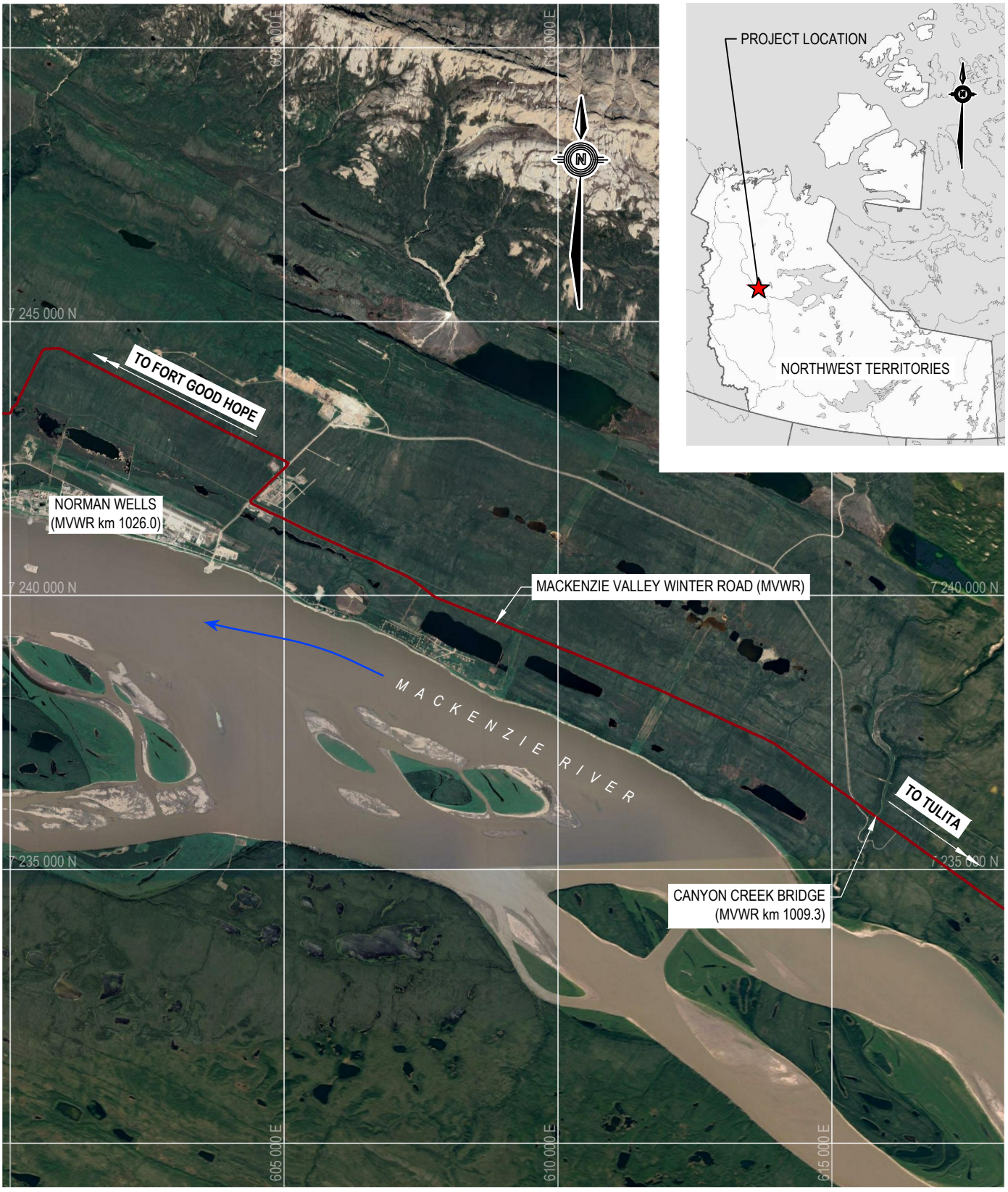
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FIGURES

Figure 1 Project Location
Figure 2 Site Plan
Figure 3 Bridge Plan and Profile



NOTES:

1. HORIZONTAL DATUM / PROJECTION: UTM ZONE 9N, NAD83 (CSRS) (2010) - METERS.
2. IMAGERY OBTAINED FROM GOOGLE EARTH PRO.

0 5,000m

Scale: 1:100,000 @ 8.5"x11"

CLIENT

Kãlo Stantec

TETRA TECH

CANYON CREEK BRIDGE THERMAL
MVWR km 1009.3, NORTHWEST TERRITORIES

PROJECT LOCATION

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05.002	EL	TB	IFU

OFFICE	DATE
EDMONTON	JUNE 2021

FIGURE 1

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NOTES:

1. HORIZONTAL DATUM / PROJECTION: UTM ZONE 9N, NAD83 (CSRS) (2010) - METERS.
2. IMAGERY OBTAINED FROM ESRI ARCMAP DESKTOP SOFTWARE.

0 500m

Scale: 1:10,000 @ 8.5"x11"

CLIENT

Kãlo Stantec

TETRA TECH

CANYON CREEK BRIDGE THERMAL
MVWR km 1009.3, NORTHWEST TERRITORIES

SITE PLAN

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05.002	EL	TB	IFU

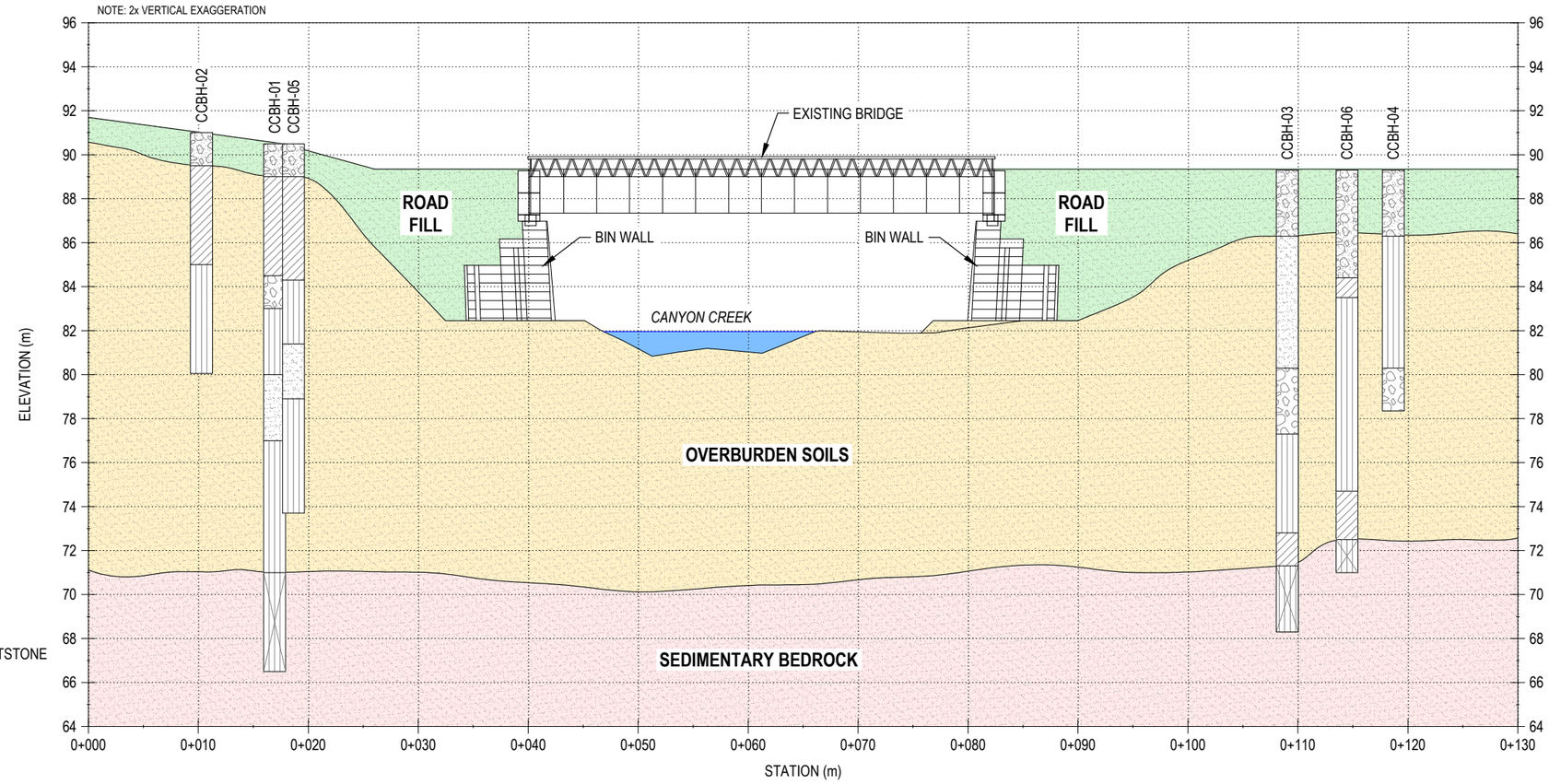
OFFICE	DATE
EDMONTON	JUNE 2021

FIGURE 2

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NOTE: 2x VERTICAL EXAGGERATION



LEGEND:

CLAY | SILT | SILTSTONE | SAND | GRAVEL

BOREHOLE INFORMATION SUMMARY			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
CCBH-01	7,235,987.2	615,764.0	90.5
CCBH-02	7,235,991.2	615,758.7	91.0
CCBH-03	7,235,932.9	615,838.4	89.3
CCBH-04	7,235,927.4	615,846.3	89.3
CCBH-05	7,235,986.5	615,765.6	90.3
CCBH-06	7,235,930.1	615,843.0	89.2

NOTES:

- HORIZONTAL DATUM: UTM ZONE 9N [NAD83, CSRS (2010)]
- VERTICAL EXAGGERATION IN CROSS-SECTION IS 2X.
- PROFILE VIEW NOT TO SCALE.
- STRATIGRAPHIC BOUNDARIES BETWEEN BOREHOLES ARE INTERPRETED.

2020 BOREHOLE (TETRA TECH)

2021 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)

CLIENT

Kãlo Stantec

TETRA TECH

CANYON CREEK BRIDGE THERMAL MVWR km 1009.3, NORTHWEST TERRITORIES

BRIDGE PLAN AND PROFILE

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05.002	EL	TB	IFU

OFFICE: EDMONTON

DATE: JUNE 2021

FIGURE 3

Q:\Edmonton\Engineering\E1411\Projects\ENG.YARC03354-05\ENG.YARC03354-05-Figure 3_Canyon Creek.dwg [FIGURE 3] June 23, 2021 - 12:53:07 pm (BY: LEE, ELVIN)

PHOTOGRAPHS

Photo 1 Canyon Creek Bridge, North Abutment.
Photo 2 Canyon Creek Bridge, South Approach.
Photo 3 Drilling Borehole CCBH-05 (North Abutment).
Photo 4 Drilling Borehole CCBH-05 (North Abutment).
Photo 5 Drilling Borehole CCBH-06 (South Abutment).
Photo 6 Drilling Borehole CCBH-06 (South Abutment).
Photo 7 Ground temperature cable Installed in Borehole CCBH-05 (North Abutment).
Photo 8 Measuring ground temperatures in Boreholes CCBH-05 (North Abutment).



Photo 1: Canyon Creek Bridge, North Abutment.
(Photo taken March 13, 2021 looking southbound)



Photo 2: Canyon Creek Bridge, South Approach.
(Photo taken March 12, 2021 looking northbound)



Photo 3: Drilling Borehole CCBH-05 (North Abutment).
(Photo taken March 13, 2021 looking southbound)



Photo 4: Drilling Borehole CCBH-05 (North Abutment).
(Photo taken March 13, 2021 looking northbound)



Photo 5: Drilling Borehole CCBH-06 (South Abutment). (Photo taken March 12, 2021 looking northbound)



Photo 6: Drilling Borehole CCBH-06 (South Abutment). (Photo taken March 12, 2021 looking southbound)



Photo 7: Ground temperature cable installed in Borehole CCBH-05 (North Abutment). (Photo taken March 13, 2021)



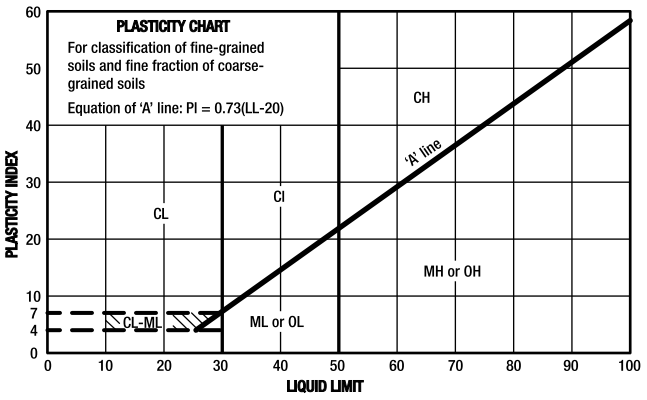
Photo 8: Measuring ground temperatures in Borehole CCBH-05 (North Abutment). (Photo taken March 15, 2021 looking southbound)

APPENDIX A

BOREHOLE LOGS

MODIFIED UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS More than 50% retained on 75 µm sieve*	GRAVELS 50% or more of coarse fraction retained on 4.75 mm sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines GW, GP, SW, SP GM, GC, SM, SC Borderline Classification requiring use of dual symbols $C_U = D_{60} / D_{10}$ Greater than 4 $C_C = \frac{(D_{30})2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits plot above "A" line or plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes 4.75 mm sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines	Less than 5% Pass 75 µm sieve More than 12% Pass 75 µm sieve 5% to 12% Pass 75 µm sieve $C_U = D_{60}/D_{10}$ Greater than 6 $C_C = \frac{(D_{30})2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines	Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures	Atterberg limits plot above "A" line or plasticity index greater than 7	
FINE-GRAINED SOILS (by behavior) 50% or more passes 75 µm sieve*	SILTS Liquid limit <50		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands of slight plasticity		
	SILTS Liquid limit >50		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
	CLAYS Above "A" line on plasticity chart negligible organic content Liquid limit <30		CL	Inorganic clays of low plasticity, gravelly clays, sandy clays, silty clays, lean clays		
	CLAYS Above "A" line on plasticity chart negligible organic content Liquid limit 30-50		CI	Inorganic clays of medium plasticity, silty clays		
	CLAYS Above "A" line on plasticity chart negligible organic content Liquid limit >50		CH	Inorganic clays of high plasticity, fat clays		
	ORGANIC SILTS AND CLAYS Liquid limit <50		OL	Organic silts and organic silty clays of low plasticity		
	ORGANIC SILTS AND CLAYS Liquid limit >50		OH	Organic clays of medium to high plasticity		
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils		



* Based on the material passing the 75 mm sieve

† ASTM Designation D 2487, for identification procedure see D 2488 USC as modified by PFRA

SOIL COMPONENTS

FRACTION	SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY MASS OF MINOR COMPONENTS	
	PASSING	RETAINED	PERCENTAGE	DESCRIPTOR
GRAVEL coarse fine	75 mm 19 mm	19 mm 4.75 mm	>35 % 21 to 35 % 11 to 20 % >0 to 10 %	"and" "y-adjective" "some" "trace"
SAND coarse medium fine	4.75 mm 2.00 mm 425 µm	2.00 mm 425 µm 75 µm		
SILT (non plastic) or CLAY (plastic)	75 µm		as above but by behavior	

OVERSIZE MATERIAL

Rounded or subrounded

COBBLES	75 mm to 300 mm
BOULDERS	> 300 mm

Not rounded

ROCK FRAGMENTS	>75 mm
ROCKS	> 0.76 cubic metre in volume

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GROUND ICE DESCRIPTION

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	SKETCH	PHOTOGRAPH
V	Vx	Individual ice crystals or inclusions		
	Vc	Ice coatings on particles		
	Vr	Random or irregularly oriented ice formations		
	Vs	Stratified or distinctly oriented ice formations		
	Vu	Ice formations uniformly distributed throughout frozen soil		

ICE NOT VISIBLE

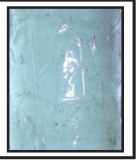
GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	SKETCH	PHOTOGRAPH
N	Nf	Poorly-bonded or friable		
	Nbn	No excess ice, well-bonded		
	Nbe	Excess ice, well-bonded		

LEGEND: Soil ☐ Ice ■

NOTES:

1. Dual symbols are used to indicate borderline or mixed ice classifications.
2. Visual estimates of ice contents indicated on borehole logs ± 5%
3. This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes.

VISIBLE ICE GREATER THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	SKETCH	PHOTOGRAPH
ICE	ICE + Soil Type	Ice with soil inclusions (greater than 25 mm thick)		
	ICE	Ice without soil inclusions (greater than 25 mm thick)		

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TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075 mm sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as inferred from laboratory or in situ tests.

descriptive term	relative density	n (blows per 0.3 m)
Very Loose	0 to 20%	0 to 4
Loose	20 to 40%	4 to 10
Compact	40 to 75%	10 to 30
Dense	75 to 90%	30 to 50
Very Dense	90 to 100%	greater than 50

The number of blows, N, on a 51 mm O.D. split spoon sampler of a 63.5 kg weight falling 0.76 m, required to drive the sampler a distance of 0.3 m from 0.15 m to 0.45 m.

FINE GRAINED SOILS (major portion passing 0.075 mm sieve): Includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as estimated from laboratory or in situ tests.

descriptive term	unconfined compressive strength (kPa)
Very Soft	Less than 25
Soft	25 to 50
Firm	50 to 100
Stiff	100 to 200
Very Stiff	200 to 400
Hard	Greater than 400

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

GENERAL DESCRIPTIVE TERMS

Slickensided - having inclined planes of weakness that are slick and glossy in appearance.
Fissured - containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated - composed of thin layers of varying colour and texture.
Interbedded - composed of alternate layers of different soil types.
Calcareous - containing appreciable quantities of calcium carbonate.;
Well graded - having wide range in grain sizes and substantial amounts of intermediate particle sizes.
Poorly graded - predominantly of one grain size, or having a range of sizes with some intermediate size missing.

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ROCK DESCRIPTION TERMS USED ON BOREHOLE LOGS

MECHANICAL STRENGTH CALCULATIONS			
TERM	UCS* (MPa)	GRADE	FIELD IDENTIFICATION**
Extremely Strong	> 250	R6	Specimen can only be chipped with geological hammer
Very Strong	100 - 250	R5	Specimen requires many blows of geological hammer to fracture
Strong	50 - 100	R4	Specimen requires more than one blow of geological hammer to fracture
Medium Strong	25 - 50	R3	Cannot be scraped or peeled with pocket knife; can be fractured with single firm blow of geologic hammer
Weak	5 - 25	R2	Can be peeled by pocket knife with difficulty; shallow indentation made by firm blow with geological hammer
Very Weak	1 - 5	R1	Crumbles under firm blow with point of geological hammer; can be peeled by a pocket knife
Extremely Weak	0.25 - 1	R0	Indented by thumbnail
*UCS - unconfined compressive strength; **Correlations determined by Field Identification are approximate.			

GRAIN SIZE			
NON-CARBONATE DETRITAL SEDIMENTARY ROCKS		OTHER ROCKS	GRAIN SIZE
Conglomerate or Breccia		Very Coarse Grained	More than 80 mm
Conglomerate or Breccia		Coarse Grained	4 to 80 mm
Sandstone [1]		Medium Grained	80 µm to 4 mm
FISSILE	NON-FISSILE		
Silt Shale	Siltstone	Fine Grained	> 2/3 silt-sized (2 to 80 µm)
Mud Shale	Mudstone	Fine Grained	Silt and clay-sized (<80 µm)
Clay Shale	Claystone	Very Fine Grained	> 2/3 clay-sized (<2 µm)
[1] Sandstone further subdivided where appropriate into fine, medium, coarse			

DISCONTINUITY SPACING		
BEDDING	OTHER DISCONTINUITY	SPACING
Very Thickly Bedded	Very Widely Spaced	More than 2 m
Thickly Bedded	Widely Spaced	600 mm to 2 m
Medium Bedded	Moderately Widely Spaced	200 to 600 mm
Thinly Bedded	Closely Spaced	60 to 200 mm
Very Thinly Bedded	Very Closely Spaced	20 to 60 mm
Laminated	Extremely Closely Spaced	6 to 20 mm
Thinly Laminated	Extremely Closely Spaced	2 to 6 mm
Fissile	Extremely Closely Spaced	Less than 2 mm

ROCK QUALITY	
TERM	RQD
Very Poor Quality	0 to 25
Poor Quality	25 to 50
Fair Quality	50 to 75
Good Quality	75 to 90
Excellent Quality	90 to 100

WEATHERED STATE	
TERM	DEGREE
Fresh	No visible signs of weathering
Slightly Weathered	Weathering only on open discontinuity surfaces
Moderately Weathered	Rock mass weathered but not friable
Highly Weathered	Rock mass weathered and partly friable
Completely Weathered	Wholly decomposed but texture and structure preserved
Residual Soil	Original rock texture and structure destroyed

CORE RECOVERY	
TERM	DESCRIPTION
Total Core Recovery	Total recovery expressed as a percentage of run length
Solid Recovery	Solid recovery expressed as a percentage of run length
Rock Quality Designation (RQD)	Sum of lengths of solid core more than 100 mm long expressed as a percentage of run length
Fracture Frequency (FF)	The number of fractures per metre of core (FF's in excess of 30 denoted at 30+)

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BOREHOLE KEYSHEET

Water Level Measurement

 Measured in standpipe, piezometer or well

 Inferred

Sample Types

 A-Casing

 Core

 Disturbed, Bag, Grab

 HQ Core

 Jar

 Jar and Bag

 75 mm SPT

 No Recovery

 Split Spoon/SPT

 Tube

 CRREL Core

Backfill Materials

 Asphalt

 Bentonite

 Cement/ Grout

 Drill Cuttings

 Grout

 Gravel

 Sand

 Slough

 Topsoil Backfill

Lithology - Graphical Legend[1]

 Asphalt

 Bedrock

 Cobbles/Boulders

 Clay

 Coal

 Concrete

 Fill

 Gravel

 Limestone

 Mudstone

 Organics

 Peat

 Sand

 Sandstone

 Shale

 Silt

 Siltstone

 Conglomerate

 Topsoil

 Till

1. The graphical legend is an approximation and for visual representation only. Soil strata may comprise a combination of the basic symbols shown above. Particle sizes are not drawn to scale

TETRA TECH

Borehole No: **CCBH-05**

Kâlo Stantec

Project: Canyon Creek Bridge Thermal Investigation	Project No: ENG.YARC03354-05.002
Location: North Abutment	Ground Elev: 90.3 m
MVWR km 1009.3, Northwest Territories	UTM: 615765.6 E; 7235986.6 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	#2726	Elevation (m)
0	Solid Stem Auger	SAND AND GRAVEL (ROAD FILL) - some silt, well graded, light grey, angular gravel	Frozen, Nbn	-14.2				90
1				-11				89
		CLAY - silty, trace sand, dark brown		-8.6				
2				-6.5				88
		- trace gravel, subrounded gravel to 15 mm diameter		-4.2				
3				-2.1				87
				-0.3				
4		- gravel to 30 mm diameter		-0.1				86
		- some gravel and sand		-0.1				
5		- subrounded to angular gravel						85
		- trace gravel, subrounded gravel to 15 mm diameter		-0.1				
6								84
		SILT - clayey, trace sand, occasional gravel, grey, subrounded gravel to 20 mm diameter		-0.1				
7								83
		- rounded gravel to 40 mm diameter		-0.1				
8		- some clay, no visible gravel						82
9		- trace gravel, rounded gravel to 10 mm diameter		-0.1				81
		SAND - silty, trace clay, poorly graded, grey, fine sand						
10								

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Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 16.8 m
Drilling Rig Type: Locust Tracked Air Rotary	Start Date: 2021 March 13
Logged By: TAB	Completion Date: 2021 March 13
Reviewed By: EG	Page 1 of 2

Borehole No: **CCBH-05**

Project: Canyon Creek Bridge Thermal Investigation	Project No: ENG.YARC03354-05.002
Location: North Abutment	Ground Elev: 90.3 m
MVWR km 1009.3, Northwest Territories	UTM: 615765.6 E; 7235986.6 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	#2726	Elevation (m)
10	Solid Stem Auger	- trace gravel, rounded gravel to 10 mm diameter		-0.2				80
11		- some gravel, angular gravel to 40 mm diameter						79
		- no visible gravel						
12		SILT - some sand, trace clay, light grey		-0.2				78
13		- occasional gravel, rounded gravel to 15 mm diameter						77
14		- sandy						76
15				-0.2				75
16		- some clay						74
17		END OF BOREHOLE (16.8 metres) slough - 16.6 metres at completion Installed GTC #2726 in 25 mm PVC pipe backfilled with 10/20 filter sand to 15.0 metres. Borehole backfilled with cuttings. Ground temperatures measured on March 18, 2021						73
18								72
19								71
20								

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 16.8 m
Drilling Rig Type: Locust Tracked Air Rotary	Start Date: 2021 March 13
Logged By: TAB	Completion Date: 2021 March 13
Reviewed By: EG	Page 2 of 2

Borehole No: **CCBH-06**

Project: Canyon Creek Bridge Thermal Investigation	Project No: ENG.YARC03354-05.002
Location: South Abutment	Ground Elev: 89.3 m
MVWR km 1009.3, Northwest Territories	UTM: 615843 E; 7235930.1 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	#2727	Elevation (m)
0	Solid Stem Auger	SAND AND GRAVEL (ROAD FILL) - some silt, well graded, light grey, angular gravel	Frozen, Nbn	-11.7				89
1				-9.1				88
2				-6.3				87
3				-3.9				86
4				-1.7				85
5		SILT - clayey, trace sand and gravel, dark brown, subrounded gravel to 10 mm diameter - some sand, light brown - gravel to 45 mm diameter - sandy, dry, non plastic, brown, gravel to 15 mm diameter		-0.2 -0.1 -0.1				84
6			Unfrozen	-0.1				83
7		CLAY - silty, trace sand, dry, low plastic, brown - trace gravel, subrounded gravel to 20 mm diameter - wood chunks and debris, 150 mm thick black organic layer - some gravel, some sand, gravel to 35 mm diameter		0.3				82
8		- gravelly, some silt, gravel to 60 mm dimeter - trace sand, damp, wood debris, gravel to 50 mm diameter		0.4				81
9		- 100 mm thick black coal seam - rounded gravel to 70 mm diameter - some gravel, moist - trace gravel, damp		0.3				80
10		- subrounded to rounded gravel to 35 mm diameter						

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 18.3 m
Drilling Rig Type: Locust Tracked Air Rotary	Start Date: 2021 March 12
Logged By: TAB	Completion Date: 2021 March 12
Reviewed By: EG	Page 1 of 2

Borehole No: **CCBH-06**

Project: Canyon Creek Bridge Thermal Investigation	Project No: ENG.YARC03354-05.002
Location: South Abutment	Ground Elev: 89.3 m
MVWR km 1009.3, Northwest Territories	UTM: 615843 E; 7235930.1 N; Z 9

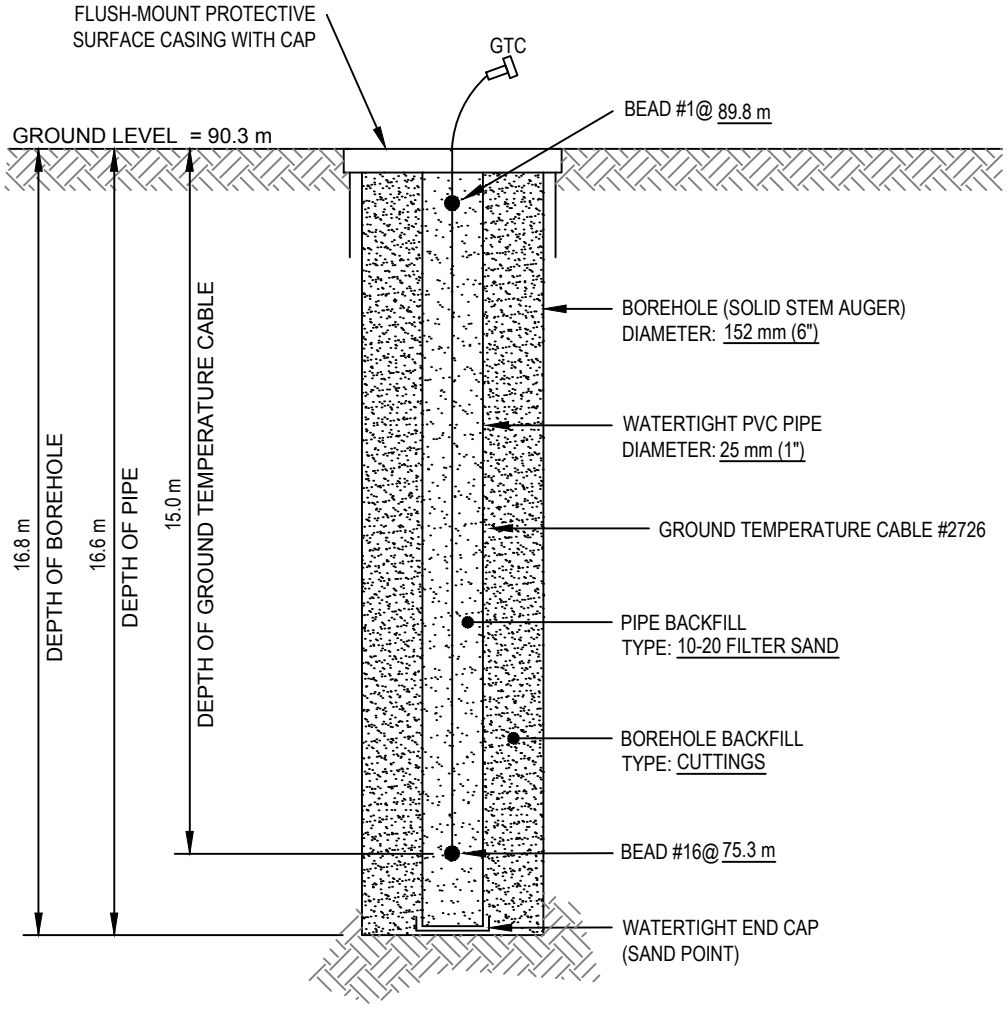
Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	#2727	Elevation (m)
10	Solid Stem Auger	- wood debris and chunks - gravel to 65 mm diameter - some gravel, rounded gravel to 40 mm diameter		0.3				79
11				0.5				78
12								77
13		SILT - some sand, trace gravel and clay, damp, non plastic, grey, subrounded gravel to 50 mm diameter		0.8				76
14		- no visible gravel						75
15		CLAY - some silt, trace sand and gravel, damp, low plastic, grey						74
16		- no visible gravel		0.8				73
17								72
18		SILTSTONE - dry, light grey						
19		END OF BOREHOLE (18.3 metres) slough - 16.0 metres at completion water - 7.3 metres at completion GTC #2727 installed in 25 mm PVC pipe backfilled with 10/20 filter sand to 16.0 metres. Borehole backfilled with cuttings. Ground temperatures measured on March 18, 2021						71
20								70

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 18.3 m
Drilling Rig Type: Locust Tracked Air Rotary	Start Date: 2021 March 12
Logged By: TAB	Completion Date: 2021 March 12
Reviewed By: EG	Page 2 of 2

APPENDIX B

GROUND TEMPERATURE INSTRUMENTATION INSTALLATION DIAGRAMS

SITE:	CANYON CREEK BRIDGE	BOREHOLE NO.:	CCBH-05
LOCATION:	MVWR km 1009.3	CABLE SERIAL NO.:	2726
COORDINATES:	7 235 986.6 N	DRILLING DATE:	MARCH 13, 2021
	615 765.6 E	INSTALLATION DATE:	MARCH 13, 2021
GROUND ELEVATION:	90.3 m	LEAD LENGTH:	2.0 m
CABLE LENGTH:	15.0 m	1ST BEAD ELEVATION:	89.8 m
NUMBER OF BEADS:	16	HOLE DEPTH:	16.8 m



BEAD NO.	DEPTH BELOW OG (m)
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5
10	5.5
11	6.5
12	7.5
13	9.0
14	10.5
15	12.5
16	15.0

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

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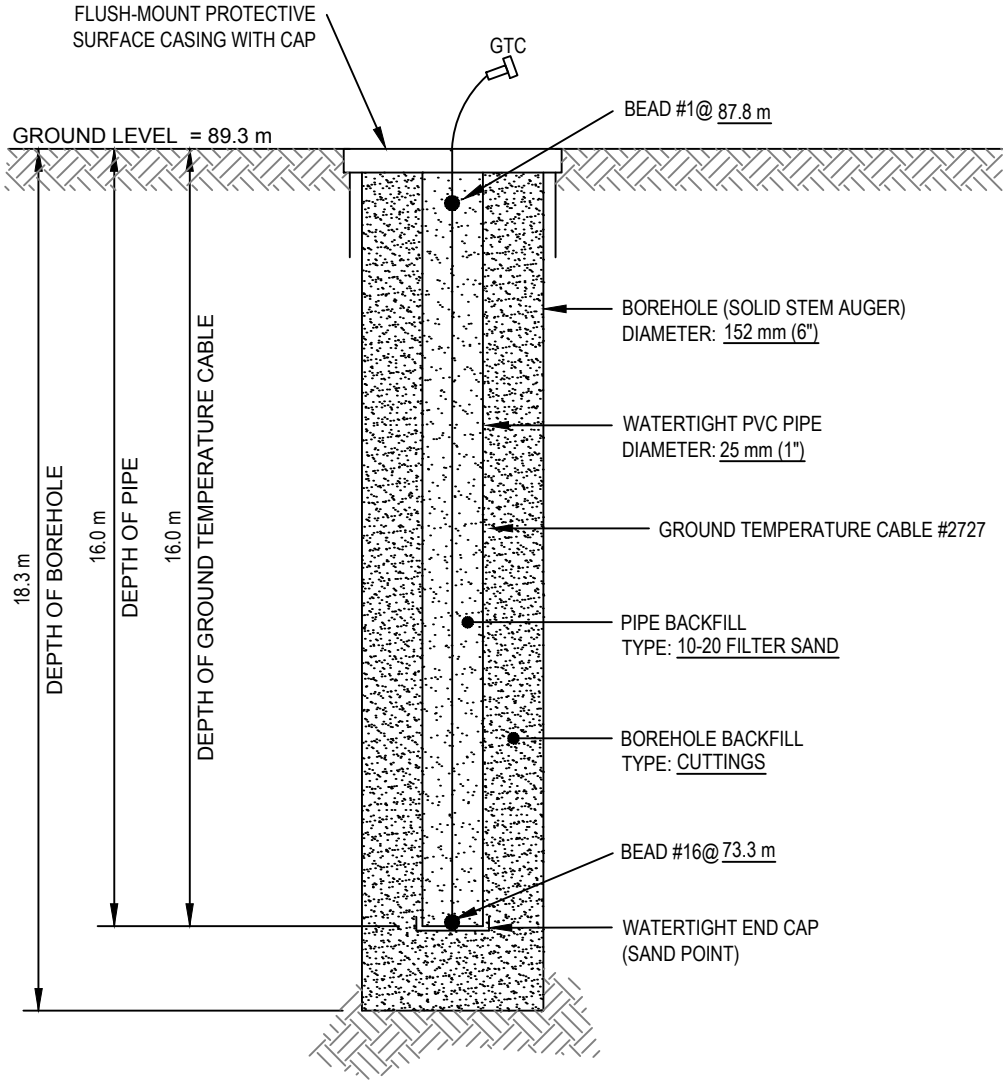
CANYON CREEK BRIDGE THERMAL
MVWR km 1009.3, NORTHWEST TERRITORIES

GTC #2726 INSTALLATION DIAGRAM (NORTH ABUTMENT)

PROJECT NO.	DWN	CKD	REV	
ENG.YARC03354-05.002	EL	TB	IFU	**CCBH-05**
OFFICE	DATE			
EDMONTON	JUNE 2021			

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SITE:	CANYON CREEK BRIDGE	BOREHOLE NO.:	CCBH-06
LOCATION:	MVWR km 1009.3	CABLE SERIAL NO.:	2727
COORDINATES:	7 235 930.1 N	DRILLING DATE:	MARCH 12, 2021
	615 843.0 E	INSTALLATION DATE:	MARCH 12, 2021
GROUND ELEVATION:	89.3 m	LEAD LENGTH:	2.0 m
CABLE LENGTH:	15.0 m	1ST BEAD ELEVATION:	87.8 m
NUMBER OF BEADS:	16	HOLE DEPTH:	18.3 m



BEAD NO.	DEPTH BELOW OG (m)
1	1.5
2	2.0
3	2.5
4	3.0
5	3.5
6	4.0
7	4.5
8	5.0
9	5.5
10	6.5
11	7.5
12	8.5
13	10.0
14	11.5
15	13.5
16	16.0

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

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CANYON CREEK BRIDGE THERMAL
MVWR km 1009.3, NORTHWEST TERRITORIES

GTC #2727 INSTALLATION DIAGRAM (SOUTH ABUTMENT)

PROJECT NO.	DWN	CKD	REV	
ENG.YARC03354-05.002	EL	TB	IFU	**CCBH-06**
OFFICE	DATE			
EDMONTON	JUNE 2021			

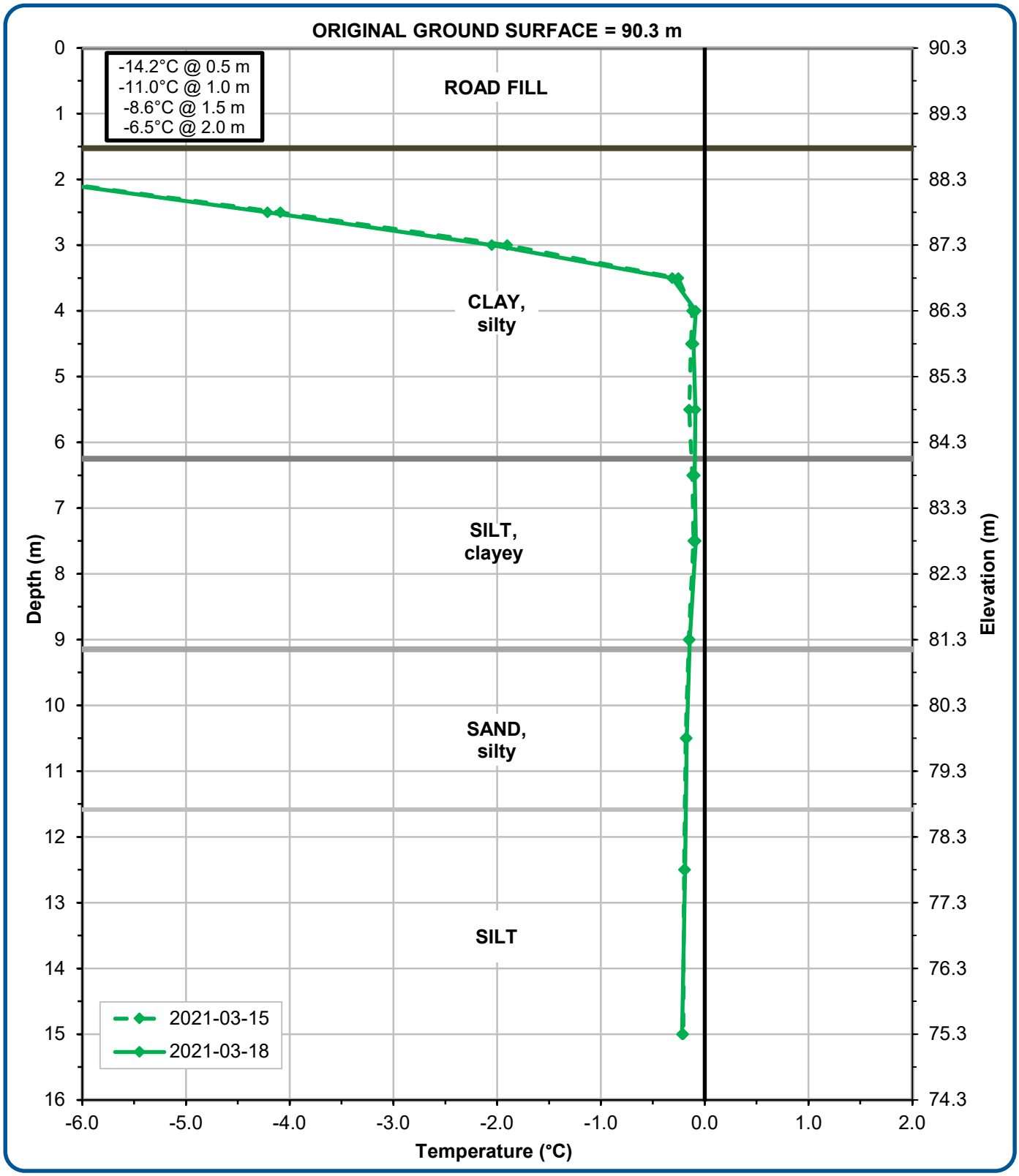
Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-05\ENG.YARC03354-05-CCBH-06_Canyon Creek.dwg [CCBH-06] June 23, 2021 - 12:28:46 pm (BY: LEE, ELVIN)

APPENDIX C

GROUND TEMPERATURE PROFILES

Canyon Creek Bridge (MVWR km 1009.3)

704-ENG.YARC03354-05.002 | North Abutment | March 2021



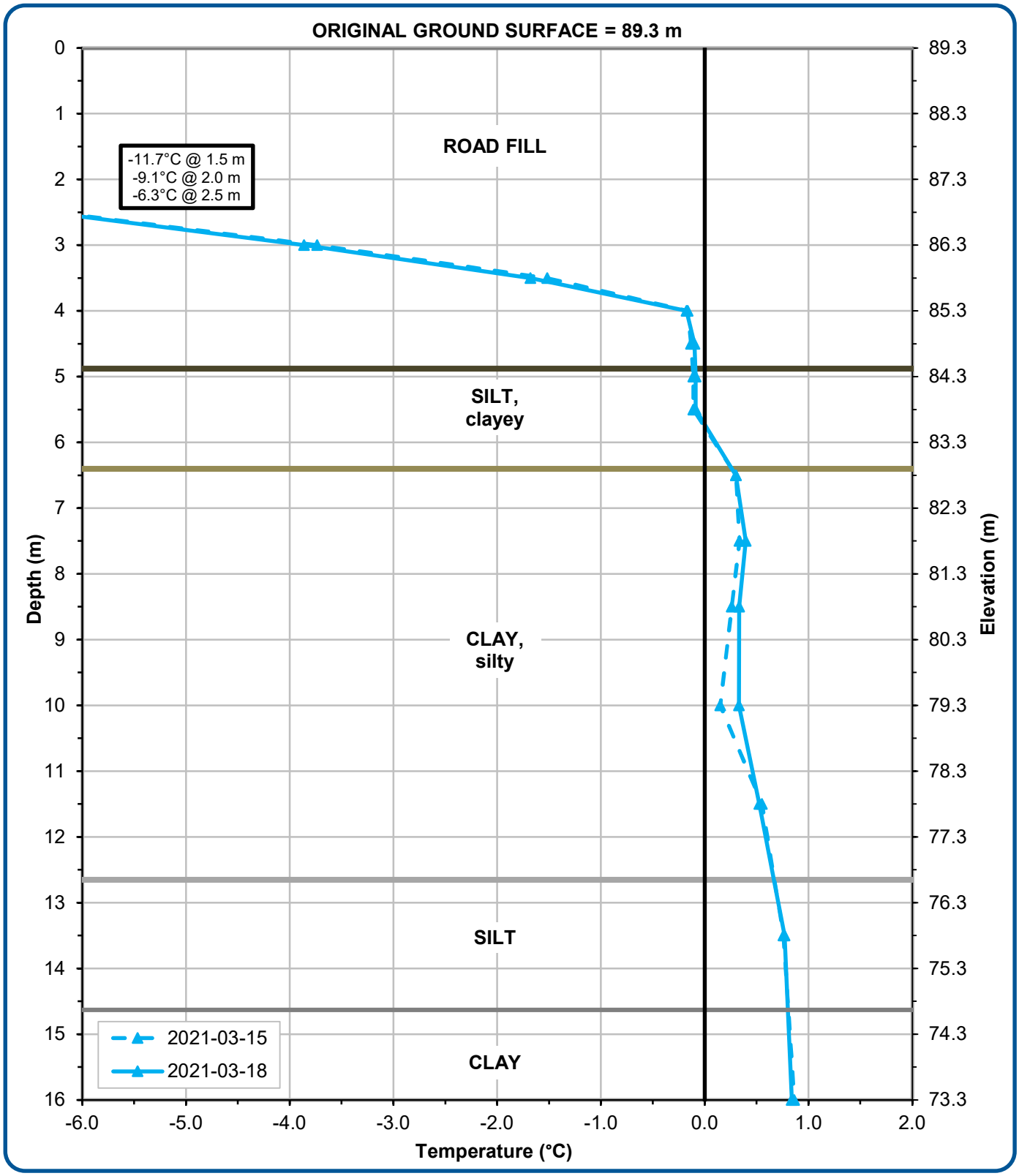
GTC Serial No. 2726
Date Installed: March 13, 2021

Borehole CCBH-05
Ground Temperature Profile

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Canyon Creek Bridge (MVWR km 1009.3)

704-ENG.YARC03354-05.002 | South Abutment | March 2021



GTC Serial No. 2727
Date Installed: March 12, 2021

Borehole CCBH-06
Ground Temperature Profile

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APPENDIX D

TETRA TECH'S LIMITATIONS ON USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

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TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

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

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards 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. TETRA TECH 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.

1.9 LOGS OF TESTHOLES

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.

1.10 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 historical environment. TETRA TECH 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 exploration and review may be necessary.

1.11 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.

1.12 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.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact 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, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and 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.

1.15 DRAINAGE SYSTEMS

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. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters 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 used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH 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.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

NRCan-02: Permafrost Conditions in the Project Area - Geotechnical and Thermal Conditions

Reviewer Preamble:

The Proponent has utilized the extensive data that are available (including Geological Survey of Canada reports) for the Mackenzie Valley in its description of baseline permafrost conditions and assessment of environmental assessment (Vol 3 sec. 14, App 14A). The Proponent has indicated that it has drilled a limited number of boreholes within the project region that appear to be located near infrastructure already constructed or under construction (e.g., Prohibition Creek Access Road) rather than the infrastructure considered in this assessment. There is also limited thermal information (1 year) available from these new boreholes and not yet adequate to describe baseline conditions. NRCan realizes that more site-specific information is normally acquired as design advances. However, any additional information the Proponent has collected since the investigations conducted by Tetra Tech in 2020 would facilitate understanding of the baseline permafrost conditions in the project area.

Reviewer Request:

NRCan requests from the Proponent:

1. Please clarify if any additional geotechnical investigations (including borehole drilling) have been conducted in the project area since the investigations conducted by Tetra Tech in 2020 and provide details of any additional investigations conducted (e.g. geotechnical, thermal data).

2. Provide any additional information regarding ground temperatures collected since 2020 from the boreholes instrumented by Tetra Tech during the 2020 investigations.

Response from the Government of the Northwest Territories:

1. Additional geotechnical investigations, including borehole drilling, were completed for the Prohibition Creek Access Road (PCAR) as well as the Canyon Creek Bridge (Mackenzie Valley Winter Road [MVWR] kilometre [km] 1009.3) in March 2021. These are in the Regional Assessment Area for terrain, soils and permafrost. Details on each of these geotechnical investigation programs are provided below:

    - Attachment 6-1, 2021 PCAR Culvert Crossings Geotechnical Investigation (Tetra Tech 2021a):

        - A total of 10 boreholes were completed for five proposed culvert crossings along the PCAR alignment between MVWR km 997.0 and km 1007.2. Single-bead ground temperature instrumentation was installed in a total of five boreholes (one at each proposed culvert crossing) to depths up to 9.4 metres (m) below ground surface.

    - Attachment 6-2, 2021 Canyon Creek Bridge Thermal Investigation (Tetra Tech 2021b):

        - A total of two boreholes, one within each bridge abutment, were completed for the Canyon Creek Bridge (MVWR km 1009.3). Multi-bead ground temperature instrumentation was installed in both boreholes to depths of 15.0 m and 16.0 m below road surface.

2. In 2020, geotechnical investigation programs were completed for the PCAR (Tetra Tech 2021c) and the Mount Gaudet Access Road (MGAR) (Tetra Tech, 2021d); these are provided as Attachment 6-3 and 6-4. Multi-bead ground temperature instrumentation were installed in five boreholes along the PCAR in August 2020 as well as five boreholes along the MGAR in July 2020. Since installation, ground temperature data has been collected from each location as follows:

    - PCAR Ground Temperatures: October 2020, March 2021, July 2021

    - MGAR Ground Temperatures: September 2020, November 2020

References

Tetra Tech, 2021a. *Culvert Crossings C3, C9, C24, C29, and C33 Geotechnical Recommendations Report, Prohibition Creek Access Road, Northwest Territories.* Issued for Use Report prepared for K'alo-Stantec Limited by Tetra Tech Canada Inc. October 26, 2021. Tetra Tech File: 704-ENG.YARC03354-05.001

Tetra Tech, 2021b. *Canyon Creek Bridge Thermal Investigation Data Report, MVWR km 1009.3, Northwest Territories.* Issued for Use Report prepared for K'alo-Stantec Limited by Tetra Tech Canada Inc. June 24, 2021. Tetra Tech File: 704-ENG.YARC03354-05.002

Tetra Tech, 2021c. *Prohibition Creek Access Road Thermal Assessment Report, MVWR km 995.3 to km 1009.3, Northwest Territories.* Issued for Use Report prepared for K'alo-Stantec Limited by Tetra Tech Canada Inc. June 10, 2021. Tetra Tech File: 704-ENG.YARC03354-02

Tetra Tech, 2021d. *Mount Gaudet Access Road Thermal Assessment Report, MVWR km 687 to km 708, Northwest Territories.* Issued for Use Report prepared for K'alo-Stantec Limited by Tetra Tech Canada Inc. June 18, 2021. Tetra Tech File: 704-ENG.YARC03354-02

Geotechnical Recommendations Report

Culvert Crossings C3, C9, C24, C29, and C33
Prohibition Creek Access Road, Northwest Territories



PRESENTED TO
K'alo-Stantec Limited

OCTOBER 26, 2021
ISSUED FOR USE
FILE: 704-ENG.YARC03354-05.001

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EXECUTIVE SUMMARY

The Government of the Northwest Territories (GNWT) is currently advancing a project to replace the Mackenzie Valley Winter Road (MVWR) by extending the Mackenzie Valley Highway (MVH) from Wrigley to Norman Wells with an all-season, two-lane, gravel highway. One section of the existing MVWR alignment to be upgraded to an all-season road is the 14 km-long Prohibition Creek Access Road (PCAR), which starts from Prohibition Creek Bridge and extends northwest to the end of the Canyon Creek All-Season Access Road. Five bridge-sized culverts (i.e., culverts with an equivalent diameter of 1,500 mm or greater) were initially anticipated along the proposed PCAR alignment: Crossings C3, C9, C24, C29, and C33. Hydrotechnical designs for each proposed culvert crossing were recently completed and it was determined that only Crossing C9 required a bridge-sized culvert and Crossing C33 was reconfigured as twin, side-by-side culverts. The other proposed bridge-sized culvert crossings were either reduced in size or replaced with multiple smaller, separate culverts.

Tetra Tech Canada Inc. (Tetra Tech) completed geotechnical investigations at each of the proposed culvert crossings between March 7 to 11, 2021. Ten boreholes (two at each crossing) were drilled as part of the program using a Locust Geotechnical air rotary and auger tracked drill rig. Geotechnical logging, permafrost classification, sampling, field testing, and ground temperature instrumentation installation was conducted onsite by Tetra Tech. Recovered soil and sedimentary rock samples were tested at Tetra Tech's materials laboratories in Yellowknife and Calgary to determine relevant geotechnical and geochemical engineering properties.

Subsurface conditions in all 10 boreholes generally consist of three stratigraphic layers: surface organics, fine-grained overburden soils, and sedimentary bedrock. Organics at the ground surface consist of grasses, peat, rootlets, or topsoil. Overburden soils comprise primarily silty clays and sandy silts with occasional sand and gravelly layers. Sedimentary bedrock consists of a fissile, non-carbonate, mud shale. Visible ground ice was observed in 8 of the 10 boreholes drilled below the expected depth of the active layer, indicating the presence of permafrost. Notably, high moisture contents and ground ice were encountered in upper fine-grained layers at Crossings C3, C9, and C29, indicative of excess ground ice conditions. Thaw settlement is likely to occur within these layers during the construction of the PCAR. Ground temperature data collected from the instrumented boreholes provided preliminary thermal conditions at each proposed culvert crossing. Further ground temperature readings will better define the seasonal active layer depth and permafrost conditions underlying each proposed culvert crossing.

Seismic classification for the PCAR site is recommended to be *Site Class C (Very Dense Soil and Soft Rock)*, based on using the average properties in the top 30 m of standard penetration resistance. The proposed culvert crossings are assumed to be classified as *Buried Structures* which requires designs to resist inertial forces associated with seismic events having a 2% chance of being exceeded in 50 years (2,475 Year Return Period). Based on seismic hazard values and classification, a full seismic analysis is not required for the proposed PCAR culvert crossings.

Generally, the foundation soils at each proposed crossing can provide adequate support for the proposed culverts; however, excavation beneath each culvert footprint is recommended to replace frozen organics and fine-grained soil layers with thaw-stable Engineered Backfill. This will extend the backfill below the estimated active layer depth and will found the culverts on competent overburden layers. Foundation excavations should extend horizontally at least three-times the culvert diameter (3D), centered on the culvert, to provide structural support for the culvert and limit the influence from the surrounding subgrade. The ultimate depth and width of each foundation excavation should be determined at the time of construction by a Geotechnical Engineer based on the subsurface conditions observed in the field. Foundation grades are recommended to be covered with a woven geotextile to provide confinement, separation, and reinforcement for the Engineered Backfill within the frozen subgrade. Vertical cutoff walls, comprising of Bentonite-Augmented Backfill, are recommended to be installed at the inlets and outlets of each culvert to seal, intercept, and prevent seepage from undercutting the structure.

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ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
CHBDC	Canadian Highway Bridge Design Code, CSA S6:19 (2019)
CSA	Canadian Standards Association
GNWT	Government of the Northwest Territories, Department of Infrastructure
GPS	Global Positioning System
K'alo-Stantec	K'alo-Stantec Limited
km	Kilometres
m	Metres
mm	Millimetres
MUSC	Modified Unified Soil Classification
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NAD83	North American Datum of 1983
NCSPA	National Corrugated Steel Pipe Association
NT	Northwest Territories
Ollerhead	Ollerhead & Associates Ltd.
PCAR	Prohibition Creek Access Road
PGA	Peak Ground Acceleration
SBT	Single-Bead Thermistor
SMSD	Sahtu Midnight Sun Drilling Inc.
SPT	Standard Penetration Testing
TAC	Transportation Association of Canada
Tetra Tech	Tetra Tech Canada Inc.
UTM	Universal Transverse Mercator

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of K'alo-Stantec Limited, the Government of the Northwest Territories, and their agents. Tetra Tech Canada Inc. does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than K'alo-Stantec Limited and the Government of the Northwest Territories, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached in Appendix I.

1.0 INTRODUCTION

1.1 General

Tetra Tech Canada Inc. (Tetra Tech) was retained by K'alo-Stantec Limited (K'alo-Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to undertake geotechnical investigations for five anticipated bridge-sized culvert crossings along the proposed Prohibition Creek Access Road (PCAR), Northwest Territories (NT). The PCAR is a 14 km-long section of the Mackenzie Valley Winter Road (MVWR) that is expected to be upgraded to an all-season road as part of the proposed extension to the Mackenzie Valley Highway (MVH). Authorization to proceed with this work was granted by Warren McLeod of K'alo-Stantec via a signed subconsultant agreement dated March 5, 2021.

The objective of the geotechnical investigation program was to characterize the geotechnical and permafrost subsurface conditions at five proposed PCAR culvert crossings: C3, C9, C24, C29, and C33. Results from these investigations were then used by Tetra Tech to prepare recommendations for the future design of each culvert crossing. This report presents data collected during the geotechnical investigation including borehole logs, ground temperature data, as well as geotechnical, geochemical, and environmental laboratory test results. It also includes geotechnical, permafrost, and seismic recommendations for the design of each culvert crossing.

Previously in 2020, Tetra Tech completed a preliminary hydrotechnical assessment of the PCAR which identified each crossing location and provided preliminary culvert design flows and diameters (Tetra Tech 2021a). In 2021, Tetra Tech completed hydrotechnical designs for each crossing along PCAR and redesigned some of the culvert configurations and diameters. This report should be read in conjunction with the hydrotechnical design work from that program which is presented in a separate report titled *Mackenzie Valley Highway, Prohibition Creek Access Road Hydrotechnical Design, Northwest Territories* (Tetra Tech 2021b). Additionally, Tetra Tech has previously provided other relevant technical services for the PCAR including a geotechnical and geophysical evaluation of the road alignment (Tetra Tech 2020a) as well as a thermal assessment (Tetra Tech 2020b).

1.2 Project Description

The MVWR extends from Wrigley (MVWR km 690) to Fort Good Hope (MVWR km 1173), with supplementary access roads connecting to Déljne (106 km) and Colville Lake (165 km). The winter road is constructed and maintained by the GNWT on an annual basis and operates from late December to late March. The GNWT is currently advancing a project to replace the MVWR by extending the MVH (NT Highway 1) with an all-season, two-lane, gravel highway from Wrigley to Norman Wells.

One section of the existing MVWR alignment to be upgraded to an all-season road is the 14 km-long PCAR, located between Tulita (MVWR km 938) and Norman Wells (MVWR km 1026). It starts from Prohibition Creek Bridge (MVWR km 995.3) and extends northwest to the end of the Canyon Creek All-Season Access Road near the Canyon Creek Bridge (MVWR km 1009.3). Initially, five bridge-sized culvert crossings (i.e., culverts with an equivalent diameter of 1,500 mm or greater) were anticipated along the proposed PCAR alignment: Crossings C3, C9, C24, C29, and C33 (Tetra Tech 2021a). After further hydrotechnical analysis and modelling, Tetra Tech (2021b) determined that only Crossing C9 (MVWR km 999.0) required a bridge-sized culvert while Crossing C33 (MVWR km 1007.2) was better configured as twin, side-by-side culverts.

A plan view showing the crossing locations is presented on Figure 1. The coordinate system referenced for the project is the Universal Transverse Mercator (UTM) Zone 9 using the following datums:

- Horizontal: North American Datum of 1983 (NAD83) [CSRS] Epoch 2010.0
- Vertical: CGVD2013 (CGG2013a)

The geotechnical investigation was completed between March 7 to 11, 2021. Geotechnical logging, permafrost classification, sampling, field testing, and ground temperature instrumentation installation was conducted onsite by Thomas Bradshaw, P.Eng. of Tetra Tech. At the request of the GNWT, soil sampling, field testing, and laboratory testing was completed for one borehole at each proposed culvert crossing. Ground temperature instrumentation was also installed in one borehole at each proposed culvert crossing.

Drilling was completed by Sahtu Midnight Sun Drilling Inc. (SMSD) from Norman Wells, NT. Snow clearing, site access, and traffic control support were provided by HRN Contracting Ltd. from Norman Wells, NT. Survey support for the project was provided by Ollerhead & Associates Ltd. (Ollerhead) from Yellowknife, NT. Onsite environmental and wildlife monitoring was provided throughout the project by the Norman Wells Renewable Resource Council. All of these support services were subcontracted by Tetra Tech for the project.

1.3 Design Basis

Five bridge-sized culvert crossings were originally identified along the PCAR based on a hydrotechnical assessment conducted by Tetra Tech in 2020 (Tetra Tech 2021a). Two of the proposed crossings, C9 and C33, have defined creeks that cross the PCAR alignment from northeast to southwest, draining towards the Mackenzie River. Crossings C3, C24, and C29 were identified as larger watershed areas that span the PCAR alignment and have no defined flow paths (i.e., drainage swales). Hydrotechnical designs for each proposed culvert crossing were recently completed by Tetra Tech (2021b) and it was determined that only Crossing C9 required a bridge-sized culvert while Crossing C33 was reconfigured as twin, side-by-side culverts. The other proposed bridge-sized culvert crossings were either reduced in size or replaced with multiple smaller, separate culverts.

The proposed crossing locations and design culvert diameters are summarized in Table 1-1.

Table 1-1: Culvert Crossings Design Basis

Culvert Crossing	Mackenzie Valley Winter Road Milepost (km)	Crossing Coordinates (m, UTM Zone 9: NAD83 [CSRS] Epoch 2010)		Watershed Area (km^2)	Design Culvert Diameter (mm)
		Northing (m)	Easting (m)		
C3	997.0	7,229,174	625,245	1.2	1,200
C9	999.0	7,230,321	623,648	8.8	2,280
C24 [a]	1004.5	7,233,370	619,458	4.4	1,200
	1004.6	7,233,417	619,389		1,200
	1004.6	7,233,433	619,365		1,200
C29 [b]	1006.2	7,234,226	618,216	2.7	1,000
	1006.3	7,234,278	618,146		1,000
	1006.4	7,234,313	618,097		1,200
C33 [c]	1007.2	7,234,787	617,437	2.7	1,200 (x 2)

[a] *Culvert Crossing C24 reconfigured to three smaller, separate culverts during hydrotechnical design (Tetra Tech 2021b).*
[b] *Culvert Crossing C29 reconfigured to three smaller, separate culverts during hydrotechnical design (Tetra Tech 2021b).*
[c] *Culvert Crossing C33 reconfigured to twin, side-by-side culverts during hydrotechnical design (Tetra Tech 2021b).*

The recommendations provided in this report are based on the Canadian Standards Association (CSA) *S6:19 Canadian Highway Bridge Design Code* (CSA 2019a) and assume that the proposed culverts are classified as *Round Soil-Metal Structures with Shallow Corrugations*, as defined in Section 7 (Buried Structures). In the absence of owner input, the geotechnical consequence classification has been assessed as *Typical Consequence*, per Section 6.5.1 of the Canadian Highway Bridge Design Code (CHBDC). The degree of site and prediction model understanding for the PCAR culvert crossings has been assessed as *Typical Understanding* as per Section 6.5.3 of the CHBDC.

2.0 SITE DESCRIPTION

2.1 Surface Conditions

Surface conditions along the PCAR alignment are characterized as gently rolling terrain with a consistent northeast-southwest slope towards the Mackenzie River. Ground cover along the MVWR alignment is predominantly muskeg, often wet and marshy in low-lying areas, that is vegetated with grass, peat, shrubs, and small trees. The trees along the alignment, which are 10 m to 20 m from the edge of the winter road surface, are predominantly Black Spruce (*picea mariana*) with heights upwards of 10 m and trunk diameters of approximately 0.1 m. The road alignment runs in a straight line from southeast to northwest, perpendicular to the nearby Franklin Mountains.

Surficial materials along the PCAR alignment generally consist of glacial till veneer and blanket deposits, based on surficial mapping for areas southeast of Norman Wells (Duk-Rodkin 2002). The till deposits typically consist of unsorted silts and clays with sands and coarser clasts, ranging from 2 m to 6 m thick. The PCAR alignment also parallels along the boundary of an area mapped as a glaciolacustrine deposit between MVWR km 1004 to km 1005. The alignment is underlain by sedimentary rocks, including mud shale or siltstone, both of the Imperial Formation (Fallas and MacNaughton 2013).

2.2 Subsurface Conditions

Subsurface conditions along the PCAR alignment were established from Tetra Tech's 2020 geotechnical and geophysical investigations (Tetra Tech 2020a). A total of 25 boreholes were drilled along the road alignment, spaced approximately 500 m apart, and overland geophysical surveys were conducted. Drilling depths ranged from 5.5 m to 8.1 m and both unfrozen and frozen soils, including visible ground ice, were encountered at depth. The soils recovered were predominantly glacial till consisting of clays and silts with sand and gravel components, consistent with the heterogeneous characteristics of glacial deposits. Groundwater was encountered in one borehole near MVWR km 1004 at a depth of 2.5 m; however, this was the only instance where groundwater was identified along the PCAR alignment.

2.3 Climate

Environment Canada operates a meteorological station at the nearby town of Norman Wells with public records available from 1944 to the present. The mean annual air temperature for the period of record is -5.6°C, which has been gradually increasing from the start of data collection. The temperature warming trend was analyzed using linear interpolation of the average annual temperature data between 1944 and 2019. The average rate of annual temperature increase has been 0.03°C/year over the period of record, with the biggest increase occurring in the autumn and winter months of October to April. Over the past 30 years, the mean annual air temperature has averaged -4.8°C.

Over the period of record, the freezing index has decreased by approximately 12.8 freezing degree-days/year, while the thawing index has increased by about 2.6 thawing degree-days/year. Using the published data for Norman Wells from Environment Canada, it is determined that Norman Wells had an average freezing index of 3,542 freezing degree-days and an average thawing index of 1,816 thawing degree-days over the past 30 years (1990 to 2019). The freezing index has decreased by about 31 freezing degree-days/year and the thawing index has increased by about 4 thawing degree-days/year over the past 30 years; however, there is a lot of variability in the climate data available.

The mean annual total precipitation over the period of record (1964 to 2019) is estimated to be 313 mm/year; however, analysis of the precipitation data does not indicate a clear trend.

2.4 Permafrost Conditions

The PCAR is located within a zone of extensive, discontinuous permafrost, meaning permafrost covers 50% to 90% of the landscape (NRC 2009). Permafrost is typically present in poorly drained muskeg terrain and heavily treed areas. Layers of unfrozen ground surrounded by permafrost (taliks) can be expected beneath the streambed of active watercourses, such as the defined creeks at Crossings C9 and C33.

During Tetra Tech's 2020 geotechnical investigation of the PCAR alignment, seasonally frozen (active) layers were observed in all 25 boreholes drilled (Tetra Tech 2020a). Permafrost conditions were encountered below the estimated active layer in 23 of 25 boreholes. Generally, ground ice contents were higher closer to the surface and decreased with depth.

Five existing ground temperature cables are currently installed and are being monitored along the PCAR alignment, including boreholes near MVWR km 996.0 (Borehole BH-25), km 999.2 (Borehole BH-19), km 1001.8 (BH-14), km 1005.0 (Borehole BH-08), and km 1008.2 (Borehole BH-02). Ground temperatures measured to date have generally decreased (become colder) with depth in all boreholes, except near MVWR km 1001.8 where ground temperatures were the warmest. The depth of the active layer generally decreased in the boreholes advancing from south to north along the PCAR alignment, ranging from 0.6 m to 1.5 m thick. Ground temperatures were typically marginally frozen below the active layer to depth, except for an unfrozen zone between depths of 2.2 m to 5.6 m below ground in Borehole BH-14. Thermal conditions along the PCAR alignment are detailed in Tetra Tech's *Prohibition Creek Access Road Thermal Assessment Report* (Tetra Tech 2020b).

3.0 GEOTECHNICAL INVESTIGATION

3.1 Borehole Locations

Ten boreholes were drilled between March 7 to 11, 2021 as part of the PCAR Culvert Crossings geotechnical investigation, two at each proposed crossing location. Boreholes at crossings with defined watercourses (i.e., Crossings C9 and C33) were located adjacent to the creeks to avoid disturbing the streambed. As-drilled borehole coordinates and elevations are shown in the Tables section and summarized in Table 3-1.

Table 3-1: Borehole Coordinates and Elevations

Borehole Number	Culvert Crossing	Mackenzie Valley Winter Road Milepost (km)	Coordinates (m, UTM Zone 9: NAD83 [CSRS] Epoch 2010)		Ground Elevation (m)	Depth Drilled (m)	Completion Elevation (m)
			Northing	Easting			
PCARBH-C3-1	C3 (North)	997.0	7,229,180.2	625,246.7	90.2	9.1	81.1
PCARBH-C3-2	C3 (South)		7,229,169.2	625,242.1	89.9	9.1	80.8
PCARBH-C9-1	C9 (North)	999.0	7,230,328.9	623,648.5	85.5	6.6	78.9
PCARBH-C9-2	C9 (South)		7,230,315.9	623,637.6	85.4	8.5	76.9
PCARBH-C24-1	C24 (North)	1004.6	7,233,391.3	619,392.3	78.3	9.1	69.2
PCARBH-C24-2	C24 (South)		7,233,373.1	619,395.5	78.1	9.1	69.0
PCARBH-C29-1	C29 (North)	1006.2	7,234,231.4	618,218.9	75.2	6.4	68.8
PCARBH-C29-2	C29 (South)		7,234,215.0	618,218.1	74.5	9.1	65.4
PCARBH-C33-1	C33 (North)	1007.2	7,234,794.9	617,439.0	78.4	9.8	68.6
PCARBH-C33-2	C33 (South)		7,234,778.8	617,432.9	77.4	9.1	68.3

Tetra Tech flagged the borehole locations in the field using a handheld Garmin GPSMAP 64S global positioning system (GPS) receiver prior to drilling. Following the completion of drilling, the as-drilled borehole locations were surveyed by Ollerhead on March 15, 2021. The borehole coordinates and elevations are also presented on the borehole logs in Appendix A.

3.2 Drilling Methodology

The geotechnical investigation program was completed using a Locust Geotechnical air rotary and auger tracked drill rig (Photo A), owned and operated by SMSD of Norman Wells, NT. The drill rig was equipped for solid stem and hollow stem augering as well as Standard Penetration Testing (SPTs). Boreholes were typically drilled with 152 mm (6 inch) diameter solid stem augers in 1.5 m (5 feet) runs. SPTs were performed at 1.5 m (5 feet) intervals in one borehole at each proposed culvert crossing, as requested by the GNWT.



Photo A: Locust Geotechnical Drill Rig used for geotechnical investigations.

3.3 Geotechnical Logging

All recovered soils and sedimentary rock were logged and photographed at the drilling locations, allowing for accurate classification and sampling of the subsurface materials and ground ice encountered.

Soils were classified according to the Modified Unified Soil Classification (MUSC) system and Tetra Tech's Work Method *WM4400 – Geotechnical Soil Classification*. The frozen state of the soils was described according to National Research Council Canada's Ground Ice Classification system and Tetra Tech's Work Method *WM4102 – Logging of Perennially Frozen Soils and Ground Ice for Engineering Purposes*. Soil logging consisted of identifying the following parameters:

- Soil Composition;
- Particle Size;
- Angularity/Shape;
- Moisture;
- Consistency;
- Plasticity;
- Colour;
- Odour;
- Frozen/Unfrozen State; and
- Ground Ice Description.

Sedimentary rock, where encountered, was logged for geologic description, weathering, rock strength, and discontinuity spacing (if possible). Borehole logs and a summary of the classification systems are included in Appendix A. Select photographs of recovered samples are included in the Photographs section of this report.

3.4 Field Sampling and Testing

Field sampling and testing was only undertaken in one borehole at each proposed culvert crossing site (i.e., five boreholes in total) at the request of the GNWT. The sampling and testing conducted at these select boreholes included SPTs and Auger Sampling, as detailed in the following subsections.

3.4.1 Standard Penetration Testing

SPTs were undertaken in one borehole at each proposed culvert crossing. The testing consisted of driving a conventional 50 mm split spoon sampler into the subsurface a distance of 450 mm (18 inches) and recording the number of blows needed to advance the last 300 mm to determine the penetration resistance SPT N-value. SPTs were also used to obtain soil samples. An initial disturbance penetration of 150 mm (6 inches) was made to set the sampler and an additional fourth 150 mm (6 inches) increment of sampler penetration was occasionally driven to retrieve further soil sample.

SPTs were performed following the American Society for Testing and Materials (ASTM) D1586 and Tetra Tech's Work Method *WM3405 – Standard Penetration Testing*. A 63.5 kg (140 lbs.) automated trip hammer, manufactured by MARL Technologies, with a drop height of 760 mm (30 inches), was used to perform each hammer blow. AW rods with a 41 mm (1-¾ inches) outside diameter were used for all SPTs conducted.

Testing was stopped (i.e., refusal) when any of the following conditions were met:

- 50 hammer blows applied during any one of the three 150 mm increments;
- 100 cumulative hammer blows applied in three 150 mm increments; or
- No observed advance of sampler after 10 successive hammer blows.

It is important to note that SPT results vary significantly in frozen ground conditions due to the increased strength of frozen materials and SPT N-values in frozen soils are not a direct correlation to the soil's consistency or strength. Gravel and cobble particles also raise SPT N-values, if encountered, and the higher strength is not necessarily representative of the stratigraphic layer. SPT N-values are presented on the borehole logs included in Appendix A. Select photographs of split-spoon samples are included in the Photographs section.

3.4.2 Auger Sampling

Sampling was also undertaken while auger drilling in one borehole at each proposed culvert crossing. Representative soil and rock samples were taken in 0.3 m (1 foot) sections from each 1.5 m (5 feet) auger run along the entire depth of select boreholes. Frozen samples recovered on the auger flights were generally thermally disturbed due to auger drilling. The disturbed bulk samples were placed in plastic bags, double-bagged for moisture preservation, and transported to Tetra Tech's materials laboratory in Yellowknife for geotechnical laboratory testing. Select photographs of auger samples are included in the Photographs section.

3.5 Ground Temperature Instrumentation

Ground temperature instrumentation was installed in five boreholes, one at each proposed culvert crossing. Multiple Single-Bead Thermistors (SBTs) were taped together at measured intervals to maximize the range of readings possible downhole. Sections of 25 mm (1 inch) threaded PVC pipe were placed down each borehole and the SBTs were installed down the conduit. The PVC conduit pipe was backfilled with *Target Filter Sand (10-20)* while the remainder of the borehole (i.e., outside of the PVC) was backfilled with drill cuttings. Each SBT was tested after installation and a set of ground temperature readings were taken after the geotechnical investigation program on March 18, 2020.

SBT installation diagrams showing the thermistor bead depths and temperature calibration corrections for each installation are presented in Appendix B. Table 3-2 summarizes the ground temperature instrumentation installed at each proposed PCAR culvert crossing.

Table 3-2: Ground Temperature Instrumentation Installed

Borehole Number	Culvert Crossing	Number of SBTs Installed	SBT Serial Numbers	Installation Depths* (m)	Date Installed
PCARBH-C3-1	C3 (North)	4	1B, 17 1A, 492	1.3, 2.3, 5.3, 8.3	March 7, 2021
PCARBH-C9-2	C9 (South)	4	34, 35, 1C, 3	0.6, 2.1, 5.1, 8.1	March 8, 2021
PCARBH-C24-1	C24 (North)	4	36, 37, 1133, 1134	0.9, 1.9, 4.9, 7.9	March 9, 2021
PCARBH-C29-2	C29 (South)	4	38, 39, 1140, 1141	1.2, 2.7, 5.2, 7.7	March 10, 2021
PCARBH-C33-1	C33 (North)	4	40, 1143, 1135, 1128	1.6, 4.2, 6.8, 9.4	March 11, 2021

** Depth below ground of each SBT shown on Ground Temperature Profiles in Appendix C.*

The SBTs are manual read installations. A multimeter needs to be connected to the thermistor strings in the field to obtain readings. Resistances are recorded from the thermistor bead at the end of each string and are then converted to ground temperatures using an equation. Measured ground temperatures are illustrated on ground temperature profiles for each installation in Appendix C and are discussed further in Section 4.2.

3.6 Geotechnical Laboratory Testing

Geotechnical laboratory testing was completed at Tetra Tech's material laboratory in Yellowknife, NT. As requested by the GNWT, laboratory testing was only conducted on samples from one borehole at each proposed culvert crossing. The geotechnical laboratory testing program included the following:

- Moisture Contents;
- Particle Size Analyses (Sieves and Hydrometers); and
- Atterberg Limits.

A summary of all laboratory testing completed for the program is presented in the Tables section of this report and shown on the borehole logs in Appendix A. Detailed results for all geotechnical laboratory testing is available in Appendix D.

3.6.1 Moisture Contents

Moisture contents were determined on 50 soil samples from 5 select boreholes and were tested in accordance with ASTM D2216. Moisture content results are included on the geotechnical laboratory test results summary in the Tables section and are presented on the borehole logs in Appendix A.

3.6.2 Particle Size Analyses

Particle size analyses, including sieves and hydrometers, were performed on select samples to characterize the soil sampled throughout the geotechnical investigation. Seven hydrometers and three sieve analyses were completed in accordance with ASTM D7928 and ASTM C136, respectively. Particle size analyses test results are summarized in Table 3-3.

Table 3-3: Particle Size Analyses Test Results

Borehole Number	Sample Number	Sample Depth (m)		Moisture Content (%)	Particle Size Distribution (%)			
		From	To		Gravel	Sand	Silt	Clay
PCARBH-C3-1	A3	2.6	2.9	12.9	16	42	42	
	A7	5.2	5.5	11.7	0	8	66	26
PCARBH-C9-1	A14	2.4	2.7	17.7	25	26	35	14
	A18	5.3	5.6	11.2	0	7	73	20
PCARBH-C24-1	A23	2.3	2.6	21.2	4	33	49	14
	A25	4.3	4.6	11.8	8	32	45	15
PCARBH-C29-1	A36	2.3	2.6	12.7	3	64	33	
	A40	5.2	5.5	9.4	7	37	41	15
PCARBH-C33-1	A45	2.1	2.4	12.6	20	54	26	
	A49	5.5	5.8	9.6	28	47	19	6

3.6.3 Atterberg Limits

Atterberg Limits testing, performed in accordance with ASTM D4318, was completed on 10 soil samples. Test results are summarized in Table 3-4.

Table 3-4: Atterberg Limits Test Results

Borehole Number	Sample Number	Depth (m)		Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	MUSC Group Symbol
		From	To					
PCARBH-C3-1	A1	1.2	1.5	32.0	40	28	12	OL
	A5	3.7	4.0	13.4	32	18	14	CL-CI
PCARBH-C9-1	SS13	1.5	2.0	43.6	53	34	19	OH
	A16	4.1	4.4	17.6	36	21	15	CI
PCARBH-C24-1	SS22	1.5	2.0	17.6	Non-Plastic			SM
	SS24	3.0	3.7	17.2	28	17	11	CL-CI
PCARBH-C29-1	A34	1.1	1.4	58.9	62	44	18	OH
	A38	3.7	4.0	19.1	23	15	8	CL
PCARBH-C33-1	A47	4.0	4.3	15.7	Non-Plastic			ML
	A51	7.0	7.3	9.2	24	14	10	CL

3.7 Geochemical Laboratory Testing

Geochemical laboratory testing was completed at Tetra Tech's materials laboratories in Calgary, Alberta. Electrochemical and geochemical analyses were completed on five soil samples, one from each proposed culvert crossing, in accordance with American Association of State Highway and Transportation Officials (AASHTO) standards. A suite of testing was performed to quantify pH (per AASHTO T 289), Chlorides (per AASHTO T 291), Sulphates (per AASHTO T 290), Resistivity (per AASHTO T 288), and Organic Content (per AASHTO T 267). Geochemical test results are summarized in Table 3-5.

Table 3-5: Geochemical Analyses Test Results

Borehole Number	Sample Number	Depth (m)		pH	Chloride (ppm)	Sulphate (ppm)	Resistivity (Ohm·cm)	Organic Content (%)
		From	To					
PCARBH-C3-1	SS4	3.0	3.5	8.2	110	45	3,575	4.2
PCARBH-C9-1	SS15	3.0	3.5	8.1	32	64	2,533	4.3
PCARBH-C24-1	A23	2.3	2.6	8.1	35	95	3,748	2.4
PCARBH-C29-1	SS37	2.7	3.0	8.2	45	88	10,000	2.3
PCARBH-C33-1	SS44	1.5	2.0	8.2	44	33	8,667	2.3

A summary of all laboratory testing completed for the program is included in the Tables section of this report and shown on the borehole logs in Appendix A. Detailed laboratory results for all geochemical testing are available in Appendix E.

3.8 Environmental Soil Analysis

Environmental soil analysis was undertaken on one auger sample collected from Crossing C9, after hydrocarbon odours were detected in Borehole PCARBH-C9-2 during the geotechnical investigation at a depth of 7.3 m. The sample was sub-sampled and sent for environmental soil analysis to ALS Canada Ltd. in Yellowknife, NT. Details on the environmental sampling and laboratory testing are documented in a technical memo provided in Appendix F.

4.0 CROSSING SUBSURFACE CONDITIONS

Subsurface conditions for each proposed culvert crossing location are summarized herein based on results from the geotechnical investigation. It should be noted that drilling at crossings with defined creeks (Crossings C9 and C33) was conducted adjacent to and not directly within the channel to avoid watercourse disturbance; therefore, the subsurface conditions at these locations are not entirely representative of what may be encountered during construction.

The locations of each crossing and borehole drilled are shown on Figures 2 and 3. Interpreted subsurface conditions for the proposed culvert crossings are outlined on Figures 4 to 8. Geotechnical data is shown on the borehole logs in Appendix A.

4.1 Stratigraphy

Ground conditions in all 10 boreholes generally consist of three material layers: surface organics, fine-grained overburden soils, and sedimentary bedrock. The organics consist of grasses, peat, rootlets, or topsoil at the ground surface. Overburden soils comprise primarily silty clays and sandy silts with occasional sand and gravelly layers. Sedimentary bedrock was encountered in 8 out of 10 boreholes drilled and consists of mud shale, a fissile, non-carbonate, fine-grained sedimentary rock.

4.1.1 Crossing C3

Two geotechnical boreholes were drilled at the proposed C3 culvert crossing location near MVWR km 997.0: PCARBH-C3-1 on the northeast side of the PCAR alignment (Photo 1) and PCARBH-C3-2 on the southwest side, as shown on Figure 4. Subsurface conditions encountered at Crossing C3 consist of surface organics, overburden soils, and sedimentary bedrock. The ground surface is covered with a thin layer of organic topsoil. Frozen soils, with visible ground ice up to 5% by volume, were observed from surface to depths of 7.3 m in both boreholes.

Borehole PCARBH-C3-1 was drilled to a depth of 9.1 m, approximately 7 m offset to the northeast of the PCAR centreline. A 0.3 m-thick layer of organic topsoil was encountered from the ground surface and underlain by overburden clay and sand layers to a depth of 4.0 m. Clays were typically silty, low to medium plastic, and light to dark brown in colour with some sand components. Sands were silty with some subangular to rounded gravel up to 30 mm in diameter. The material was tan in colour with visible ground ice, up to 5% by volume, noted at a depth of 2.5 m. When thawed, the overburden soils were damp to wet with moisture contents ranging from 13% to 32%. Below the overburden soils, Mud Shale bedrock extended to the depth of borehole. The sedimentary rock was fissile, thinly laminated, and light grey in colour (Photo 2). Rock strength was very weak to weak and measured moisture contents ranged from 8% to 12%.

Borehole PCARBH-C3-2 was drilled approximately 4 m to the southwest of the PCAR centreline to a depth of 9.1 m (Photo 4). Organic topsoil, including rootlets and grass, extended from ground surface to a depth of 1.0 m. Underlying the organics was a frozen overburden layer of sandy silt extending to a depth of 4.0 m. The silt was non-plastic and light brown in colour with trace clay and gravel components. Visible ground ice of up to 5% by volume was noted at a depth of 1.1 m within the sandy silt layer. Mud Shale bedrock was encountered under the overburden layer to the depth of borehole. The sedimentary rock was fissile, very weak, and light grey in colour. Unfrozen conditions were inferred at a depth of 7.3 m within the Mud Shale.

4.1.2 Crossing C9

Crossing C9, near MVWR km 999.0, was investigated with two geotechnical boreholes: PCARBH-C9-1 to the northeast and PCARBH-C9-2 to the southwest of the PCAR alignment, as shown on Figure 5. Generally, the crossing consists of organics (up to 1.2 m thick) overlying overburden clays and silts (up to 5.5 m thick) underlain by sedimentary rock. Both boreholes were frozen to depth with visible ground ice noted throughout.

Borehole PCARBH-C9-1 was drilled to auger refusal at a depth of 6.6 m at an offset of approximately 8 m northeast of the proposed PCAR centreline (Photo 5). A 300 mm-thick layer of organic topsoil was logged from ground surface and underlain by overburden clay and silt layers to a depth of 5.2 m. The clay is silty, medium to high plastic, and light to medium grey in colour. Silts were sandy, non-plastic, and brown in colour with subrounded to subangular gravelly components up to 55 mm in diameter (Photo 6). Moisture contents within the overburden generally decreased with depth, when thawed, and were very wet to damp with values ranging from 61% near ground surface to 17% at depth. Visible ground ice, up to 20% by volume, was observed in the overburden layer. Higher ground ice was noted in the upper silty clay layer between depths of 1.0 m and 2.0 m, where moisture contents were found to be above 44%. Below the overburden soils, Mud Shale bedrock extended to the depth of borehole. The rock was very weak, fissile, and light grey in colour. The Mud Shale was laminated to thinly laminated and dry, with moisture contents ranging between 11% and 12% when thawed.

Borehole PCARBH-C9-2 was drilled to a depth of 8.5 m, approximately 9 m southwest of the PCAR alignment (Photo 7). A layer of dark brown, woody peat was encountered from ground surface to a depth of 1.2 m. Visible ground ice up to 10% by volume was observed in the peat layer at a depth of 1.1 m. Underlying the peat were fine-grained, overburden layers of clay and silt extending to a depth of 6.7 m. Clays were silty, medium to high plastic, and light grey to brown-grey in colour. Silts were sandy, non-plastic, and light brown in color with trace subangular gravel components up to 60 mm in diameter. Visible ground ice up to 2% by volume was observed at a depth of 5.8 m within silty clay. Below the overburden soils, Mud Shale sedimentary rock with trace sand components was logged to depth. The rock was fissile, very weak, and light grey in colour. Native hydrocarbon odours were noted within the Mud Shale at a depth of 7.4 m, as detailed in Section 3.8.

4.1.3 Crossing C24

Two geotechnical boreholes were drilled at the proposed C24 culvert crossing location near MVWR km 1004.6: PCARBH-C24-1 on the northeast side of the PCAR alignment and PCARBH-C24-2 on the southwest side, as shown on Figure 6. Drilling at Crossing C24 encountered organic topsoil and fine-grained overburden soils. The overburden materials are underlain by sedimentary bedrock; however, bedrock was not encountered in either of the boreholes drilled at Crossing C24. Frozen soils, with visible ground ice up to 40% by volume, were observed from surface in both boreholes to depths of 6.7 m or greater.

Borehole PCARBH-C24-1 was drilled approximately 10 m northeast of the PCAR centreline to a depth of 9.1 m (Photo 9). A 0.6 m-thick layer of dark brown topsoil with wood debris was logged from ground surface and underlain by overburden clay and silt layers to depth. Clays were low to medium plastic and light brown in colour with some silt and sand components. Silts were sandy, non-plastic, and brown to light grey in colour. Rounded to subangular gravel was noted to increase with depth with diameters up to 50 mm (Photo 10). A 75 mm-diameter, subrounded cobble was noted within the sandy silt at a depth of 5.8 m. Visible ground ice, up to 40% by volume, was observed within the overburden layers, notable at depths of 3.9 m and 6.6 m. Moisture contents from the overburden were damp to moist with values ranging from 6% to 21%, generally decreasing with depth.

Borehole PCARBH-C24-2 was drilled approximately 3 m southwest of the PCAR centreline to a depth of 9.1 m (Photo 12). A layer of clayey, organic topsoil, up to 300 mm thick, was logged from ground surface and underlain by overburden clay and silt layers to depth. Clays were silty, low plastic, and light brown to grey in colour. Silts were

light brown in colour with trace sand and rounded to subangular gravel up to 40 mm in diameter. Frozen conditions were inferred to a depth of 6.7 m after which the borehole appeared to be unfrozen to depth based on handheld temperature measurements. No visible ground ice was observed in the borehole.

4.1.4 Crossing C29

Crossing C29, near MVWR km 1006.2, was investigated through two geotechnical boreholes: PCARBH-C29-1 to the northeast and PCARBH-C29-2 to the southwest of the PCAR alignment, as shown on Figure 7. Generally, the crossing consists of organics (up to 0.5 m thick) overlying overburden clay, silt, and sand layers (up to 3.9 m thick) underlain by sedimentary rock. Both boreholes were frozen to depth with significant visible ground ice noted in Borehole PCARBH-C29-1.

Borehole PCARBH-C29-1 was drilled to auger refusal at a depth of 6.4 m, at an offset of approximately 8 m northeast of the proposed PCAR centreline (Photo 13). A 0.5 m-thick, dark brown layer of organic topsoil was logged from ground surface and underlain by overburden layers of clay and sand. Clays were silty, low to high plastic, and light to dark brown in colour. Sands were poorly graded, fine grained, and brown in colour with some silt and clay components. Massive, cloudy ground ice with a thickness of 0.4 m was encountered between clay and sand layers at a depth of 1.4 m (Photo 14). Other visible ground ice, up to 20% by volume, was noted throughout the overburden layer. When thawed, moisture contents ranged from damp to very wet in the overburden and were notably over 50% above the layer of massive ground ice. Underlying the overburden soils, Mud Shale bedrock was logged from 4.4 m to depth. The sedimentary rock was fissile, weak, and light grey in colour. Measured moisture contents within the Mud Shale layer were found to range from 9% to 13%.

Borehole PCARBH-C29-2 was drilled approximately 6.5 m southwest of the PCAR centreline to a completion depth of 9.1 m (Photo 15). A 300 mm-thick layer of dark brown, organic topsoil was encountered from ground surface and underlain by overburden clay and silt layers to a depth of 4.6 m. Clays were low plastic, brown in colour and included some silt and sand components with subrounded gravels up to 40 mm in diameter. Silts were sandy, non-plastic, and light brown in colour with trace rounded to subangular gravel noted up to 50 mm in diameter. Below the overburden layers, Mud Shale bedrock was observed from 4.6 m to depth. The bedrock is fissile, weak, and light to dark grey in colour. The borehole was frozen to depth; however, no visible ground ice was encountered.

4.1.5 Crossing C33

Two geotechnical boreholes were drilled at the proposed C33 culvert crossing location near MVWR km 1007.2: PCARBH-C33-1 on the northeast side of the PCAR alignment and PCARBH-C33-2 on the southwest side, as shown on Figure 8. Subsurface conditions at Crossing C33 consisted of three layers: surface organics and ice, overburden soils, and sedimentary bedrock. Ground surfaces were covered with thin layers of peat and ice. Frozen soils were observed to depth in both boreholes, with visible ground ice up to 15% by volume noted in the overburden layers.

Borehole PCARBH-C33-1 was drilled to a depth of 9.8 m, at an offset of 9.5 m southwest of the PCAR centreline (Photo 17). A 150 mm-thick layer of dark brown peat was encountered from ground surface and was underlain by overburden clay, sand, and silt layers to a depth of 7.6 m. Clays were silty, low plastic, and brown-grey to black-brown in colour. Sands were silty, well graded, and brown in colour with some subrounded to subangular gravel up to 35 mm in diameter (Photo 18). Silts were brown, non-plastic, and sandy. Visible ground ice, up to 15% by volume was observed in all overburden layers at varying depths. Moisture contents, when thawed, varied from dry to moist with values ranging from 9% to 21%. Below the overburden layers, Mud Shale sedimentary rock was observed to depth. The bedrock is fissile, very weak, and grey in colour. Visible ground ice, up to 10% by volume, was observed in the Mud Shale between depths of 7.8 m and 8.3 m and measured moisture contents ranged from 8% to 10%.

Borehole PCARBH-C33-2 was drilled approximately 7 m to the southwest of the PCAR centreline to a depth of 9.1 m (Photo 20). Clear, white ice up to 125 mm thick, was noted at ground surface and underlain by overburden layers of silt, sand, and clay. Silts were non-plastic and light brown to grey in colour with some sand and gravel components up to 70 mm in diameter. Sands were dark brown and gravelly with subrounded particles up to 50 mm in diameter. Clays were silty, low plastic, and medium to dark brown in colour. The borehole was frozen to depth and visible ground ice, up to 10% by volume, was only noted in the sand layer at a depth of 1.1 m. The overburden layers are underlain by sedimentary bedrock; however, bedrock was not encountered in Borehole PCARBH-C33-2.

4.2 Thermal Conditions

Thermal conditions and the ground temperature data collected at each proposed PCAR culvert crossing are summarized below based on results from the geotechnical investigation. An initial set of ground temperature readings were collected on March 15, 2021 following the installation of the SBTs to confirm that they were functioning, and the second set of ground temperature readings were collected on March 18, 2021.

Further ground temperature readings are required to define the seasonal active layer depth and confirm the permafrost conditions at each proposed culvert crossing. Based on recent readings from the 2020 ground temperature cables installed along PCAR (Tetra Tech 2020a), active layer depths appear to range from 0.6 m to 1.5 m deep. Crossings with defined watercourses (Crossings C9 and C33) might contain more unfrozen soils than what was encountered during the geotechnical investigation, since drilling was conducted adjacent to and not within the streambed. Defined channels are expected to contain deeper active layers of unfrozen soils directly beneath the creek channel.

Ground temperature profiles for each proposed culvert crossing are presented in Appendix C and noted on the borehole logs in Appendix A.

4.2.1 Crossing C3

Four SBTs were installed up to depths of 8.3 m in Borehole PCARBH-C3-1 on the northeast side of Crossing C3 (Photo 3). The ground temperature data collected for Crossing C3 is summarized in Table 4-1.

Table 4-1: Crossing C3 Ground Temperature Data Summary

SBT Serial Number	Depth Below Ground (m)	Ground Temperature Readings from Borehole PCARBH-C3-1 (°C)	
		March 15, 2021	March 18, 2021
1B	1.3	-0.6	-1.0
17	2.3	-0.1	-0.1
1A	5.3	-0.4	-0.4
492	8.3	-0.4	-0.4

Measured ground temperatures from Crossing C3 (Borehole PCARBH-C3-1) indicate frozen subsurface conditions from ground surface to a depth of 8.3 m, approximately 4.3 m into bedrock. Visible random ice formations (V_r), up to 5% by volume, were observed in Borehole PCARBH-C3-1 at 2.5 m which suggests ice-poor permafrost is present. Visible random (V_r) and stratified ice formations (V_s), up to 5% by volume, were noted at a depth of 1.1 m in Borehole PCARBH-C3-2. Higher moisture content values of 32% in the upper silty clay layer of Borehole PCARBH-C3-1 suggests that non-visible excess ice (N_{be}) may be present at a depth of 1.1 m. Unfrozen

ground conditions were inferred in Borehole PCARBH-C3-2 at a depth of 7.4 m; however, this was based on field measurements of thermally disturbed soil samples following auger drilling.

Based on the above, warm permafrost appears to be present at Crossing C3. There is potential for limited thaw settlement in the upper silty clay layer where elevated moisture contents were noted.

4.2.2 Crossing C9

Ground temperature data for Crossing C9 was collected from four SBTs installed in Borehole PCARBH-C9-2 on the southwest side of the PCAR (Photo 8). The ground temperature data collected for Crossing C9 is summarized in Table 4-2.

Table 4-2: Crossing C9 Ground Temperature Data Summary

SBT Serial Number	Depth Below Ground (m)	Ground Temperature Readings from Borehole PCARBH-C9-2 (°C)	
		March 15, 2021	March 18, 2021
34	0.6	-1.2	-2.0
35	2.1	-0.4	-0.4
1C	5.1	-0.6	-0.6
3	8.1	-0.8	-0.9

Ground temperature readings from Borehole PCARBH-C9-2 indicate frozen conditions from ground surface to a depth of 8.1 m, approximately 1.4 m below the depth where bedrock was encountered. Field temperature measurements indicate both Crossing C9 boreholes were frozen to depth. Visible ground ice including ice crystals (V_x), random formations (V_r), and stratified formations (V_s) were noted in both boreholes at up to 20% by volume. Higher moisture content values from 44% to 60% were measured between depths of 1.1 m and 1.9 m in Borehole PCARBH-C9-1, where the highest volume of ice crystals (V_x) were observed within fine-grained soils. No unfrozen zones were identified in either borehole.

Based on the high moisture contents and the visible ground ice observed during drilling, permafrost with excess ground ice is present in the upper silty clay layer to an approximate depth of 2.1 m. Thaw settlement is expected to occur in this layer during and after construction of the PCAR and as the permafrost degrades over time with a warming climate. The settlement will be a combination of permafrost thaw and soil consolidation beneath the road embankment.

4.2.3 Crossing C24

Four SBTs were installed up to depths of 7.9 m in Borehole PCARBH-C24-1 on the northeast side of Crossing C24 (Photo 11). The ground temperature data collected for Crossing C24 is summarized in Table 4-3.

Table 4-3: Crossing C24 Ground Temperature Data Summary

SBT Serial Number	Depth Below Ground (m)	Ground Temperature Readings from Borehole PCARBH-C24-1 (°C)	
		March 15, 2021	March 18, 2021
36	0.9	-1.2	-2.0
37	1.9	-0.1	-0.2
1133	4.9	-0.5	-0.5
1134	7.9	-0.5	-0.6

Measured ground temperatures from Crossing C24 (Borehole PCARBH-C24-1) indicate that frozen soils exist to a minimum depth of 7.9 m. Visible stratified ice formations (V_s) and ice crystals (V_x), up to 40% by volume, were observed in Borehole PCARBH-C24-1 between depths of 3.5 m and 6.5 m. No visible ground ice was observed in Borehole PCARBH-C24-2 and unfrozen conditions were inferred at a depth of 6.7 m.

The presence of visible ground ice below the expected depth of the active layer indicates that warm permafrost is present to the depth of borehole at Crossing C24. Moisture contents within the overburden layers were relatively low (ranging from 6% to 21%); therefore, the permafrost soils should be relatively thaw-stable.

4.2.4 Crossing C29

Ground temperature data for Crossing C29 was collected from four SBTs installed in Borehole PCARBH-C29-2 on the southwest side of the PCAR (Photo 16). Crossing C29 ground temperature data is summarized in Table 4-4.

Table 4-4: Crossing C29 Ground Temperature Data Summary

SBT Serial Number	Depth Below Ground (m)	Ground Temperature Readings from Borehole PCARBH-C29-2 (°C)	
		March 15, 2021	March 18, 2021
38	1.2	-0.1	-0.1
39	2.7	-0.4	-0.4
1140	5.2	-0.6	-0.6
1141	7.7	-0.8	-0.8

Ground temperature readings from Borehole PCARBH-C29-2 indicate frozen conditions from the ground surface to a minimum depth of 7.7 m, approximately 3.1 m into sedimentary bedrock. Both Crossing C29 boreholes were logged as frozen to depth based on temperature readings performed in the field. Massive ground ice, between 1.4 m and 1.8 m depth, was encountered in Borehole PCARBH-C29-1, likely just below the active layer depth. Visible ground ice, including random ice formations (V_r) and ice crystals (V_x) up to 20% by volume, were observed below the expected active layer in Borehole PCARBH-C29-1.

Based on these observations, the upper clay and ice layers at Crossing C29 will be prone to thaw settlement during the construction of PCAR. Materials below these layers are likely within warm permafrost but were not observed to contain excess ground ice.

4.2.5 Crossing C33

Four SBTs were installed up to depths of 9.4 m in Borehole PCARBH-C33-1 on the northeast side of Crossing C33 (Photo 19). The ground temperature data collected for Crossing C33 is summarized in Table 4-5.

Table 4-5: Crossing C33 Ground Temperature Data Summary

SBT Serial Number	Depth Below Ground (m)	Ground Temperature Readings from Borehole PCARBH-C33-1 (°C)	
		March 15, 2021	March 18, 2021
40	1.6	-0.4	-0.9
1143	4.2	-0.5	-0.5
1135	6.8	-0.7	-0.7
1128	9.4	-0.9	-0.9

Measured ground temperatures from Crossing C33 (Borehole PCARBH-C33-1) indicate permafrost subsurface conditions from ground surface to a minimum depth of 9.4 m, approximately 1.8 m below the depth to sedimentary bedrock. Visible random ice formations (V_r), stratified ice formations (V_s), and ice crystals (V_x) up to 15% by volume, were observed below the expected depth of active layer in Borehole PCARBH-C33-1, up to depths of 8.2 m. Visible stratified ice formations (V_s), up to 10% by volume, were noted at a depth of 1.2 m in Borehole PCARBH-C33-2 while 125 mm-thick massive ice was also noted at ground surface. Moisture contents within the fine-grained overburden soils ranged from 9% to 21% indicating that the permafrost soils are not likely ice-rich. No unfrozen conditions were observed in either borehole at Crossing C33.

Based on the two boreholes at this crossing, it appears the permafrost soils encountered at this site contain low visible ground ice and the measured moisture contents are generally low. Limited thaw settlement would be expected at Crossing C33 as the frozen soils encountered are not likely ice-rich.

5.0 SEISMIC DESIGN RECOMMENDATIONS

5.1 Site Classification

Seismic classification for the PCAR site was determined using the average properties in the top 30 m of standard penetration resistance, as defined in Section 4.4.3 of the CHBDC. Based on a rod energy ratio (ER_r) of 70%, the recorded SPT blow counts were corrected and normalized to an energy level of 60%. The energy-corrected average penetration resistance values ($\bar{N}_{60}$) for the proposed culvert crossings varied between 52 and 104. It should be noted that these values were based on frozen SPT blow counts as the soils encountered in all boreholes tested were frozen.

Based on the above considerations, it is recommended that *Site Class C (Very Dense Soil and Soft Rock)* be used for seismic design of the proposed PCAR culvert crossings. This site classification is considered conservative given the relatively shallow depth to sedimentary rock at several of the proposed crossings.

5.2 Seismic Design Parameters

The proposed culvert crossings are assumed to be classified as *Buried Structures* (see Section 1.3) which requires designs to resist inertial forces associated with seismic events having a 2% chance of being exceeded in 50 years

(2,475 Year Return Period), as defined in Section 7.5.8 of the CHBDC. Seismic hazard values for the PCAR site were obtained from Earthquakes Canada (via the Natural Resources Canada website) and the seismic hazard calculation sheet is included in Appendix G.

Seismic design parameters determined for the PCAR, including peak ground acceleration (PGA) and site-adjusted PGA, are summarized in Table 5-1 below.

Table 5-1: Seismic Design Parameters for PCAR Culvert Crossings

Return Period (years)	Probability of Exceedance in 50 Years (%)	PGA (g)	S_a (0.2) (g)	PGA_{ref} (g)	Site Classification	Site-Adjusted PGA* (g)
2,475	2	0.336	0.683	0.336	C	0.336

** Site-Adjusted PGA determined using F(PGA) of 1.00 for 2,475 Year Return Period, per Section 4.4.3.3 of the CHBDC.*

For seismic design of the proposed culvert crossings, the total factored thrust (T_f), including additional thrust due to earthquake loadings (T_E), should be calculated per Section 7.5.8.2 of the CHBDC, as follows:

$$T_f = \alpha_D T_D + T_E = \alpha_D T_D + T_D A_V$$

Where:

- T_f *= maximum factored thrust including earthquake loadings in a soil-metal structure wall per unit length (kN/m)*
- T_D *= maximum thrust in a soil-metal structure wall per unit length due to unfactored dead loads (kN/m)*
- T_E *= additional thrust in a soil-metal structure wall per unit length due to earthquake loading (kN/m)*
- α_D *= load factor for dead loads*
- A_V *= 0.224, vertical acceleration ratio due to earthquake loading taken as two-thirds of* A_H
- A_H *= 0.336, horizontal acceleration ratio due to earthquake loading taken as the Site-Adjusted PGA*

5.3 Seismic Analysis

Per Section 7.5.8.1 of the CHBDC, a full seismic analysis is to be performed for *Buried Structures* that meet either of the following criteria:

1. Locations where the design spectral response acceleration for a period of 0.2 seconds, $F(0.2)S_a(0.2)$ at a 2% probability of exceedance in 50 years, is greater than 0.7 g; or
2. Site Classification F.

Based on the above criteria, a full seismic analysis is not required for the proposed PCAR culvert crossings.

6.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

Geotechnical design recommendations for the proposed PCAR culvert crossings are provided based on guidance from the CHBDC (CSA 2019a) and the Transportation Association of Canada's (TAC) *Guidelines for Development and Management of Transportation Infrastructure in Permafrost* Regions (TAC 2010). All recommendations are based on the design basis outlined in Section 1.3.

6.1 Geotechnical Design Parameters

Geotechnical design parameters for each proposed culvert crossing were estimated based on data gathered from the geotechnical investigation program as well as recommendations from the CHBDC and *the Canadian Foundation Engineering Manual* (CGS 2006). Soil layers were generalized based on classification, gradation, density, and plasticity. Ground temperature conditions, that should be considered during design, are also presented for each crossing. Warm permafrost conditions were encountered below the seasonally frozen (active) layer at each proposed crossing location; however, the design parameters presented below assume unfrozen soils and is considered conservative given the long-term potential for warming climate conditions. Interpreted subsurface profiles for each crossing are shown on Figures 4 to 8.

6.1.1 Crossing C3

Geotechnical design parameters for Crossing C3 are provided for the soil layers from the ground surface, as outlined in Table 6-1.

Table 6-1: Geotechnical Design Parameters for Crossing C3

Depth Below Ground*		Soil Type	Geotechnical Design Parameters			Thermal Condition
From (m)	To (m)		γ (kN/m^3)	c' (kPa)	ϕ' (°)	
0.0	0.7	Organics (Topsoil)	14.0	-	-	Seasonally Frozen
0.7	1.9	Clay, Silty	19.0	15	28	
1.9	3.0	Sand, Silty	20.5	-	32	Frozen (Ice-Poor)
3.0	4.0	Clay, Silty	19.0	15	28	
4.0	9.1	Mud Shale	23.0	5	28	

Notes:
** Average depth below ground surface for Boreholes PCARBH-C3-1 and PCARBH-C3-2.*
γ = Total Unit Weight, c' = Effective Cohesion, ϕ' = Effective Friction Angle

6.1.2 Crossing C9

Crossing C9 geotechnical design parameters are provided in Table 6-2 for the soil layers from the ground surface.

Table 6-2: Geotechnical Design Parameters for Crossing C9

Depth Below Ground*		Soil Type	Geotechnical Design Parameters			Thermal Condition
From (m)	To (m)		γ (kN/m^3)	c' (kPa)	ϕ' (°)	
0.0	0.8	Organics (Peat)	12.0	-	-	Seasonally Frozen
0.8	1.9	Clay (Ice-Rich)	18.5	40	-	
1.9	4.1	Silt, Sandy	20.0	2	32	Frozen (Ice-Poor)
4.1	6.0	Clay, Silty	19.0	15	28	
6.0	8.5	Mud Shale	23.0	5	28	

Notes:
** Average depth below ground surface for Boreholes PCARBH-C9-1 and PCARBH-C9-2.*
γ = Total Unit Weight, c' = Effective Cohesion, ϕ' = Effective Friction Angle

6.1.3 Crossing C24

Geotechnical design parameters for Crossing C24 are provided for the soil layers from the ground surface, as outlined in Table 6-3.

Table 6-3: Geotechnical Design Parameters for Crossing C24

Depth Below Ground*		Soil Type	Geotechnical Design Parameters			Thermal Condition
From (m)	To (m)		γ (kN/m^3)	c' (kPa)	ϕ' (°)	
0.0	0.5	Organics (Topsoil)	14.0	-	-	Seasonally Frozen
0.5	1.5	Clay	19.5	20	27	Frozen (Ice-Poor)
1.5	5.3	Silt, Sandy	20.0	2	32	
5.3	6.6	Clay	19.5	20	27	
6.6	9.1	Silt, Sandy	20.0	2	32	

Notes:
** Average depth below ground surface for Boreholes PCARBH-C24-1 and PCARBH-C24-2.*
γ = Total Unit Weight, c' = Effective Cohesion, ϕ' = Effective Friction Angle.

6.1.4 Crossing C29

Crossing C29 geotechnical design parameters are provided in Table 6-4 for the soil layers from the ground surface.

Table 6-4: Geotechnical Design Parameters for Crossing C29

Depth Below Ground*		Soil Type	Geotechnical Design Parameters			Thermal Condition
From (m)	To (m)		γ (kN/m^3)	c' (kPa)	ϕ' (°)	
0.0	0.4	Organics (Topsoil)	14.0	-	-	Seasonally Frozen
0.4	1.5	Clay (Ice-Rich)	18.5	40	-	
1.5	3.9	Sand, Silty	20.0	-	33	Frozen (Ice-Poor)
3.9	4.5	Clay, Silty	19.0	15	28	
4.5	9.1	Mud Shale	23.0	5	28	

Notes:
** Average depth below ground surface for Boreholes PCARBH-C29-1 and PCARBH-C29-2.*
γ = Total Unit Weight, c' = Effective Cohesion, ϕ' = Effective Friction Angle.

6.1.5 Crossing C33

Geotechnical design parameters for Crossing C33 are provided for the soil layers from the ground surface, as outlined in Table 6-5.

Table 6-5: Geotechnical Design Parameters for Crossing C33

Depth Below Ground*		Soil Type	Geotechnical Design Parameters			Thermal Condition
From (m)	To (m)		γ (kN/m^3)	c' (kPa)	ϕ' (°)	
0.0	0.2	Organics (Peat)	12.0	-	-	Seasonally Frozen
0.2	4.9	Sand and Silt	20.5	-	34	
4.9	6.2	Sand, Gravelly	21.0	-	35	Frozen (Ice-Poor)
6.2	7.6	Clay, Silty	19.0	15	28	
7.6	9.8	Mud Shale	23.0	5	28	

Notes:
** Depth below ground surface for Borehole PCARBH-C33-1.*
γ = Total Unit Weight, c' = Effective Cohesion, ϕ' = Effective Friction Angle.

6.2 Culvert Foundations

Based on guidance from Section 7.5.7.3 of the CHBDC, buried structures constructed in embankment conditions should be founded on competent subsurface layers and have engineered backfill extending beyond the structure's spring line. In general, the foundation soils at each proposed crossing site can provide adequate support for the proposed culverts (outlined in Section 1.3); however, excavation beneath the culvert footprint is recommended to remove frozen organics and fine-grained soil layers.

Excavation for each proposed culvert crossing is required to remove materials prone to consolidation or settlement during thaw. Where deleterious materials are encountered, the material should be excavated, wasted, and replaced with thaw-stable, Engineered Backfill. The backfill should extend below the estimated active layer depth and be founded on competent sand and silt layers. Foundation grades are recommended to be covered with a woven geotextile to provide confinement, separation, and reinforcement for the Engineered Backfill within the frozen subgrade. Thaw settlement and consolidation at each proposed crossing site are expected to be negligible if excavation and backfill recommendations are followed; however, actual settlement magnitudes are dependent on the type of material and quality of construction.

Vertical cutoff walls comprised of Bentonite-Augmented Backfill are recommended to be installed at the inlets and outlets of each culvert to seal, intercept, and prevent seepage from undercutting the structure. Cutoff walls should be installed to a minimum thickness of 4.0 m into the road embankment at both ends of the culverts. The height of the cutoff walls should extend from the top of the Engineered Backfill zone to the bottom of the foundation excavation. Cutoff walls should extend the full width of the foundation excavation.

Typical drawings illustrating the recommendations for culvert foundations are provided in Appendix H. Geotechnical considerations for construction are provided in Section 6.3, including requirements for foundation preparation, geosynthetics, granular materials, and seepage control. The foundation recommendations for each proposed culvert crossing, including burial depth and excavation dimensions, are summarized in Table 6-6.

Table 6-6: PCAR Culvert Crossings Foundation Recommendations

Culvert Crossing	Proposed Culvert Diameter (mm)	Culvert Invert Burial Depth[1] (mm)	Excavation Dimensions (mm)			Target Foundation Layer
			Depth[2]	Width[3]	Sideslopes	
C3	1,200	300	N/A*	N/A*	1H:1V	N/A*
C9	2,280	570	2,000	6,840		Silt, Sandy
C24 [a]	1,200	300	N/A*	N/A*		N/A*
C29 [b]	1,000 – 1,200	250 – 300	N/A*	N/A*		N/A*
C33 [c]	1,200 (x 2)	300	600	4,800		Sand and Silt

[1] Minimum recommended depth of culvert invert below ground surface.
[2] Minimum recommended depth of excavation below ground surface.
[3] Minimum recommended bottom width of excavation centred on culvert.
[a] Culvert Crossing C24 reconfigured to three smaller, separate culverts during hydrotechnical design (Tetra Tech 2021b).
[b] Culvert Crossing C29 reconfigured to three smaller, separate culverts during hydrotechnical design (Tetra Tech 2021b).
[c] Culvert Crossing C33 reconfigured to twin, side-by-side culverts during hydrotechnical design (Tetra Tech 2021b).
** Excavation details to follow typical culvert construction as redesigned culverts are not bridge-sized or twinned.*

The above excavation depths are the minimum recommended depths from ground surface for each culvert crossing foundation, ranging from 0.6 m to 2.1 m deep. Excavation depths were selected based on the subsurface conditions encountered during the 2021 geotechnical investigation, as outlined in Section 4.0. The foundation excavation should extend horizontally at least three-times the culvert diameter (3D), centered on the culvert, to ensure no influence from the surrounding subgrade. It is recommended that the culvert invert be buried one-quarter of its diameter (D/4) below the streambed of each crossing, up to a maximum burial depth of 1.0 m. The ultimate depth and width of each excavation should be determined at the time of construction by a Geotechnical Engineer based on the subsurface conditions observed in the field.

6.3 Construction Considerations

The following subsections outline geotechnical construction considerations for the installation of the proposed PCAR culvert crossings. Culvert installation should be performed in accordance with the *Buried Structure* design requirements outlined in Section 7.5 of the CHBDC (CSA 2019a) and should follow the recommendations in Section 6.3 of TAC (2010).

6.3.1 Construction Timing

It is recommended that culvert construction be conducted during the winter when creeks are frozen and water flows are reduced. Groundwater was not encountered at any of the proposed crossings during the geotechnical investigation undertaken in March 2021; however, subsurface flows can be encountered, and should be anticipated, depending on climatic conditions (air temperature, precipitation, snow cover) and the time of year that construction is undertaken (i.e., early winter, late winter). Culvert installations require that work be completed in dry conditions and that groundwater is controlled, if encountered. Adequate pumping equipment should be available onsite. Dewatering of the culvert excavations using conventional sump and pump techniques should be adequate; however, if larger groundwater flows are encountered during construction, then cofferdams enclosing the work area may be required.

For winter construction, it is important to use clean, thaw-stable granular backfill for the culvert foundations (see Section 6.3.4). One limitation of winter construction is that frozen granular materials cannot be compacted to the

same density when unfrozen, resulting in greater thaw settlement of the backfill materials. Compaction and density of frozen granular materials decrease at moisture contents greater than 2%. Lower moisture contents increase the maximum compaction that can be achieved in winter conditions.

6.3.2 Excavation and Foundation Preparation

Excavation and foundation preparation for culvert installations should include removal of all organics, vegetation, ice-rich permafrost, snow, and other deleterious materials (as described in Section 4.0) from the lateral extents of the foundation prior to placing backfill. The excavations should have open-cut sideslopes to a minimum gradient of 1H:1V (45°) sloped from the bottom of the excavation, depending on the type of material excavated and whether it is frozen or unfrozen.

The base of the excavation should be examined by a Geotechnical Engineer to confirm that the foundation soils are consistent with those observed during the geotechnical investigation and that no deleterious materials are present. Any soft, yielding, or organic material identified during the inspection should be removed or stabilized. Once the subgrade is deemed satisfactory, the base of the excavation should be compacted a minimum of six passes using a 454 kg (1,000 lbs.) vibratory plate compactor (i.e., Mikasa MVH-402, Dynapac LG 400, or similar) prior to the placement of any backfill. If the subgrade is found to be frozen, mechanical compaction may not be possible and the subgrade should not be allowed to thaw. The compacted foundation subgrade should then be covered with a woven geotextile, that meets the requirements outlined in Section 6.3.3.1.

Construction excavations for the culvert installations should be undertaken in accordance with Part 17 of the current GNWT *Occupational Health and Safety Regulations.* It is recommended that excavations greater than 1.5 m deep should be sloped from the bottom of the excavation or shored for worker protection. A flatter sideslope of 2H:1V should be used if groundwater is encountered during excavation due to the increased potential for localized sloughing. Deep excavations or trenches may require temporary support if space limitations or economic considerations preclude the use of sloped excavations.

6.3.3 Geosynthetics

6.3.3.1 Woven Geotextile

Woven geotextile is recommended to be installed along the bottom of the excavation, prior to placing backfill materials, to provide confinement, separation, and reinforcement for the culvert foundations. Minimum recommended properties for high-strength woven geotextiles are outlined in Table 6-7.

Table 6-7: Woven Geotextile Recommended Properties

Physical Property	Minimum Requirement	ASTM Test Method
Grab Tensile Strength	1,300 N	D4632
Elongation	15%	D4632
Tear Strength	500 N	D4533
CBR Puncture Strength	4,400 N	D6241
UV Resistance	70%	D4355
Flow Rate	160 l/m/m^2	D4491
Permittivity	0.05 sec^{-1}	D4491

** Adopted from Minimum Woven Geotextile Properties of GNWT's Standard Specifications for Highway Construction, Division 3, Section 3.3.2.3 (GNWT 2021).*

Woven geotextile should be composed of continuous monofilaments, staple fibres, multi-filament yarns, or slit films that are woven into a fabric. Installation of woven geotextile should be undertaken following the below recommendations:

- Place woven geotextile perpendicular to culvert alignment;
- Place woven geotextile smooth and free of tension, stress, folds, wrinkles, and creases; and
- Seams should be overlapped in the direction of anticipated drainage a minimum of 0.6 m, or per the manufacturer's instructions.

6.3.3.2 Non-Woven Geotextile

Non-woven geotextile is recommended beneath the rock aprons to be installed at the ends of each culvert (see Section 6.3.6) to control sediment transport and provide additional stabilization. A highly durable geotextile should be used that meets the minimum recommended properties outlined in Table 6-8.

Table 6-8: Non-Woven Geotextile Recommended Properties

Physical Property	Minimum Requirement	ASTM Test Method
Grab Tensile Strength	1,300 N	D4632
Elongation	50%	D4632
Tear Strength	500 N	D4533
CBR Puncture Strength	2,200 N	D6241
UV Resistance	70%	D4355
Flow Rate	3,000 l/m/m^2	D4491
Permittivity	1.0 sec^{-1}	D4491

** Adopted from Minimum Non-Woven Geotextile Properties of GNWT's Standard Specifications for Highway Construction, Division 3, Section 3.3.2.3 (GNWT 2021).*

Non-woven geotextile should consist of needle-punched polypropylene fabric made of 100% polypropylene staple fibres. Installation of non-woven geotextile should be undertaken following the below recommendations:

- Place non-woven geotextile perpendicular to culvert alignment in one continuous length, where possible;
- Place non-woven geotextile smooth and free of tension, stress, folds, wrinkles, and creases; and
- Seams should be overlapped in the direction of anticipated drainage a minimum of 0.6 m, or per the manufacturer's instructions.

If non-woven geotextile is not readily available during construction, it is acceptable to use woven geotextile as a substitute for the above applications. It should be noted that woven geotextiles tend to be more expensive than non-woven geotextiles and there are advantages to using both as each geosynthetic type is intended for different functions.

6.3.4 Granular Materials

6.3.4.1 Engineered Backfill

Engineered Backfill should be used as the primary backfill for the culvert's foundation and engineered fill zone, as shown on Drawing H1 in Appendix H. Material should consist of a thaw-stable, non-cohesive aggregate that is free of organics, vegetation, snow, and other deleterious material. Engineered Backfill should meet the requirements for *Group I* fill outlined in Section 7.5.7.4 of the CHBDC which will require processing to achieve the specified gradation. Aggregate specifications for Engineered Backfill are provided in Table 6-9.

Table 6-9: Aggregate Specifications for Engineered Backfill

Metric Sieve Designation*		Percent Passing by Weight (%)
Sieve Size (mm)	50.000	100
	37.500	87 – 100
	20.000	60 – 95
	12.500	46 – 80
	5.000	35 – 60
	2.000	25 – 45
	0.400	10 – 20
	0.080	2 – 12

** Adopted from Designation Granular Subbase, Class 50 mm of GNWT's Standard Specifications for Highway Construction, Division 5, Section 5.1.3.4 b) iii) (GNWT 2021).*

Additionally, Engineered Backfill should meet the following geotechnical classification requirements:

- MUSC Group Symbol GW, SW, GP, GW-GM, GP-GM, or SW-SM (per ASTM D2487);
- Minimum Percent Fracture by Weight (2 Faces) = 50;
- Maximum Plasticity Index (per ASTM D4318) = 6%; and
- Maximum Los Angeles Abrasion Loss (per CSA A23.2-16A/17A) = 50%.

6.3.4.2 Crushed Aggregate

Crushed Aggregate should be used as bedding during culvert installation and as the granular component for seepage control (see Section 6.3.5). The material should consist of a thaw-stable, non-cohesive aggregate that is free of organics, vegetation, snow, and other deleterious material. The material should meet the requirements for *Group I* fill outlined in Section 7.5.7.4 of the CHBDC and will require processing to achieve the specified gradation. Aggregate specifications for Crushed Aggregate are provided in Table 6-10.

Table 6-10: Aggregate Specifications for Crushed Aggregate

Metric Sieve Designation*		Percent Passing by Weight (%)
Sieve Size (mm)	20.000	100
	10.000	63 – 86
	5.000	40 – 67
	1.250	20 – 43
	0.630	14 – 34
	0.315	9 – 26
	0.160	5 – 18
	0.080	2 – 10

** Adopted from Designation Granular Base Course, Class 20.0 mm of GNWT's Standard Specifications for Highway Construction, Division 5, Section 5.1.3.4 b) ii) (GNWT 2021).*

Additionally, Crushed Aggregate should meet the following geotechnical classification requirements:

- MUSC Group Symbol GW, SW, GP, GW-GM, GP-GM, or SW-SM (per ASTM D2487);
- Minimum Percent Fracture by Weight (2 Faces) = 60;
- Maximum Plasticity Index (per ASTM D4318) = 4%; and
- Maximum Los Angeles Abrasion Loss (per CSA A23.2-16A/17A) = 50%.

6.3.4.3 Placement and Compaction

Granular materials for the proposed culvert crossings should be placed and compacted in accordance with Section 7.5.7.5 of the CHBDC, including:

- Engineered Backfill should be placed up to a maximum loose lift thickness of 250 mm;
- Engineered Backfill should be compacted a minimum of six passes using a 454 kg (1,000 lbs.) vibratory plate compactor;
- Engineered Backfill should be placed such that the level of backfill on one side of the culvert does not exceed the level of fill on the other side of the culvert by more than two compacted lift thicknesses or 300 mm, whichever is less;
- Engineered Backfill should be placed and compacted by equipment moving parallel to the culvert with simultaneous handwork along the culvert such that the equipment and methods of compaction do not damage the culvert walls;
- Crushed Aggregate should be placed under the culvert haunches and compacted in thin layers such that all corrugations are filled and the entire bottom surface of the culvert is in firm contact with the Engineered Backfill; and
- Equipment heavier than a 10-tonne static unballasted mass must be kept at least 1.0 m away from the sidewall of the buried structure at any level above the base of the structure.

Following placement of Engineered Backfill up to the culvert invert, a 200 mm thick layer of uncompacted Crushed Aggregate should be placed directly beneath the culvert for use as bedding. The bedding material should be preshaped to the curvature of the underside of the culvert to be used.

6.3.5 Seepage Control

Vertical cutoff walls, for controlling seepage at culvert ends, should be constructed with Bentonite-Augmented Backfill consisting of Crushed Aggregate augmented with powdered bentonite clay. To produce Bentonite-Augmented Backfill, bentonite should be placed dry and mixed with the Crushed Aggregate such that the average bentonite content is 12% by weight or greater.

Crushed Aggregate should meet the material requirements outlined in Section 6.3.4.2. Bentonite should consist of powdered bentonite clay (i.e., Wyoming bentonite, sodium bentonite, or similar) that meets the following material requirements:

- Minimum Percent Passing 0.075 mm (No. 200) Sieve = 80%; and
- Minimum Mineralogical Composition = 90% Montmorillonite.

6.3.6 Erosion and Scour Protection

Culvert ends and sideslopes should be protected with rip-rap and rock aprons to the dimensions shown in Appendix H. Rock apron rip-rap should be composed of hard, durable, and angular rock that is resistant to weathering and free of organics, vegetation, snow, and other deleterious material. Rock aprons should be underlain by a non-woven geotextile that meets the requirements outlined in Section 6.3.3.2. Aggregate specifications for Rip-Rap are provided in Table 6-11.

Table 6-11: Aggregate Specifications for Rip-Rap

Material Property	Units	Quantity
Nominal Mass	kg	40
Nominal Diameter	mm	300
100% Smaller Than	kg	130
	mm	450
20% Larger Than	kg	70
	mm	350
50% Larger Than	kg	40
	mm	300
80% Larger Than	kg	10
	mm	200

** Adopted from Heavy Rock Rip-Rap, Class I of GNWT's Standard Specifications for Highway Construction, Section HS 1150, 2.2.1 (GNWT 2021).*

6.3.7 Minimum Height of Cover

Section 7.5.6 of the CHBDC recommends that buried structures have a minimum cover of soil between the underside of the road surface and the top of the structure. The minimum height of cover (H_{min}) for the proposed PCAR culvert crossings when in service is 600 mm. During construction, the minimum cover for construction traffic (less than 30 metric tons) is 300 mm.

6.3.8 Durability in Soils

Durability recommendations for each proposed culvert crossing were developed based on data gathered from the geotechnical investigation program as well as recommendations from the Corrugated Steel Pipe Institute's *Steel Drainage & Highway Construction Products Handbook* (CSPI 2010) and the National Corrugated Steel Pipe Association's *CSP Durability Guide* (NCSPA 2000). The durability of buried structures in soil is a function of several interacting parameters including soil resistivity, acidity (pH), moisture content, soluble sulphates, and chlorides.

As detailed in Section 3.7, one soil sample from each proposed culvert crossing underwent geochemical laboratory testing to quantify pH ($CaCl_2$), Chlorides (Cl), Sulphates (SO_4), and Resistivity. The analyses were done to determine the potential for corrosion of any exposed steel as well as degradation of any concrete used in the construction of the culvert crossings. Recommendations for culvert durability, including corrosion protection and cement type, are detailed in the following subsections.

6.3.8.1 Corrosion Protection

The National Corrugated Steel Pipe Association (NCSPA) defines the environmental ranges for corrosion, due to soil and/or groundwater conditions, as a function of pH and resistivity (NCSPA 2000). Normal, non-corrosive soil conditions are considered to have pH levels between 5.8 and 8.5 for resistivity values greater than 2,000 Ohm·cm.

Analyses of pH on soil samples from each proposed culvert crossing resulted in values ranging from 8.1 to 8.2. Resistivity testing, conducted on the same five soil samples, yielded resistivity values ranging from 2,533 Ohm·cm to 10,000 Ohm·cm. Based on these results, the soil conditions at all five crossings are not expected to be highly corrosive environments. The NCSPA recommends the following metallic, protective coatings for these soil conditions:

- Zinc Coated (Galvanized); and
- Aluminum Coated Type 2.

6.3.8.2 Cement Type

Soluble sulphate content testing was performed on five soil samples, one from each proposed culvert crossing, to determine the appropriate cement type to be used. Five tests were conducted with sulphate contents ranging from 33 ppm to 95 ppm (0.0033% to 0.0095%). Soluble sulphate concentrations less than 0.1% generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and/or groundwater.

Based on this, the degree of exposure (class) to sulphate attack was considered *Negligible* at all proposed crossing locations and the following cementing materials may be used:

- Type GU;
- Type MS;
- Type MSb;
- Type LH;
- Type HS; or
- Type HSb.

Tetra Tech recommends that all concrete be designed, mixed, placed, and tested in accordance with CSA A23.1 and CSA A23.2. According to these standards, concrete should be designed to at least satisfy minimum durability requirements as defined by exposure class. Air entrainment of 4% to 6% by volume is recommended for all concrete exposed to freezing temperatures or groundwater. Type HS cement should not be used in reinforced concrete exposed to both chlorides and sulphates.

7.0 DESIGN REVIEW AND CONSTRUCTION MONITORING

Tetra Tech should be given the opportunity to review the design details, specifications, and drawings for the proposed culvert crossings prior to construction of the PCAR. Construction should be carried out by a qualified contractor experienced in earthworks and foundation construction in cold-weather regions.

All recommendations in this geotechnical report assume that an adequate level of quality assurance and geotechnical monitoring will be provided during construction to ensure the contractor is following the recommendations of this report. It should be noted that failure to provide an adequate level of geotechnical monitoring contravenes Section 6.4.6 of the CHBDC.

8.0 CLOSURE

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

Respectfully submitted,
Tetra Tech Canada Inc.

REGISTERED PROFESSIONAL ENGINEER
T.A. BRADSHAW
LICENSEE
NT/NU

October 26, 2021

FILE: 704-ENG.YARC03354-05.001
FILE: 704-ENG.YARC03354-05.001
FILE: 704-ENG.YARC03354-05.001

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26 October 2021

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PERMIT TO PRACTICE
TETRA TECH CANADA INC.
Signature
Date 26 October 2021
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

/jf

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TABLES

Table A Borehole Information Summary
Table B Laboratory Test Results Summary

TABLE A: BOREHOLE INFORMATION SUMMARY

Project:	PCAR Culvert Crossings Geotechnical	Coordinate System:	UTM Zone 9
Project No:	704-ENG.YARC03354-05.001	Drilling Dates:	March 7 to 11, 2021
Client:	K'alo-Stantec Limited	Drilled By:	Thomas Bradshaw
Location:	Prohibition Creek Access Road, Northwest Territories	Total Boreholes:	10

Borehole Number	Culvert Crossing	MVWR Milepost (km)	Coordinates (m, NAD83 [CSRS] Epoch 2010)		Ground Elevation (m)	Depth Drilled (m)	Completion Elevation (m)	Organic Layer Thickness (m)	Groundwater Encountered	Completion Date
			Northing	Easting						
PCARBH-C3-1	C3 (North)	997.0	7,229,180.2	625,246.7	90.2	9.1	81.1	0.3	No	March 7, 2021
PCARBH-C3-2	C3 (South)		7,229,169.2	625,242.1	89.9	9.1	80.8	1.1	No	March 7, 2021
PCARBH-C9-1	C9 (North)	999.0	7,230,328.9	623,648.5	85.5	6.6	78.9	0.3	No	March 8, 2021
PCARBH-C9-2	C9 (South)		7,230,315.9	623,637.6	85.4	8.5	76.9	1.2	No	March 8, 2021
PCARBH-C24-1	C24 (North)	1004.6	7,233,391.3	619,392.3	78.3	9.1	69.2	0.6	No	March 9, 2021
PCARBH-C24-2	C24 (South)		7,233,373.1	619,395.5	78.1	9.1	69.0	0.3	No	March 9, 2021
PCARBH-C29-1	C29 (North)	1006.2	7,234,231.4	618,218.9	75.2	6.4	68.8	0.5	No	March 10, 2021
PCARBH-C29-2	C29 (South)		7,234,215.0	618,218.1	74.5	9.1	65.4	0.3	No	March 10, 2021
PCARBH-C33-1	C33 (North)	1007.2	7,234,794.9	617,439.0	78.4	9.8	68.6	0.2	No	March 11, 2021
PCARBH-C33-2	C33 (South)		7,234,778.8	617,432.9	77.4	9.1	68.3	0.1	No	March 11, 2021

TABLE B: LABORATORY TEST RESULTS SUMMARY

Project: PCAR Culvert Crossings Geotechnical
Project No: 704-ENG.YARC03354-05.001
Client: K'alo-Stantec Limited
Location: Prohibition Creek Access Road, Northwest Territories

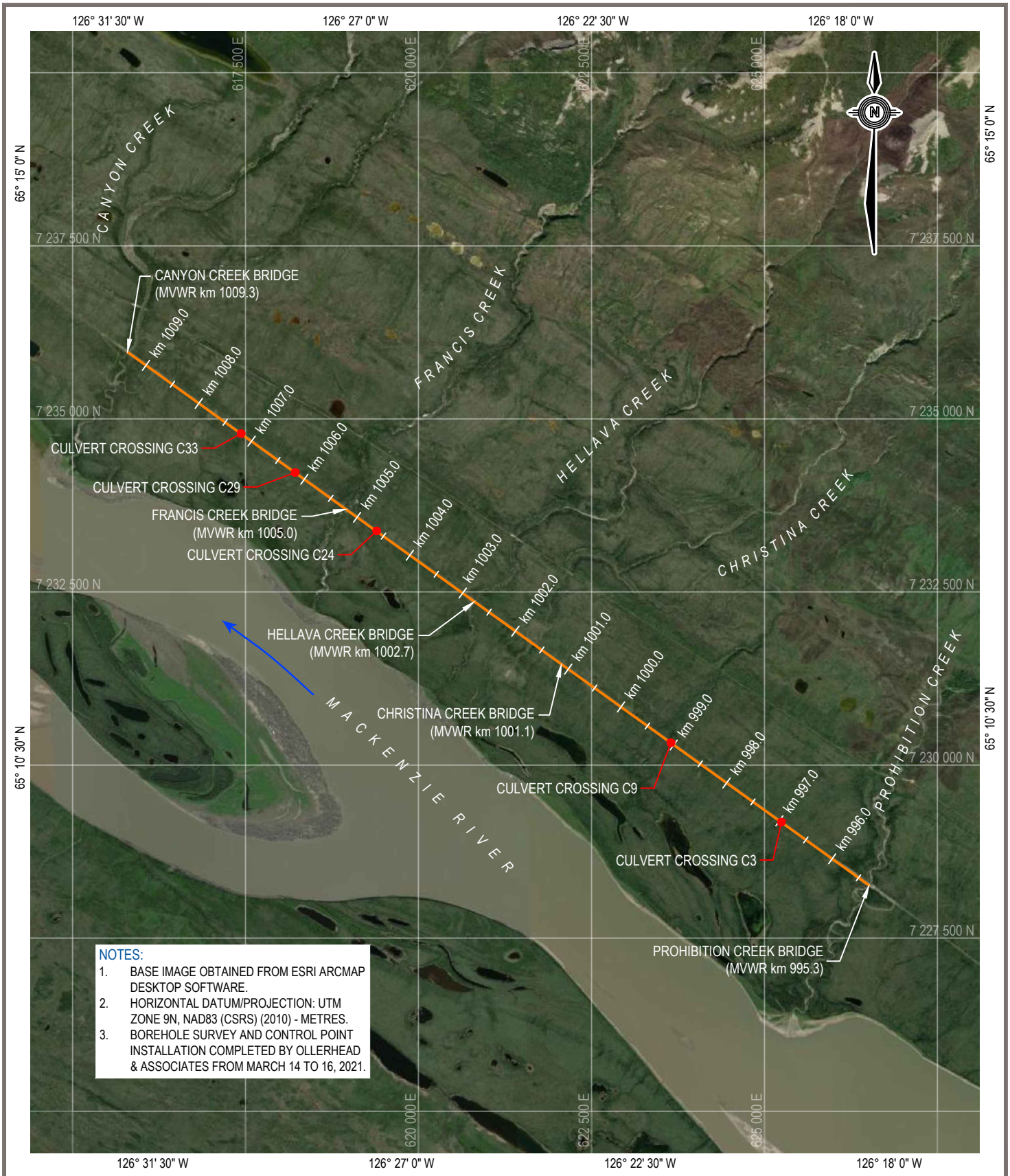
TETRA TECH

UTM Zone: 9
Drilling Dates: March 7 to 11, 2021
Sampled By: Thomas Bradshaw
Tested By: Yellowknife and Calgary Materials Laboratories

Borehole Number	Sample Number	Sample Type	Sample Depth (m)		Moisture Content	Particle Size Distribution (%)				Atterberg Limits			MUSC Group Symbol	pH	Chloride	Sulphate	Resistivity	Organic Matter
			From	To	(%)	Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index			(ppm)	(ppm)	(ohm*cm)	(%)
PCARBH-C3-1	A1	Auger	1.2	1.5	32.0					40	28	12	OL					
	SS2	SPT	1.5	2.0	21.4													
	A3	Auger	2.6	2.9	12.9	16	42	42					SM					
	SS4	SPT	3.0	3.5	15.2									8.2	110	45	3,575	4.2
	A5	Auger	3.7	4.0	13.4					32	18	14	CL-CI					
	SS6	SPT	4.6	5.0	11.9													
	A7	Auger	5.2	5.5	11.7	0	8	66	26				CL-CI					
	SS8	SPT	6.1	6.3	9.7													
	A9	Auger	7.0	7.3	8.1													
	SS10	SPT	7.6	7.9	9.7													
	A11	Auger	8.5	8.8	9.4													
PCARBH-C9-1	A12	Auger	1.2	1.5	60.7													
	SS13	SPT	1.5	2.0	43.6					53	34	19	OH					
	A14	Auger	2.4	2.7	17.7	25	26	35	14				ML					
	SS15	SPT	3.0	3.5	23.0									8.1	32	64	2,533	4.3
	A16	Auger	4.1	4.4	17.6					36	21	15	CI					
	SS17	SPT	4.6	5.0	16.9													
	A18	Auger	5.3	5.6	11.2	0	7	73	20				CI					
	SS19	SPT	6.1	6.2	12.1													
PCARBH-C24-1	A21	Auger	1.2	1.5	17.0													
	SS22	SPT	1.5	2.0	17.6					Non-Plastic			SM					
	A23	Auger	2.3	2.6	21.2	4	33	49	14				ML	8.1	35	95	3,748	2.4
	SS24	SPT	3.0	3.7	17.2					28	17	11	CL-CI					
	A25	Auger	4.3	4.6	11.8	8	32	45	15				CL-CI					
	SS26	SPT	4.6	4.9	10.6													
	A27	Auger	5.5	5.8	10.0													
	SS28	SPT	6.1	6.4	9.5													
	A29	Auger	6.6	6.9	7.5													
	A31	Auger	7.3	7.6	6.2													
	SS32	SPT	7.6	8.0	7.9													
	A33	Auger	8.5	8.8	9.5													
PCARBH-C29-1	A34	Auger	1.1	1.4	58.9					62	44	18	OH					
	SS35	SPT	1.2	1.7	49.6													
	A36	Auger	2.3	2.6	12.7	3	64	33					SM					
	SS37	SPT	2.7	3.0	13.5									8.2	45	88	10,000	2.3
	A38	Auger	3.7	4.0	19.1					23	15	8	CL					
	SS39	SPT	4.3	4.3	23.6													
	A40	Auger	5.2	5.5	9.4	7	37	41	15				ML					
	SS41	SPT	5.8	6.0	12.9													
PCARBH-C33-1	A43	Auger	0.9	1.2	21.2													
	SS44	SPT	1.5	2.0	14.5									8.2	44	33	8,667	2.3
	A45	Auger	2.1	2.4	12.6	20	54	26					SM					
	SS46	SPT	2.7	2.9	9.0													
	A47	Auger	4.0	4.3	15.7					Non-Plastic			ML					
	SS48	SPT	4.6	4.7	19.0													
	A49	Auger	5.5	5.8	9.6	28	47	19	6				SM					
	SS50	SPT	6.1	6.6	15.3													
	A51	Auger	7.0	7.3	9.2					24	14	10	CL					
	SS52	SPT	7.6	7.9	10.1													
	A53	Auger	8.5	8.8	8.4													

FIGURES

Figure 1 Project Plan
Figure 2 Culvert Crossings C3 and C9 Site Plan
Figure 3 Culvert Crossings C24, C29, and C33 Site Plan
Figure 4 Culvert Crossing C3 Plan and Profile
Figure 5 Culvert Crossing C9 Plan and Profile
Figure 6 Culvert Crossing C24 Plan and Profile
Figure 7 Culvert Crossing C29 Plan and Profile
Figure 8 Culvert Crossing C33 Plan and Profile



NOTES:

1. BASE IMAGE OBTAINED FROM ESRI ARCMAP DESKTOP SOFTWARE.
2. HORIZONTAL DATUM/PROJECTION: UTM ZONE 9N, NAD83 (CSRS) (2010) - METRES.
3. BOREHOLE SURVEY AND CONTROL POINT INSTALLATION COMPLETED BY OLLERHEAD & ASSOCIATES FROM MARCH 14 TO 16, 2021.

LEGEND:

PROHIBITION CREEK ACCESS ROAD (PROPOSED)

0 2,500m

Scale: 1:75,000 @ 8.5"x11"

CLIENT

Kʼalo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD CULVERT CROSSINGS GEOTECHNICAL

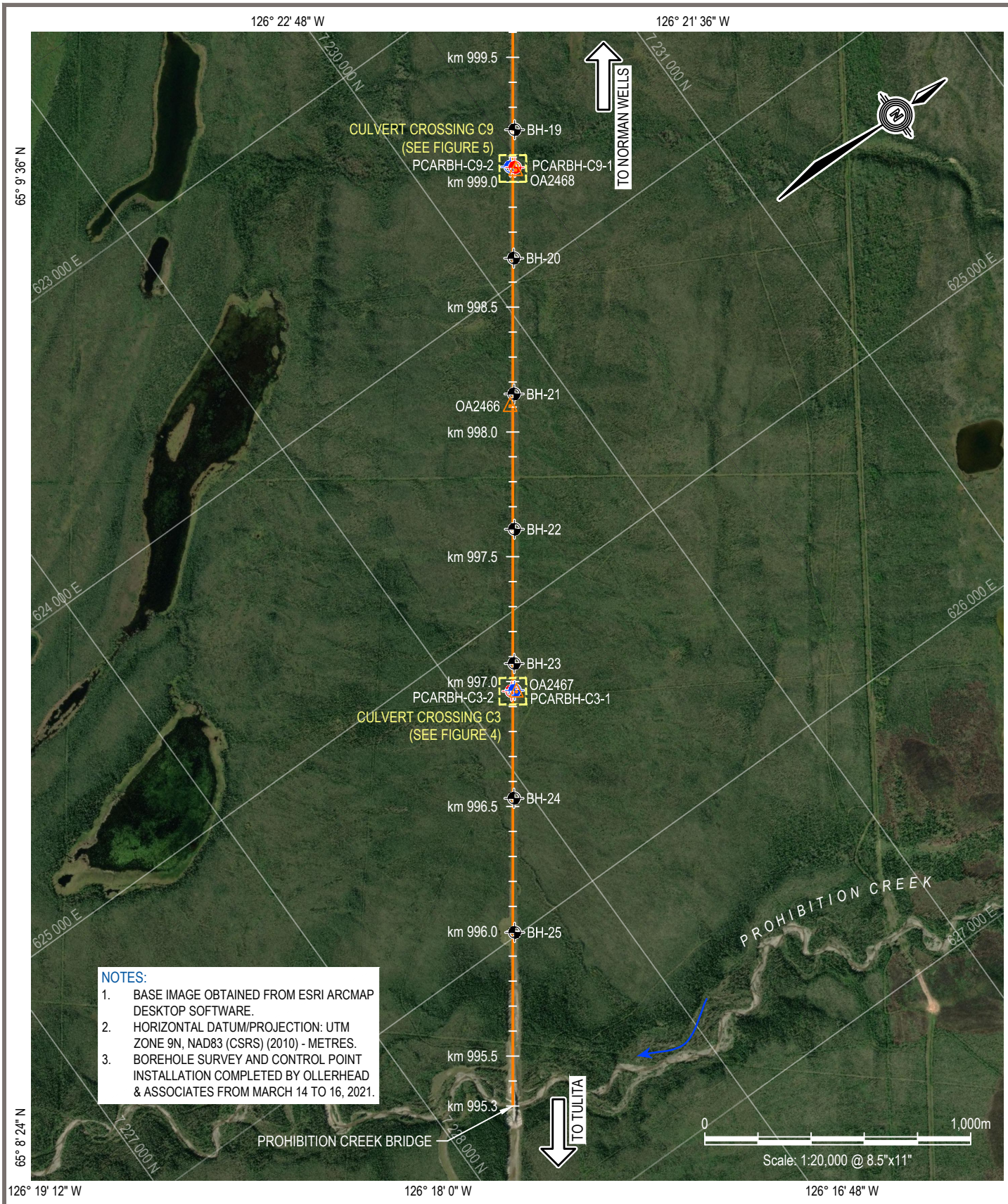
PROJECT PLAN

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

FIGURE 1

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 1_Culvert Crossing.dwg [FIGURE 1] October 25, 2021 - 9:41:07 am (BY: LEE, ELVIN)



NOTES:

1. BASE IMAGE OBTAINED FROM ESRI ARCMAP DESKTOP SOFTWARE.
2. HORIZONTAL DATUM/PROJECTION: UTM ZONE 9N, NAD83 (CSRS) (2010) - METRES.
3. BOREHOLE SURVEY AND CONTROL POINT INSTALLATION COMPLETED BY OLLERHEAD & ASSOCIATES FROM MARCH 14 TO 16, 2021.

LEGEND:

- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2020 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- SURVEY CONTROL POINT (OLLERHEAD, 2021)

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD CULVERT CROSSINGS GEOTECHNICAL

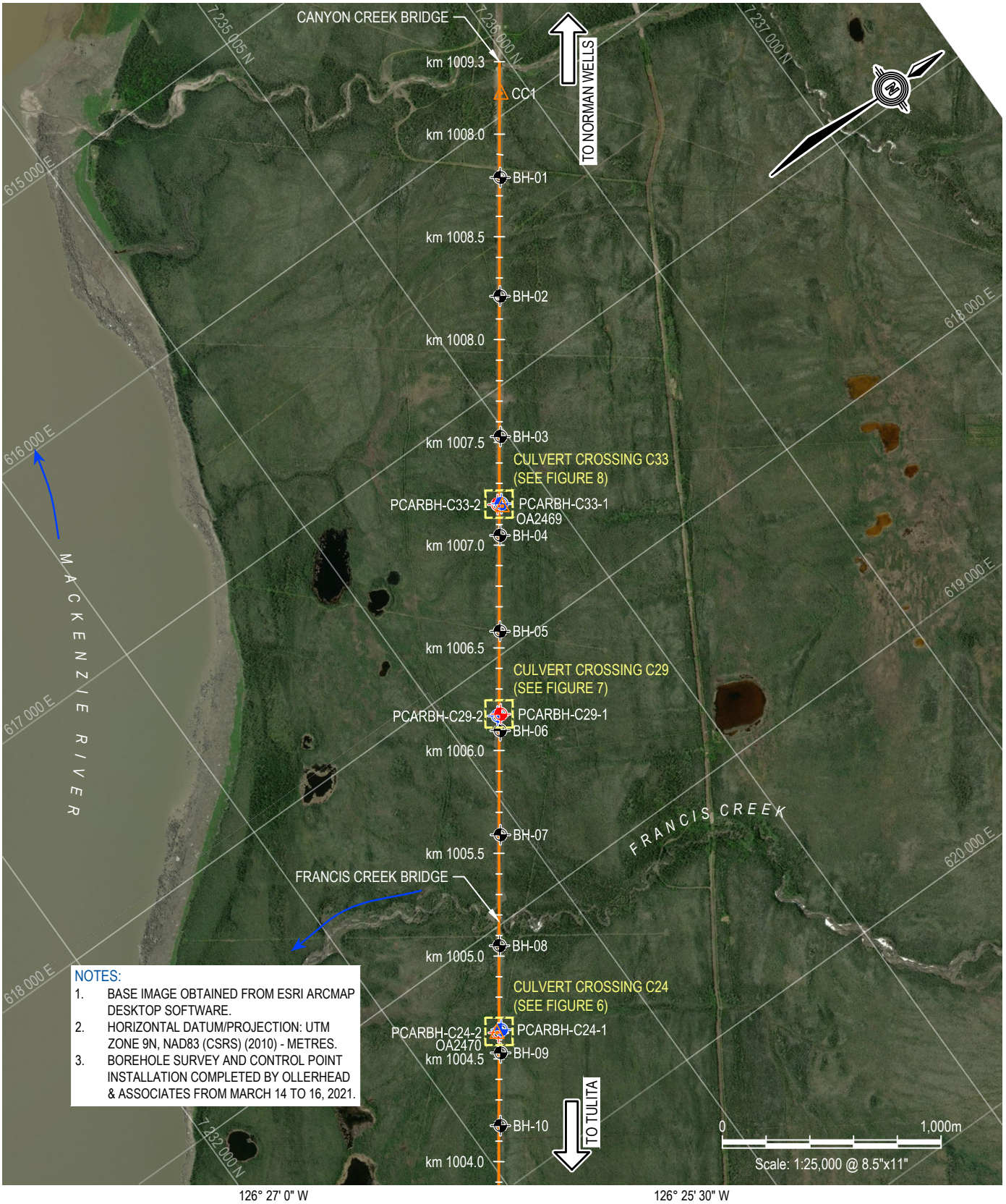
CULVERT CROSSINGS C3 AND C9 SITE PLAN

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

FIGURE 2

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 2-3_Culvert Crossing.dwg [FIGURE 2] October 25, 2021 - 9:41:17 am (BY: LEE, ELVIN)



NOTES:

1. BASE IMAGE OBTAINED FROM ESRI ARCMAP DESKTOP SOFTWARE.
2. HORIZONTAL DATUM/PROJECTION: UTM ZONE 9N, NAD83 (CSRS) (2010) - METRES.
3. BOREHOLE SURVEY AND CONTROL POINT INSTALLATION COMPLETED BY OLLERHEAD & ASSOCIATES FROM MARCH 14 TO 16, 2021.

LEGEND:

- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2020 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- SURVEY CONTROL POINT (OLLERHEAD, 2021)

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD CULVERT CROSSINGS GEOTECHNICAL

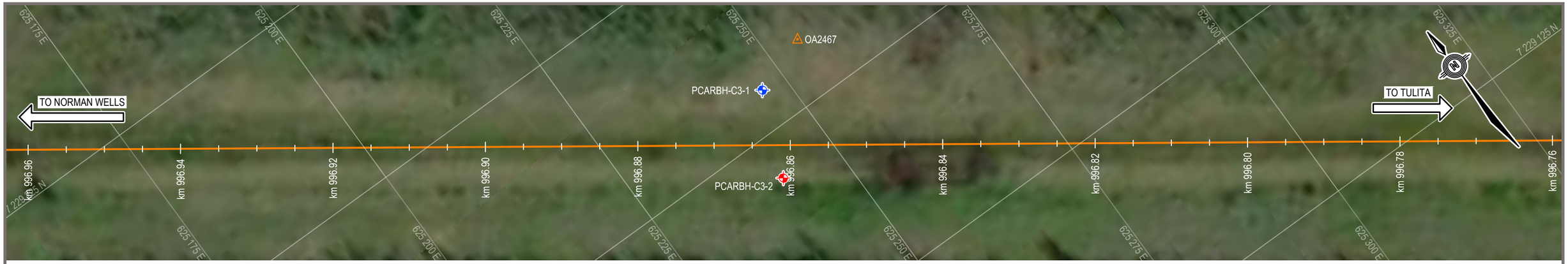
CULVERT CROSSINGS C24, C29, AND C33 SITE PLAN

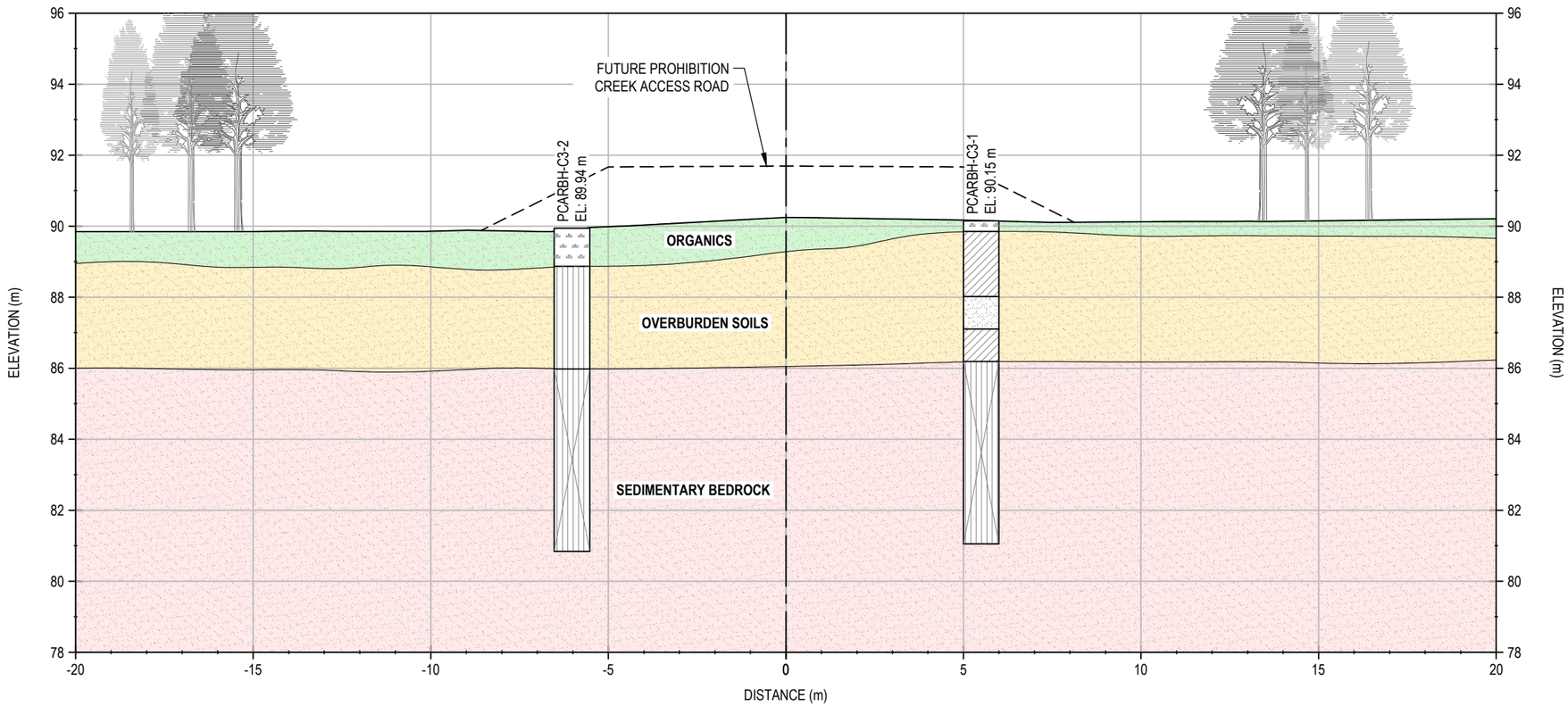
PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

FIGURE 3

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 2-3_Culvert Crossing.dwg [FIGURE 3] October 25, 2021 - 9:41:21 am (BY: LEE, ELVIN)





BOREHOLE INFORMATION SUMMARY			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
PCARBH-C3-1	7,229,180.2	625,246.7	90.2
PCARBH-C3-2	7,229,169.2	625,242.1	89.9

SURVEY CONTROL POINT			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
OA2467	7,229,182.9	625,254.3	90.2

NOTES:
- HORIZONTAL DATUM: UTM ZONE 9N [NAD83, CSRS (2010)]
- VERTICAL EXAGGERATION IN CROSS-SECTION IS 2X.
- PROFILE VIEW NOT TO SCALE.
- STRATIGRAPHIC BOUNDARIES BETWEEN BOREHOLES ARE INTERPRETED.

LEGEND:
- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- SURVEY CONTROL POINT (OLLERHEAD, 2021)
- ORGANICS
- SAND
- MUD SHALE
- CLAY
- SILT

CLIENT: Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

CULVERT CROSSING C3
PLAN AND PROFILE

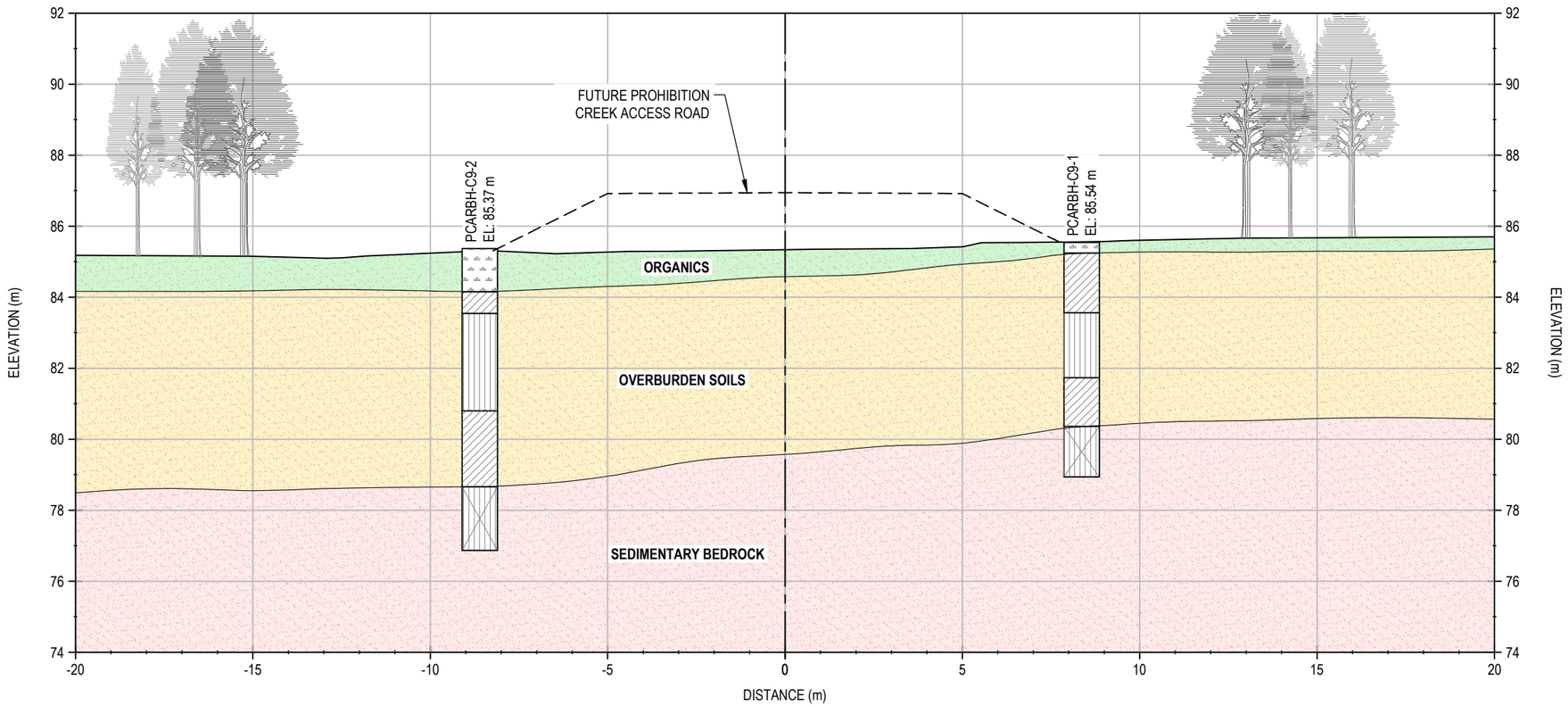
PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

FIGURE 4

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG-YARC03354-02_Figure 4-8_Culvert Crossing.dwg [FIGURE 4] October 25, 2021 - 3:57:50 pm (BY: LEE, ELVIN)





BOREHOLE INFORMATION SUMMARY			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
PCARBH-C9-1	7,230,328.9	623,648.5	85.5
PCARBH-C9-2	7,230,315.9	623,637.6	85.4

SURVEY CONTROL POINT			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
OA2468	7,230,325.5	623,658.8	85.7

NOTES:
- HORIZONTAL DATUM: UTM ZONE 9N [NAD83, CSRS (2010)]
- VERTICAL EXAGGERATION IN CROSS-SECTION IS 2X.
- PROFILE VIEW NOT TO SCALE.
- STRATIGRAPHIC BOUNDARIES BETWEEN BOREHOLES ARE INTERPRETED.

LEGEND:
- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- SURVEY CONTROL POINT (OLLERHEAD, 2021)
- ORGANICS
- SAND
- MUD SHALE
- CLAY
- SILT

CLIENT: Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD CULVERT CROSSINGS GEOTECHNICAL

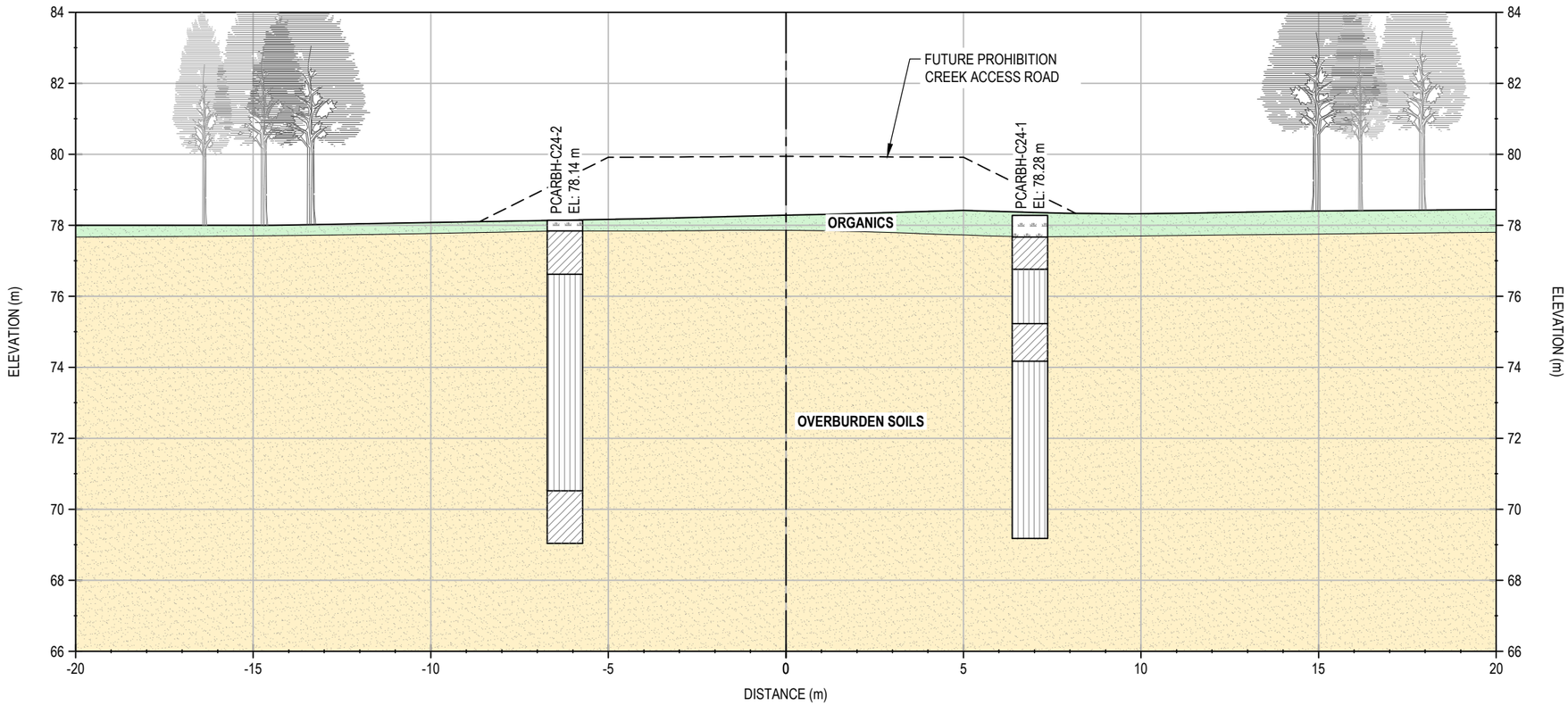
CULVERT CROSSING C9 PLAN AND PROFILE

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU
OFFICE: EDMONTON	DATE: MAY 2021		

FIGURE 5

Q:\Edmonton\Engineering\E1411\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 4-8_Culvert Crossing.dwg [FIGURE 5] October 25, 2021 - 3:57:55 pm (BY: LEE, ELVIN)





BOREHOLE INFORMATION SUMMARY			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
PCARBH-C24-1	7,233,391.3	619,392.3	78.3
PCARBH-C24-2	7,233,373.1	619,395.5	78.1

SURVEY CONTROL POINT			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
OA2470	7,233,367.8	619,392.2	78.0

NOTES:
- HORIZONTAL DATUM: UTM ZONE 9N [NAD83, CSRS (2010)]
- VERTICAL EXAGGERATION IN CROSS-SECTION IS 2X.
- PROFILE VIEW NOT TO SCALE.
- STRATIGRAPHIC BOUNDARIES BETWEEN BOREHOLES ARE INTERPRETED.

LEGEND:
- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- SURVEY CONTROL POINT (OLLERHEAD, 2021)
- ORGANICS
- SAND
- MUD SHALE
- CLAY
- SILT

CLIENT: Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

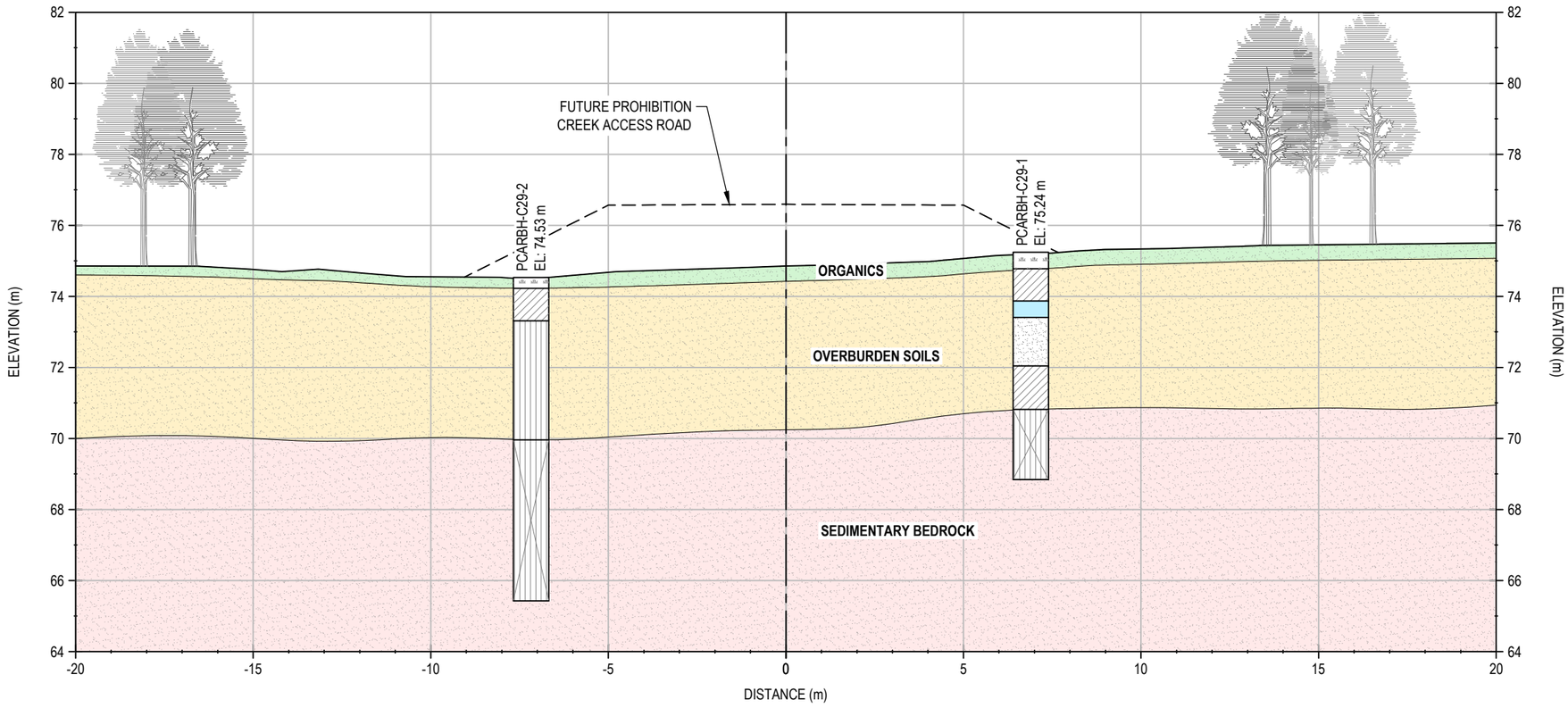
CULVERT CROSSING C24
PLAN AND PROFILE

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU
OFFICE: EDMONTON	DATE: MAY 2021		

FIGURE 6

Q:\Edmonton\Engineering\E1411\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 4-8_Culvert Crossing.dwg [FIGURE 6] October 25, 2021 - 3:58:01 pm (BY: LEE, ELVIN)





BOREHOLE INFORMATION SUMMARY			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
PCARBH-C29-1	7,234,231.4	618,218.9	75.2
PCARBH-C29-2	7,234,215.0	618,218.1	74.5

NOTES:
- HORIZONTAL DATUM: UTM ZONE 9N [NAD83, CSRS (2010)]
- VERTICAL EXAGGERATION IN CROSS-SECTION IS 2X.
- PROFILE VIEW NOT TO SCALE.
- STRATIGRAPHIC BOUNDARIES BETWEEN BOREHOLES ARE INTERPRETED.

LEGEND:
- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- ORGANICS
- SAND
- MUD SHALE
- CLAY
- SILT
- ICE

CLIENT: Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

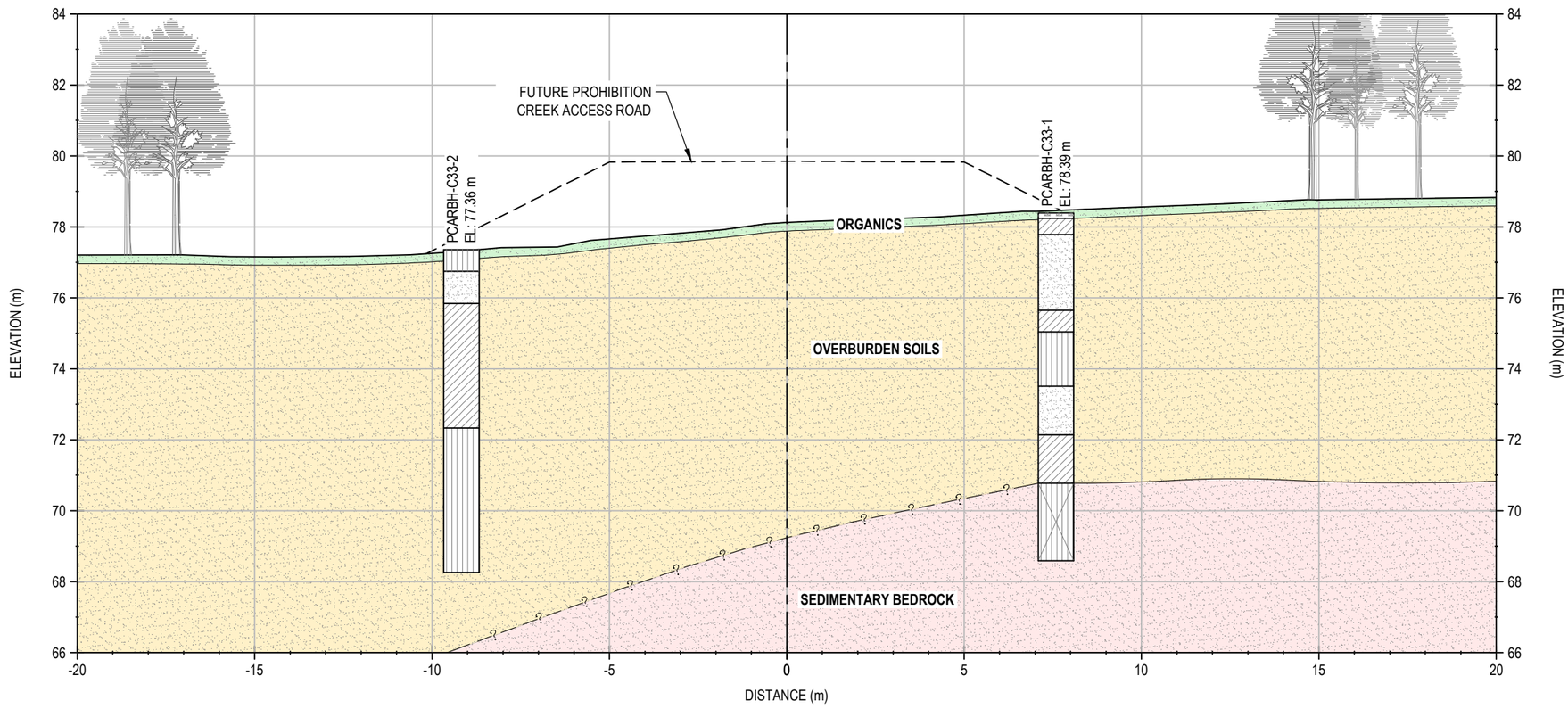
CULVERT CROSSING C29
PLAN AND PROFILE

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU
OFFICE: EDMONTON	DATE: MAY 2021		

FIGURE 7

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 4-8_Culvert Crossing.dwg [FIGURE 7] October 25, 2021 - 3:58:06 pm (BY: LEE, ELVIN)





BOREHOLE INFORMATION SUMMARY			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
PCARBH-C33-1	7,234,794.9	617,439.0	78.4
PCARBH-C33-2	7,234,778.8	617,432.9	77.4

SURVEY CONTROL POINT			
BOREHOLE	NORTHING	EASTING	ELEVATION (m)
OA2469	7,234,792.1	617,451.0	78.5

NOTES:
- HORIZONTAL DATUM: UTM ZONE 9N [NAD83, CSRS (2010)]
- VERTICAL EXAGGERATION IN CROSS-SECTION IS 2X.
- PROFILE VIEW NOT TO SCALE.
- STRATIGRAPHIC BOUNDARIES BETWEEN BOREHOLES ARE INTERPRETED.

LEGEND:
- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2021 BOREHOLE (TETRA TECH)
- 2021 BOREHOLE WITH SINGLE-BEAD THERMISTOR (TETRA TECH)
- SURVEY CONTROL POINT (OLLERHEAD, 2021)
- ORGANICS
- SAND
- MUD SHALE
- CLAY
- SILT

CLIENT: Kǻlo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

CULVERT CROSSING C33
PLAN AND PROFILE

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU
OFFICE: EDMONTON	DATE: MAY 2021		

FIGURE 8

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_Figure 4-8_Culvert Crossing.dwg [FIGURE 8] October 25, 2021 - 3:58:14 pm (BY: LEE, ELVIN)

PHOTOGRAPHS

Photo 1 Drilling Borehole PCARBH-C3-1 (Culvert Crossing C3)
Photo 2 Split-Spoon Sample from Borehole PCARBH-C3-1, Depth 4.5 m
Photo 3 Single-Bead Thermistors installed in Borehole PCARBH-C3-1 (Culvert Crossing C3)
Photo 4 Drilling Borehole PCARBH-C3-2 (Culvert Crossing C3)
Photo 5 Drilling Borehole PCARBH-C9-1 (Culvert Crossing C9)
Photo 6 Split-Spoon Sample from Borehole PCARBH-C9-1, Depth 3.2 m
Photo 7 Drilling Borehole PCARBH-C9-2 (Culvert Crossing C9)
Photo 8 Single-Bead Thermistors installed in Borehole PCARBH-C9-2 (Culvert Crossing C9)
Photo 9 Drilling Borehole PCARBH-C24-1 (Culvert Crossing C24)
Photo 10 Split-Spoon Sample from Borehole PCARBH-C24-1, Depth 7.6 m
Photo 11 Single-Bead Thermistors installed in Borehole PCARBH-C24-1 (Culvert Crossing C24)
Photo 12 Drilling Borehole PCARBH-C24-2 (Culvert Crossing C24)
Photo 13 Drilling Borehole PCARBH-C29-1 (Culvert Crossing C29)
Photo 14 Split-Spoon Sample from Borehole PCARBH-C29-1, Depth 1.2 m
Photo 15 Drilling Borehole PCARBH-C29-2 (Culvert Crossing C29)
Photo 16 Single-Bead Thermistors installed in Borehole PCARBH-C29-2 (Culvert Crossing C29)
Photo 17 Drilling Borehole PCARBH-C33-1 (Culvert Crossing C33)
Photo 18 Split-Spoon Sample from Borehole PCARBH-C33-1, Depth 1.5 m
Photo 19 Single-Bead Thermistors installed in Borehole PCARBH-C33-1 (Culvert Crossing C33)
Photo 20 Drilling Borehole PCARBH-C33-2 (Culvert Crossing C33)



Photo 1: Drilling Borehole PCARBH-C3-1 (Culvert Crossing C3).
(Photo taken March 7, 2021 looking southbound)



Photo 2: Split-Spoon Sample from Borehole PCARBH-C3-1, Depth 4.5 m.
(Photo taken March 7, 2021)



Photo 3: Single-Bead Thermistors installed in Borehole PCARBH-C3-1 (Culvert Crossing C3). (Photo taken March 7, 2021 looking southbound)



Photo 4: Drilling Borehole PCARBH-C3-2 (Culvert Crossing C3). (Photo taken March 7, 2021 looking northwest)



Photo 5: Drilling Borehole PCARBH-C9-1 (Culvert Crossing C9).
(Photo taken March 8, 2021 looking southeast)



Photo 6: Split-Spoon Sample from Borehole PCARBH-C9-1, Depth 3.2 m.
(Photo taken March 8, 2021)



Photo 7: Drilling Borehole PCARBH-C9-2 (Culvert Crossing C9).
(Photo taken March 8, 2021 looking south)



Photo 8: Single-Bead Thermistors installed in Borehole PCARBH-C9-2 (Culvert Crossing C9).
(Photo taken March 8, 2021)



Photo 9: Drilling Borehole PCARBH-C24-1 (Culvert Crossing C24).
(Photo taken March 9, 2021 looking east)

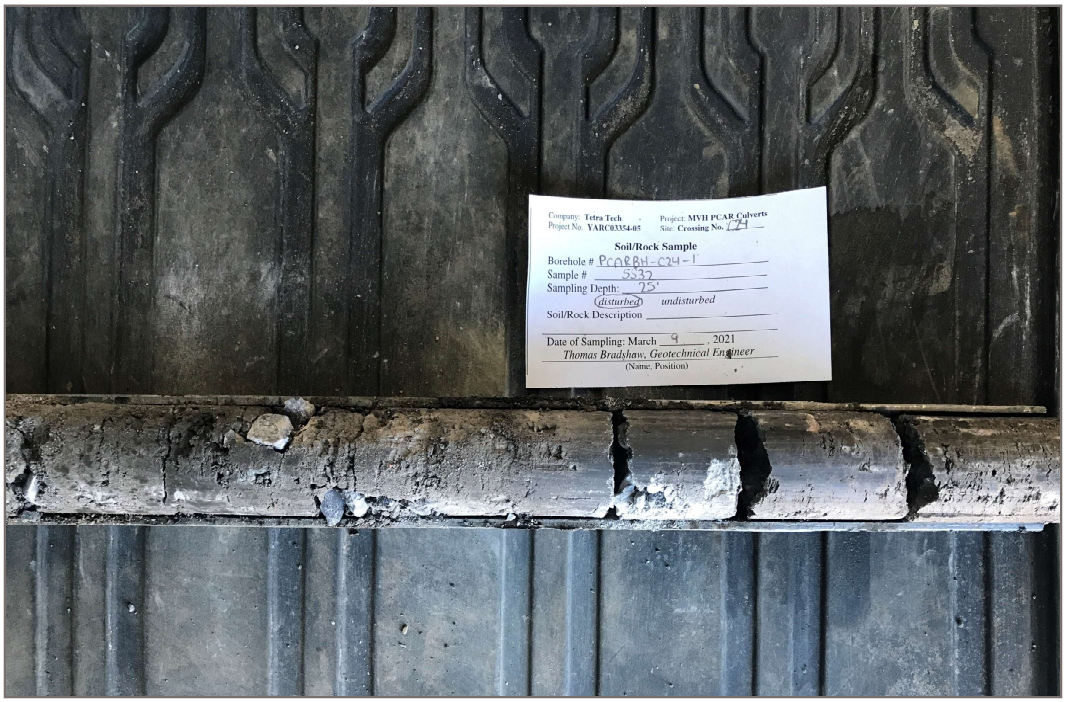


Photo 10: Split-Spoon Sample from Borehole PCARBH-C24-1, Depth 7.6 m.
(Photo taken March 9, 2021)



Photo 11: Single-Bead Thermistors installed in PCARBH-C24-1 (Culvert Crossing C24). (Photo taken March 9, 2021 looking southbound)



Photo 12: Drilling Borehole PCARBH-C24-2 (Culvert Crossing C24). (Photo taken March 9, 2021 looking southbound)



Photo 13: Drilling Borehole PCARBH-C29-1 (Culvert Crossing C29).
(Photo taken March 10, 2021 looking southbound)

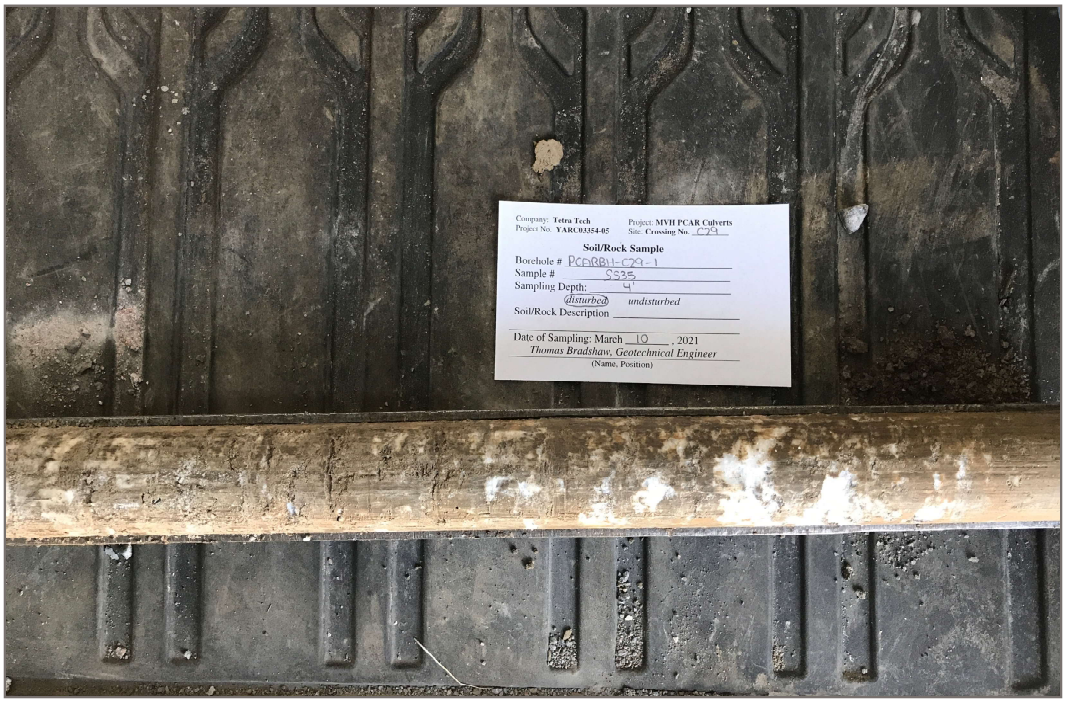


Photo 14: Split-Spoon Sample from Borehole PCARBH-C29-1, Depth 1.2 m.
(Photo taken March 10, 2021)



Photo 15: Drilling Borehole PCARBH-C29-2 (Culvert Crossing C29).
(Photo taken March 10, 2021 looking southbound)



Photo 16: Single-Bead Thermistors installed in PCARBH-C29-2 (Culvert Crossing C29).
(Photo taken March 10, 2021 looking northbound)



Photo 17: Drilling Borehole PCARBH-C33-1 (Culvert Crossing C33).
(Photo taken March 11, 2021 looking northbound)



Photo 18: Split-Spoon Sample from Borehole PCARBH-C33-1, Depth 1.5 m.
(Photo taken March 11, 2021)



Photo 19: Single-Bead Thermistors installed in PCARBH-C33-1 (Culvert Crossing C33). (Photo taken March 11, 2021 looking southbound)



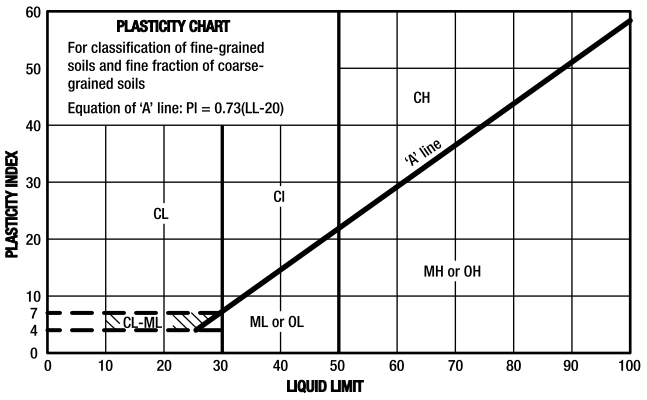
Photo 20: Drilling Borehole PCARBH-C33-2 (Culvert Crossing C33). (Photo taken March 11, 2021 looking northbound)

APPENDIX A

BOREHOLE LOGS

MODIFIED UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS More than 50% retained on 75 µm sieve*	GRAVELS 50% or more of coarse fraction retained on 4.75 mm sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines GW, GP, SW, SP GM, GC, SM, SC Borderline Classification requiring use of dual symbols $C_U = D_{60} / D_{10}$ Greater than 4 $C_C = \frac{(D_{30})2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits plot above "A" line or plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes 4.75 mm sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines	Less than 5% Pass 75 µm sieve More than 12% Pass 75 µm sieve 5% to 12% Pass 75 µm sieve $C_U = D_{60}/D_{10}$ Greater than 6 $C_C = \frac{(D_{30})2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines	Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures	Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures	Atterberg limits plot above "A" line or plasticity index greater than 7	
FINE-GRAINED SOILS (by behavior) 50% or more passes 75 µm sieve*	SILTS Liquid limit <50		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands of slight plasticity		
	SILTS Liquid limit >50		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
	CLAYS Above "A" line on plasticity chart negligible organic content Liquid limit <30		CL	Inorganic clays of low plasticity, gravelly clays, sandy clays, silty clays, lean clays		
	CLAYS Above "A" line on plasticity chart negligible organic content Liquid limit 30-50		CI	Inorganic clays of medium plasticity, silty clays		
	CLAYS Above "A" line on plasticity chart negligible organic content Liquid limit >50		CH	Inorganic clays of high plasticity, fat clays		
	ORGANIC SILTS AND CLAYS Liquid limit <50		OL	Organic silts and organic silty clays of low plasticity		
	ORGANIC SILTS AND CLAYS Liquid limit >50		OH	Organic clays of medium to high plasticity		
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils		



* Based on the material passing the 75 mm sieve

† ASTM Designation D 2487, for identification procedure see D 2488 USC as modified by PFRA

SOIL COMPONENTS

FRACTION	SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY MASS OF MINOR COMPONENTS	
	PASSING	RETAINED	PERCENTAGE	DESCRIPTOR
GRAVEL coarse fine	75 mm 19 mm	19 mm 4.75 mm	>35 % 21 to 35 % 11 to 20 % >0 to 10 %	"and" "y-adjective" "some" "trace"
SAND coarse medium fine	4.75 mm 2.00 mm 425 µm	2.00 mm 425 µm 75 µm		
SILT (non plastic) or CLAY (plastic)	75 µm		as above but by behavior	

OVERSIZE MATERIAL

Rounded or subrounded

COBBLES	75 mm to 300 mm
BOULDERS	> 300 mm

Not rounded

ROCK FRAGMENTS	>75 mm
ROCKS	> 0.76 cubic metre in volume

TETRA TECH

GROUND ICE DESCRIPTION

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	SKETCH	PHOTOGRAPH
V	Vx	Individual ice crystals or inclusions		
	Vc	Ice coatings on particles		
	Vr	Random or irregularly oriented ice formations		
	Vs	Stratified or distinctly oriented ice formations		
	Vu	Ice formations uniformly distributed throughout frozen soil		

ICE NOT VISIBLE

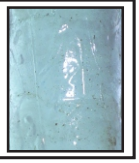
GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	SKETCH	PHOTOGRAPH
N	Nf	Poorly-bonded or friable		
	Nbn	No excess ice, well-bonded		
	Nbe	Excess ice, well-bonded		

LEGEND: Soil ☐ Ice ■

NOTES:

1. Dual symbols are used to indicate borderline or mixed ice classifications.
2. Visual estimates of ice contents indicated on borehole logs ± 5%
3. This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes.

VISIBLE ICE GREATER THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	SKETCH	PHOTOGRAPH
ICE	ICE + Soil Type	Ice with soil inclusions (greater than 25 mm thick)		
	ICE	Ice without soil inclusions (greater than 25 mm thick)		

TETRA TECH

TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075 mm sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as inferred from laboratory or in situ tests.

descriptive term	relative density	n (blows per 0.3 m)
Very Loose	0 to 20%	0 to 4
Loose	20 to 40%	4 to 10
Compact	40 to 75%	10 to 30
Dense	75 to 90%	30 to 50
Very Dense	90 to 100%	greater than 50

The number of blows, N, on a 51 mm O.D. split spoon sampler of a 63.5 kg weight falling 0.76 m, required to drive the sampler a distance of 0.3 m from 0.15 m to 0.45 m.

FINE GRAINED SOILS (major portion passing 0.075 mm sieve): Includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as estimated from laboratory or in situ tests.

descriptive term	unconfined compressive strength (kPa)
Very Soft	Less than 25
Soft	25 to 50
Firm	50 to 100
Stiff	100 to 200
Very Stiff	200 to 400
Hard	Greater than 400

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

GENERAL DESCRIPTIVE TERMS

Slickensided - having inclined planes of weakness that are slick and glossy in appearance.
Fissured - containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated - composed of thin layers of varying colour and texture.
Interbedded - composed of alternate layers of different soil types.
Calcareous - containing appreciable quantities of calcium carbonate.;
Well graded - having wide range in grain sizes and substantial amounts of intermediate particle sizes.
Poorly graded - predominantly of one grain size, or having a range of sizes with some intermediate size missing.

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ROCK DESCRIPTION TERMS USED ON BOREHOLE LOGS

MECHANICAL STRENGTH CALCULATIONS			
TERM	UCS* (MPa)	GRADE	FIELD IDENTIFICATION**
Extremely Strong	> 250	R6	Specimen can only be chipped with geological hammer
Very Strong	100 - 250	R5	Specimen requires many blows of geological hammer to fracture
Strong	50 - 100	R4	Specimen requires more than one blow of geological hammer to fracture
Medium Strong	25 - 50	R3	Cannot be scraped or peeled with pocket knife; can be fractured with single firm blow of geologic hammer
Weak	5 - 25	R2	Can be peeled by pocket knife with difficulty; shallow indentation made by firm blow with geological hammer
Very Weak	1 - 5	R1	Crumbles under firm blow with point of geological hammer; can be peeled by a pocket knife
Extremely Weak	0.25 - 1	R0	Indented by thumbnail
*UCS - unconfined compressive strength; **Correlations determined by Field Identification are approximate.			

GRAIN SIZE			
NON-CARBONATE DETRITAL SEDIMENTARY ROCKS		OTHER ROCKS	GRAIN SIZE
Conglomerate or Breccia		Very Coarse Grained	More than 80 mm
Conglomerate or Breccia		Coarse Grained	4 to 80 mm
Sandstone [1]		Medium Grained	80 µm to 4 mm
FISSILE	NON-FISSILE		
Silt Shale	Siltstone	Fine Grained	> 2/3 silt-sized (2 to 80 µm)
Mud Shale	Mudstone	Fine Grained	Silt and clay-sized (<80 µm)
Clay Shale	Claystone	Very Fine Grained	> 2/3 clay-sized (<2 µm)
[1] Sandstone further subdivided where appropriate into fine, medium, coarse			

DISCONTINUITY SPACING		
BEDDING	OTHER DISCONTINUITY	SPACING
Very Thickly Bedded	Very Widely Spaced	More than 2 m
Thickly Bedded	Widely Spaced	600 mm to 2 m
Medium Bedded	Moderately Widely Spaced	200 to 600 mm
Thinly Bedded	Closely Spaced	60 to 200 mm
Very Thinly Bedded	Very Closely Spaced	20 to 60 mm
Laminated	Extremely Closely Spaced	6 to 20 mm
Thinly Laminated	Extremely Closely Spaced	2 to 6 mm
Fissile	Extremely Closely Spaced	Less than 2 mm

ROCK QUALITY	
TERM	RQD
Very Poor Quality	0 to 25
Poor Quality	25 to 50
Fair Quality	50 to 75
Good Quality	75 to 90
Excellent Quality	90 to 100

WEATHERED STATE	
TERM	DEGREE
Fresh	No visible signs of weathering
Slightly Weathered	Weathering only on open discontinuity surfaces
Moderately Weathered	Rock mass weathered but not friable
Highly Weathered	Rock mass weathered and partly friable
Completely Weathered	Wholly decomposed but texture and structure preserved
Residual Soil	Original rock texture and structure destroyed

CORE RECOVERY	
TERM	DESCRIPTION
Total Core Recovery	Total recovery expressed as a percentage of run length
Solid Recovery	Solid recovery expressed as a percentage of run length
Rock Quality Designation (RQD)	Sum of lengths of solid core more than 100 mm long expressed as a percentage of run length
Fracture Frequency (FF)	The number of fractures per metre of core (FF's in excess of 30 denoted at 30+)

TETRA TECH

BOREHOLE KEYSHEET

Water Level Measurement

 Measured in standpipe, piezometer or well

 Inferred

Sample Types

 A-Casing

 Core

 Disturbed, Bag, Grab

 HQ Core

 Jar

 Jar and Bag

 75 mm SPT

 No Recovery

 Split Spoon/SPT

 Tube

 CRREL Core

Backfill Materials

 Asphalt

 Bentonite

 Cement/ Grout

 Drill Cuttings

 Grout

 Gravel

 Sand

 Slough

 Topsoil Backfill

Lithology - Graphical Legend[1]

 Asphalt

 Bedrock

 Cobbles/Boulders

 Clay

 Coal

 Concrete

 Fill

 Gravel

 Limestone

 Mudstone

 Organics

 Peat

 Sand

 Sandstone

 Shale

 Silt

 Siltstone

 Conglomerate

 Topsoil

 Till

1. The graphical legend is an approximation and for visual representation only. Soil strata may comprise a combination of the basic symbols shown above. Particle sizes are not drawn to scale

TETRA TECH

Borehole No: **PCARBH-C3-1**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C3	Ground Elev: 90.2 m
MVWR km 997, Northwest Territories	UTM: 625246.7 E; 7229180.2 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Temperature (°C)	SPT (N)	Moisture Content (%)	Organics (%) / SPT (N) / Plastic Limit – Moisture Content – Liquid Limit	Thermistors	Elevation (m)
0		ORGANICS (TOPSOIL) - rootlets, grass, black, (300 mm thick)	Frozen, Nbn								90
		CLAY - silty, some sand, low plastic, light brown									
1			Nbe		A1	-1		32			89
					SS2		6	21.4			
2		SAND - silty, trace clay, tan				-0.1					88
		- some gravel, brown, subangular to rounded gravel to 30 mm diameter	Vr ~5%		A3			12.9			
3		- (Gravel - 16%; Sand - 42%; Silt & Clay - 42%)									
		- (Chloride = 110 ppm; Sulphate = 45 ppm)	Nbn		SS4		36	15.2			87
		CLAY - silty, trace sand and gravel, low to medium plastic, dark brown			A5			13.4			
4		- 500 mm boulder, gravel to 25 mm diameter									
	Solid Stem Auger	MUD SHALE - trace sand, fissile, very weak, light grey									86
		- thinly laminated									
					SS6		65	11.9			
5					A7			11.7			85
		- (Gravel - 0%; Sand - 8%; Silt - 66%; Clay - 26%)				-0.4					
6					SS8		50/ 80mm	9.7			84
		- weak, very thinly bedded									
7					A9			8.1			
											83
		- very weak, thinly laminated			SS10		50/ 105mm	9.7			
8											
						-0.4					82
					A11			9.4			
9											
		END OF BOREHOLE (9.1 metres) slough - 8.3 metres at completion Installed Single Bead Thermistor #1B at 1.3 metres Installed Single Bead Thermistor #17 at 2.3 metres Installed Single Bead Thermistor #1A at 5.3 metres Installed Single Bead Thermistor #492 at 8.3 metres All in a 25 mm PVC pipe backfilled with 10/20 filter sand Borehole backfilled with cuttings Note: Ground temperatures measured on March 18, 2021								81
10											80
11											79
12											

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.1 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 7
Logged By: TB	Completion Date: 2021 March 7
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C3-2**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C3	Ground Elev: 90 m
MVWR km 997, Northwest Territories	UTM: 625242.1 E; 7229169.2 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Backfill	Elevation (m)
0								90
	Solid Stem Auger	ORGANICS (TOPSOIL) - rootlets, grass, black	Frozen, Nbn	-4.6				
1		SILT - some sand, trace clay, non plastic, light brown	Vr, Vs~5%					89
		- sandy, trace gravel, light brown, subrounded gravel to 40 mm diameter	Nbn					
2				-1.8				88
3		- occasional gravel to 20 mm diameter		-2.2				87
4		MUD SHALE - trace sand, fissile, very weak, light grey, sedimentary rock fragments to 5 mm diameter		-1				86
		- sedimentary rock fragments to 10 mm diameter		-1.7				
5								85
6		- 300 mm thick brown sand lens, sedimentary rock fragments to 50 mm diameter		-1.3				84
				-0.7				
7								83
			Unfrozen	1.5				
8				1				82
9				0.7				81
		END OF BOREHOLE (9.1 metres) Note: Backfilled at completion with cuttings Ground temperatures measured during auger drilling and are likely thermally disturbed						
10								80
11								79
12								78

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.1 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 7
Logged By: TB	Completion Date: 2021 March 7
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C9-1**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C9	Ground Elev: 85.5 m
MVWR km 999, Northwest Territories	UTM: 623648.5 E; 7230328.9 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Temperature (°C)	SPT (N)	Moisture Content (%)	Backfill	Elevation (m)
0	Solid Stem Auger	ORGANICS (TOPSOIL) - rootlets, black, (300 mm thick)	Frozen, Nbn							85
		CLAY - silty, high plastic, light grey	Vx~2%							
1			Vx~5%							
		- peaty, some silt, black, occasional wood debris	Vx ~10%		A12			60.7		
			Vx~20%			-4				84
			Vx, Vs~15%		SS13		26	43.6		
2		SILT - sandy, gravelly, some clay, non plastic, brown, subangular gravel to 40 mm diameter				-6.5				
		- (Gravel - 25%; Sand - 26%; Silt - 35%; Clay - 14%)			A14			17.7		
		- subrounded to subangular gravel to 55 mm diameter								83
3		- (Chloride = 32 ppm; Sulphate = 64 ppm)								
		- trace sand, no visible gravel, brown grey	Vr, Vs~5%		SS15		36	23		
			Vr, Vs ~10%							82
4		CLAY - silty, trace sand, medium plastic, grey			A16			17.6		
										81
					SS17	-2.5	16	16.9		
5			Vr, Vx~15%							
		MUD SHALE - trace sand, fissile, very weak, light grey	Nbn		A18			11.2		80
		- (Gravel - 0%; Sand - 7%; Silt - 73%; Clay - 20%)								
		- laminated				-3				
6		- thinly laminated			SS19		25/ 80mm	12.1		
										79
		END OF BOREHOLE (6.6 metres)								
7		Note: Stopped due to auger refusal								78
		Backfilled at completion with cuttings								
8		Ground temperatures measured during auger drilling and are likely thermally disturbed								
										77
9										
										76
10										
										75
11										
										74
12										

Moisture Content (%): △ Organics (%) △ (10, 20, 30, 40); ■ SPT (N) ■ (20, 40, 60, 80); Plastic Limit / Moisture Content / Liquid Limit (20, 40, 60, 80)

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 6.6 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 8
Logged By: TB	Completion Date: 2021 March 8
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C9-2**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C9	Ground Elev: 85.4 m
MVWR km 999, Northwest Territories	UTM: 623637.6 E; 7230315.9 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Thermistors	Elevation (m)
0	Solid Stem Auger	ORGANICS (PEAT) - silty, some sand, dark brown, odourous	Frozen, Nbn			-2				85
1		- wood debris	Vx~10% Nbn							
		CLAY - silty, some sand, trace gravel, high plastic, brown grey								84
2		SILT - sandy, some clay, trace gravel, non plastic, light brown, rounded to subangular gravel to 15 mm diameter				-0.4				
		- gravel to 60 mm diameter								83
		- some gravel, trace clay								
3										
		- some sand, no visible gravel								82
4										
		- trace gravel, subangular gravel to 20 mm diameter								
		CLAY - silty, some sand, medium plastic, light grey								81
5		- trace gravel, subangular gravel to 20 mm diameter				-0.6				
										80
6			Vx~2%							
										79
7		MUD SHALE - trace sand, fissile, very weak, light grey								
										78
		- hydrocarbon odour			A20					
8						-0.9				
										77
		END OF BOREHOLE (8.5 metres)								
9		slough - 8.1 metres at completion								
		Installed Single Bead Thermistor #34 at 0.6 metres								76
		Installed Single Bead Thermistor #35 at 2.1 metres								
		Installed Single Bead Thermistor #1C at 5.1 metres								
10		Installed Single Bead Thermistor #3 at 8.1 metres								75
		All in a 25 mm PVC pipe backfilled with 10/20 filter sand								
		Borehole backfilled with cuttings								
11		Note: Ground temperatures measured on March 18, 2021								74
12										

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 8.5 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 8
Logged By: TB	Completion Date: 2021 March 8
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C24-1**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C24	Ground Elev: 78.3 m
MVWR km 1004.6, Northwest Territories	UTM: 619392.3 E; 7233391.3 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Temperature (°C)	SPT (N)	Moisture Content (%)	Organics (%) / SPT (N) / Atterberg Limits	Thermistors	Elevation (m)
0									△ Organics (%) △ 10 20 30 40; ■ SPT (N) ■ 20 40 60 80; Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80		
0	Solid Stem Auger	ORGANICS (TOPSOIL) - dark brown - wood debris	Frozen, Nbn								78
1		CLAY - some silt, trace sand, low plastic, brown - some sand, light brown			A21	-2		17			77
2		SILT - sandy, some clay, non plastic, brown - trace gravel, rounded gravel to 10 mm diameter - (Chloride = 35 ppm; Sulphate = 95 ppm) - (Gravel - 4%; Sand - 33%; Silt - 49%; Clay - 14%) - black, subrounded gravel to 30 mm diameter			SS22 A23	-0.2	12	17.6 21.2			76
3		CLAY - some silt, trace gravel and sand, low to medium plastic, brown, black subrounded gravel to 15 mm diameter - subangular pink gravel to 30 mm diameter	Vs~2% Vx~10% Vs~30%		SS24		35	17.2			75
4		- some sand and gravel, light brown, subrounded gravel to 40 mm diameter	Nbn		A25			11.8			74
5		SILT - sandy, some clay, trace gravel, light grey, subangular gravel - (Gravel - 8%; Sand - 32%; Silt - 45%; Clay - 15%) - some sand, no visible gravel - trace sand, grey	Vs~2% Vs, Vx~25%		SS26 A27	-0.5	50/ 130mm	10.6 10			73
6		- light grey, 75 mm subrounded cobble			SS28 A29		50/ 135mm	9.5			72
7		- some gravel, subrounded to subangular gravel to 45 mm diameter - grey subrounded gravel to 50 mm diameter	Vx~40%		SS30 A31		10/ 0mm	7.5 6.2			71
8		- gravelly, grey, subangular gravel			SS32	-0.6	98/ 260mm	7.9			70
9		- trace gravel			A33			9.5			
10		END OF BOREHOLE (9.1 metres) slough - 7.6 metres at completion Installed Single Bead Thermistor #36 at 0.9 metres Installed Single Bead Thermistor #37 at 1.9 metres Installed Single Bead Thermistor #1133 at 4.9 metres Installed Single Bead Thermistor #1134 at 7.9 metres All in a 25 mm PVC pipe backfilled with 10/20 filter sand Borehole backfilled with cuttings Note: Ground temperatures measured on March 18, 2021									69
11											68
12											67

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.1 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 9
Logged By: TB	Completion Date: 2021 March 9
Reviewed By: EG	Page 1 of 1

NORTHERN ZONE9.GPJ EBA.GDT 21-10-22

Borehole No: **PCARBH-C24-2**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C24	Ground Elev: 78.1 m
MVWR km 1004.6, Northwest Territories	UTM: 619395.5 E; 7233373.1 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Backfill	Elevation (m)
0	Solid Stem Auger	ORGANICS (TOPSOIL) - clayey, rootlets, grass, black, (300 mm thick)	Frozen, Nbn					78
		CLAY - silty, low plastic, light brown						
1		- trace sand		-2.4				77
		SILT - some clay, trace sand, non plastic, light brown		-1.9				
2		- trace gravel, rounded gravel to 10 mm diameter						76
		- occasional gravel, subangular to subrounded gravel to 25 mm diameter		-1.2				
3		- trace gravel, grey		-1.7				75
				-0.7				
4		- occasional gravel, subrounded gravel to 40 mm diameter						74
		- gravel to 20 mm diameter						
5								73
6		- no visible gravel		-0.7				72
		- 100 m thick light brown silt lens						
		- damp		1.4				
7			Unfrozen					71
		- trace gravel, subangular gravel to 20 mm diameter		0.7				
8		CLAY - silty, damp, low plastic, grey						70
9		- trace sand		0.6				69
		END OF BOREHOLE (9.1 metres)						
10		slough - 7.7 metres at completion Note: Backfilled at completion with cuttings Ground temperatures measured during auger drilling and are likely thermally disturbed						68
11								67
12								

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.1 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 9
Logged By: TB	Completion Date: 2021 March 9
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C29-1**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C29	Ground Elev: 75.2 m
MVWR km 1006.2, Northwest Territories	UTM: 618218.9 E; 7234231.4 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Temperature (°C)	SPT (N)	Moisture Content (%)	Backfill	Elevation (m)
0	Solid Stem Auger	ORGANICS (TOPSOIL) - silty, dark brown, peat inclusions	Frozen, Nbn			-14.1				75
		CLAY - some silt, trace sand, low plastic, dark brown								
1		- high plastic			A34	-8.6		58.9		74
		- brown grey	Vr, Vx~20%							
		ICE - some clay, cloudy, light brown and white	Ice		SS35		51	49.6		
2		SAND - some silt, trace gravel and clay, poorly graded, brown, fine sand, subangular gravel to 25 mm diameter	Frozen, Nbn			-9				73
					A36			12.7		
		- (Gravel - 3%; Sand - 64%; Silt & Clay - 33%)								
		- some clay			SS37		50/ 125mm	13.5		
3		- (Chloride = 45 ppm; Sulphate = 88 ppm)								72
		- trace clay, light brown	Vx~20% Nbn			-2.7				
		CLAY - silty, some sand, trace gravel, low plastic, light brown, rounded gravel to 20 mm diameter	Vx~15%		A38			19.1		
4		- some gravel	Vx~20%							71
			Vr, Vs~15%		SS39		12/ 45mm	23.6		
		MUD SHALE - sandy, fissile, weak, grey	Nbn			-1.7				
5					A40			9.4		70
		- (Gravel - 7%; Sand - 37%; Silt - 41%; Clay - 15%)				-0.6				
		- trace sand								
6					SS41		50/ 70mm	12.9		69
					SS42		22/ 65mm			
7		END OF BOREHOLE (6.4 metres) Note: Stopped due to auger refusal. Initial refusal at 4.4 metres. Moved 2.0 metres south and continued Borehole backfilled at completion with cuttings Ground temperatures measured during auger drilling and are likely thermally disturbed								68
8										67
9										
10										66
11										65
12										64

Moisture Content (%): △ Organics (%) △ 10 20 30 40; ■ SPT (N) ■ 20 40 60 80; Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 6.4 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 10
Logged By: TB	Completion Date: 2021 March 10
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C29-2**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C29	Ground Elev: 74.5 m
MVWR km 1006.2, Northwest Territories	UTM: 618218.1 E; 7234215 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Thermistors	Elevation (m)
0	Solid Stem Auger	ORGANICS (TOPSOIL) - dark brown, (300 mm thick)	Frozen, Nbn					74
1		CLAY - some sand and silt, trace gravel, brown, subrounded gravel to 40 mm diameter - some gravel, gravel to 25 mm diameter		-0.1				73
2		SILT - sandy, trace gravel and clay, light brown, rounded to subrounded gravel to 15 mm diameter - occasional gravel, gravel to 25 mm diameter						72
3		- some gravel, subrounded to subangular gravel - trace gravel, gravel to 10 mm diameter		-0.4				71
4		- subangular gravel to 50 mm diameter						70
5		MUD SHALE - trace sand, fissile, weak, grey - light brown, 100 mm thick silt lens		-0.6				69
6		- dark grey, sedimentary rock fragments to 45 mm diameter						68
7								67
8		- sedimentary rock fragments to 60 mm diameter		-0.8				66
9		END OF BOREHOLE (9.1 metres) Installed Single Bead Thermistor #38 at 1.2 metres Installed Single Bead Thermistor #39 at 2.7 metres Installed Single Bead Thermistor #1140 at 5.2 metres Installed Single Bead Thermistor #1141 at 7.7 metres All in a 25 mm PVC pipe backfilled with 10/20 filter sand Borehole backfilled with cuttings Note: Ground temperatures measured on March 18, 2021						65
10								64
11								63
12								

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.1 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 10
Logged By: TB	Completion Date: 2021 March 10
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C33-1**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C33	Ground Elev: 78.4 m
MVWR km 1007.2, Northwest Territories	UTM: 617439 E; 7234794.9 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Temperature (°C)	SPT (N)	Moisture Content (%)	Thermistors	Elevation (m)
0		ORGANICS (PEAT) - rootlets, dark brown, odourous, (150 mm thick)	Frozen, Nbn							78
		CLAY - silty, black brown								
1	Solid Stem Auger	SAND - some silt, trace gravel and clay, well graded, brown, gravel to 10 mm diameter - silty, poorly graded, fine sand			A43			21.2		77
2		- some gravel and silt, subangular to subrounded gravel to 20 mm diameter - (Gravel - 20%; Sand - 54%; Silt & Clay - 26%) - subangular gravel to 35 mm diameter	Vx~10%		SS44 A45	-0.9	81	14.5 12.6		76
3		CLAY - some silt, trace sand, low plastic, brown - (Chloride = 44 ppm; Sulphate = 33 ppm)	Nbn		SS46		50/ 100mm	9		75
4		SILT - some sand and clay, non plastic, brown - sandy, trace gravel, subrounded to subangular gravel to 30 mm diameter			A47	-0.5		15.7		74
5		SAND - some gravel and silt, trace clay, brown, subrounded to angular gravel to 20 mm diameter - gravelly to 10 mm diameter - (Gravel - 28%; Sand - 47%; Silt - 19%; Clay - 6%)	Vx~2% Vr, Vx~4% Vs, Vx~15% Nbn		SS48 A49		50/ 70mm	19 9.6		73
6		- some gravel, rounded gravel to 25 mm diameter			SS50		52	15.3		72
7		CLAY - silty, some sand, trace gravel, low plastic, brown grey, angular gravel to 10 mm diameter - grey - subangular gravel to 40 mm diameter	Vr, Vs~5% Vr, Vs~15% Vs~10%		A51	-0.7		9.2		71
8		MUD SHALE - trace sand, fissile, very weak, grey - sedimentary rock fragments to 15 mm diameter	Nbn Vr, Vs~2% Vr, Vs~10%		SS52 A53		91/ 265mm	10.1 8.4		70
9										69
10		END OF BOREHOLE (9.8 metres) slough - 9.1 metres at completion Installed Single Bead Thermistor #40 at 1.6 metres Installed Single Bead Thermistor #1143 at 4.2 metres Installed Single Bead Thermistor #1135 at 6.8 metres Installed Single Bead Thermistor #1128 at 9.4 metres All in a 25 mm PVC pipe backfilled with 10/20 filter sand Borehole backfilled with cuttings Note: Ground temperatures measured on March 18, 2021				-0.9				68
11										67
12										

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.8 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 11
Logged By: TB	Completion Date: 2021 March 11
Reviewed By: EG	Page 1 of 1

Borehole No: **PCARBH-C33-2**

Project: Prohibition Creek Access Road Culvert Crossings	Project No: ENG.YARC03354-05.001
Location: PCAR Crossing C33	Ground Elev: 77.4 m
MVWR km 1007.2, Northwest Territories	UTM: 617432.9 E; 7234778.8 N; Z 9

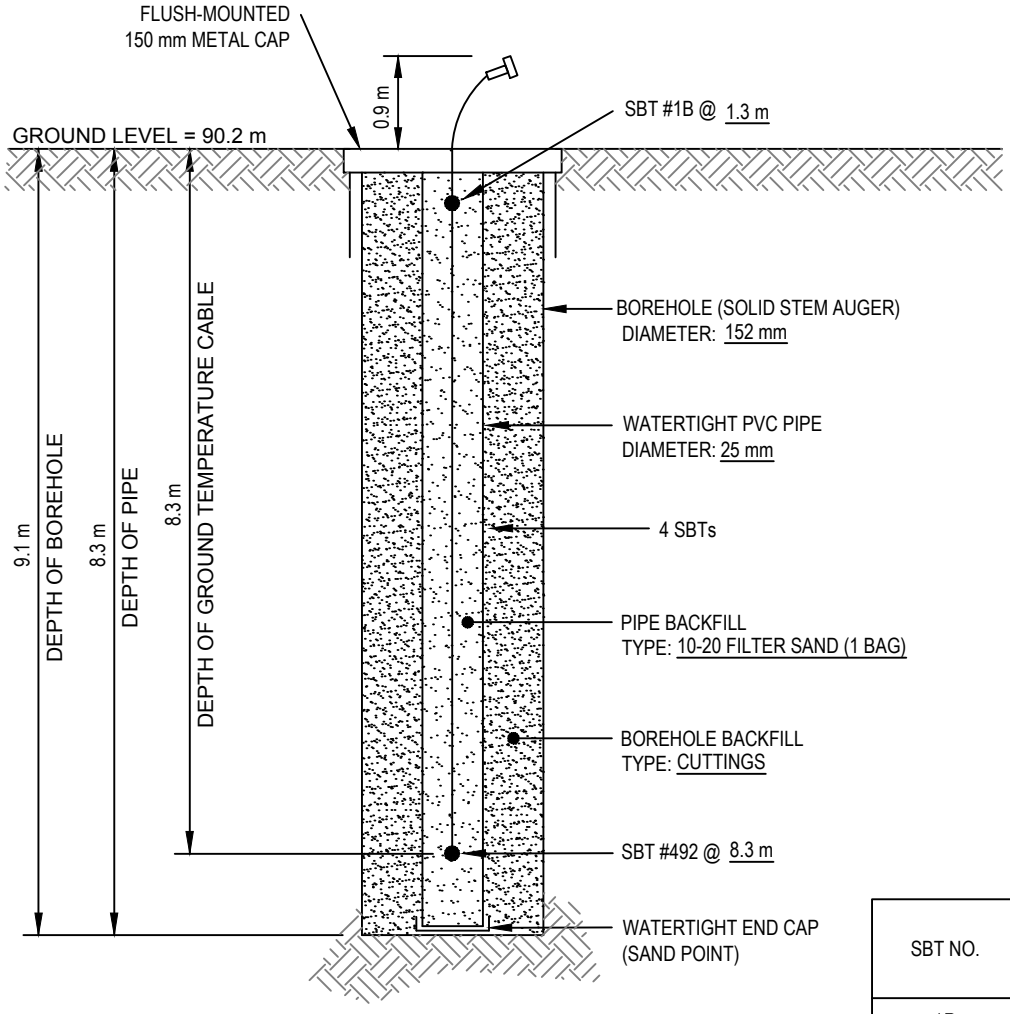
Depth (m)	Method	Soil Description	Ground Ice Description	Temperature (°C)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Backfill	Elevation (m)
0	Solid Stem Auger	ICE - clear, white, (125 mm thick)	Ice					77
		SILT - sandy, some gravel, trace clay, light brown, subangular gravel to 70 mm diameter	Frozen, Nbn	-4.3				
		SAND - some silt and gravel, trace clay, dark brown, subrounded gravel to 20 mm diameter		-4.2				
1		- gravelly, gravel to 50 mm diameter	Vs~10%					76
		CLAY - some sand and silt, trace gravel, low plastic, brown, subrounded to rounded gravel to 20 mm diameter	Nbn					
2				-3.2				75
		- silty, dark brown						
		- subrounded gravel to 55 mm diameter		-3.6				
3								74
		- some silt, trace sand						
4								
		- silty, no visible gravel		-2.4				73
5		SILT - some clay, trace sand, non plastic, grey		-2.6				
								72
6				-1.1				
		- trace gravel		-2.4				71
		- rounded gravel to 45 mm diameter						
7		- subrounded gravel to 55 mm diameter						
		- 300 mm thick sand lens - poorly graded, light brown, fine sand		-2.5				70
8				-2.2				
		- rounded gravel to 35 mm diameter						69
9				-2.2				
		END OF BOREHOLE (9.1 metres) slough - 2.6 metres at completion Note: Backfilled at completion with cuttings Ground temperatures measured during auger drilling and are likely thermally disturbed						68
10								
								67
11								
								66
12								

Contractor: Sahtu Midnight Sun Drilling	Completion Depth: 9.1 m
Equipment Type: Locust Tracked Air Rotary	Start Date: 2021 March 11
Logged By: TB	Completion Date: 2021 March 11
Reviewed By: EG	Page 1 of 1

APPENDIX B

SINGLE-BEAD THERMISTOR INSTALLATION DIAGRAMS

SITE:	PCAR CULVERT CROSSING C3	BOREHOLE NO.:	PCARBH-C3-1
LOCATION:	MVWR km 997.0	CABLE SERIAL NO.:	1B, 17, 1A, 492
COORDINATES:	7,229,180.2 N	DRILLING DATE:	MARCH 7, 2021
	625,246.7 E	INSTALLATION DATE:	MARCH 7, 2021
GROUND ELEVATION:	90.2 m	LEAD LENGTH:	0.9 m
CABLE LENGTH:	9.2 m	1ST BEAD ELEVATION:	88.9 m
NUMBER OF BEADS:	4	HOLE DEPTH:	9.1 m



SBT NO.	DEPTH BELOW OG (m)	TEMPERATURE CALIBRATION CORRECTION (°C)
1B	1.3	0.00
17	2.3	0.02
1A	5.3	0.00
492	8.3	−0.03

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

CULVERT CROSSING C3
SBT INSTALLATION DIAGRAM

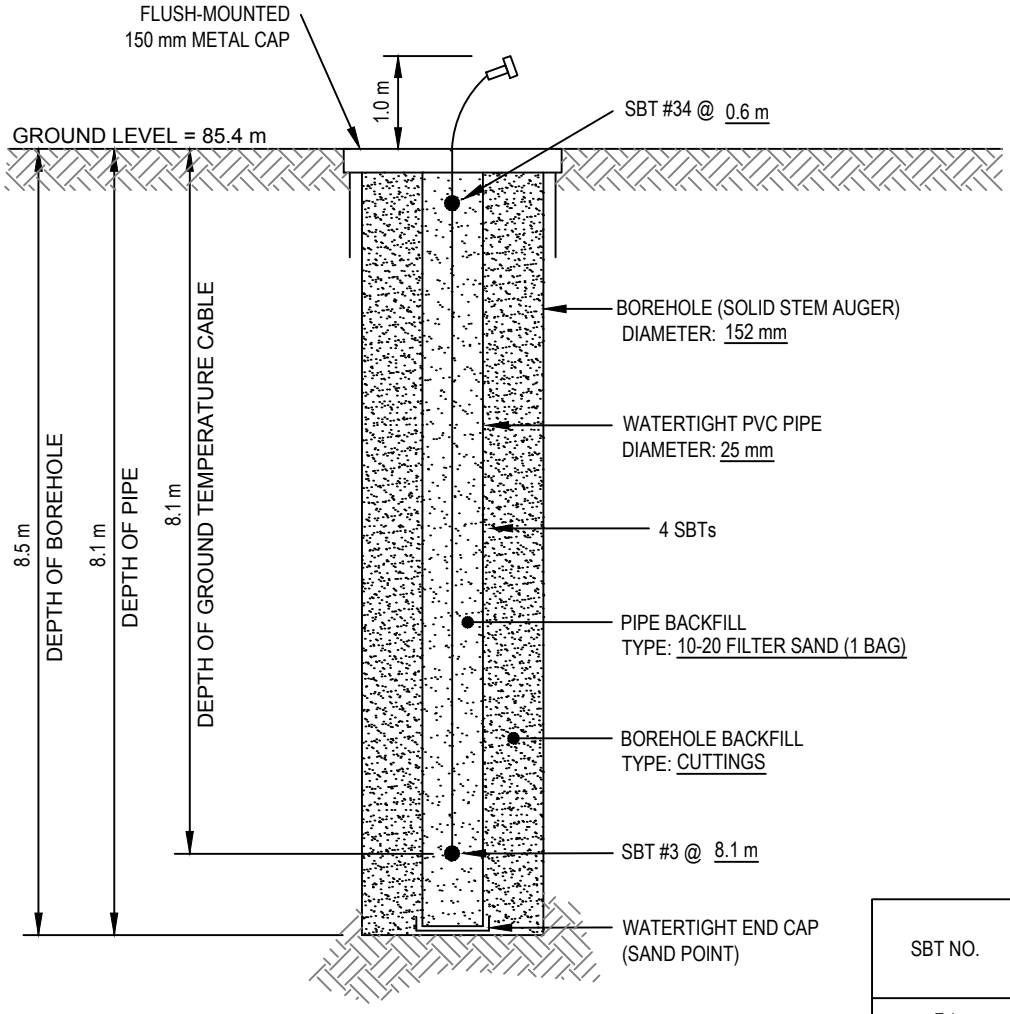
PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

B1

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_B1.dwg [B1] October 25, 2021 - 4:47:53 pm (BY: LEE, ELVIN)

SITE:	PCAR CULVERT CROSSING C9	BOREHOLE NO.:	PCARBH-C9-2
LOCATION:	MVWR km 999.0	CABLE SERIAL NO.:	34, 35, 1C, 3
COORDINATES:	7,230,315.9 N	DRILLING DATE:	MARCH 8, 2021
	623,637.6 E	INSTALLATION DATE:	MARCH 8, 2021
GROUND ELEVATION:	85.4 m	LEAD LENGTH:	1.0 m
CABLE LENGTH:	9.1 m	1ST BEAD ELEVATION:	84.8 m
NUMBER OF BEADS:	4	HOLE DEPTH:	8.5 m



SBT NO.	DEPTH BELOW OG (m)	TEMPERATURE CALIBRATION CORRECTION (°C)
34	0.6	0.00
35	2.1	0.00
1C	5.1	0.02
3	8.1	0.06

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

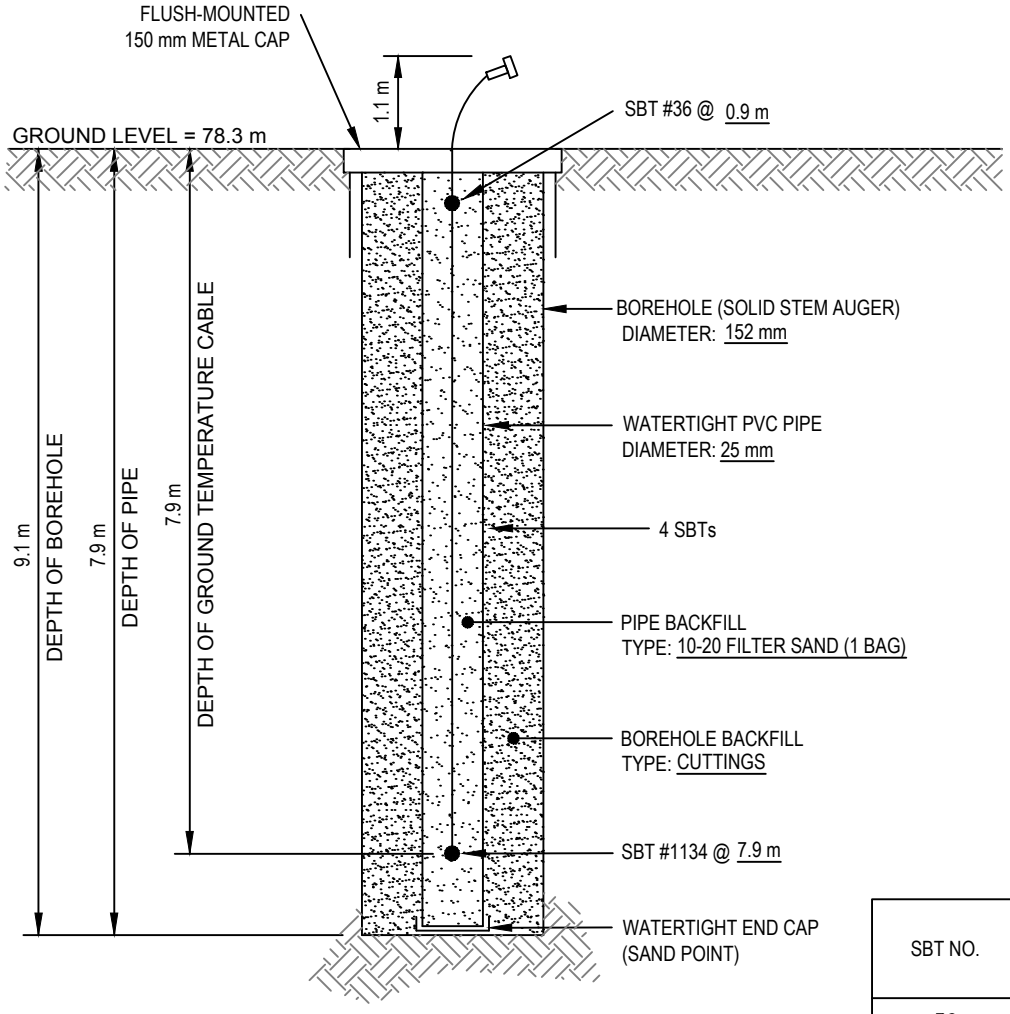
CULVERT CROSSING C9
SBT INSTALLATION DIAGRAM

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU
OFFICE: EDMONTON	DATE: MAY 2021		

B2

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SITE:	PCAR CULVERT CROSSING C24	BOREHOLE NO.:	PCARBH-C24-1
LOCATION:	MVWR km 1004.6	CABLE SERIAL NO.:	36, 37, 1133, 1134
COORDINATES:	7,233,391.3 N	DRILLING DATE:	MARCH 9, 2021
	619,392.3 E	INSTALLATION DATE:	MARCH 9, 2021
GROUND ELEVATION:	78.3 m	LEAD LENGTH:	1.1 m
CABLE LENGTH:	9.0 m	1ST BEAD ELEVATION:	77.4 m
NUMBER OF BEADS:	4	HOLE DEPTH:	9.1 m



SBT NO.	DEPTH BELOW OG (m)	TEMPERATURE CALIBRATION CORRECTION (°C)
36	0.9	0.00
37	1.9	0.00
1133	4.9	0.04
1134	7.9	−0.06

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

CULVERT CROSSING C24
SBT INSTALLATION DIAGRAM

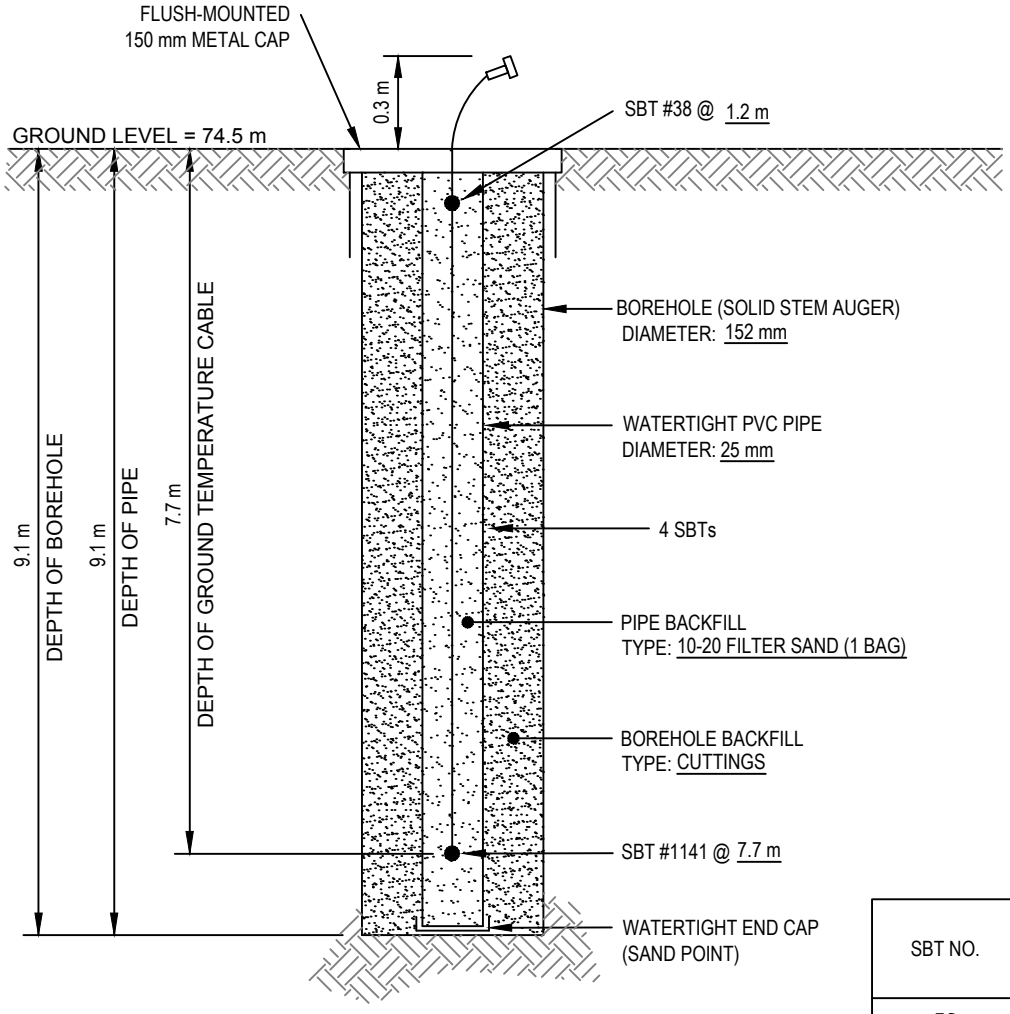
PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

B3

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SITE:	PCAR CULVERT CROSSING C29	BOREHOLE NO.:	PCARBH-C29-2
LOCATION:	MVWR km 1006.2	CABLE SERIAL NO.:	38, 39, 1140, 1141
COORDINATES:	7,234,215.0 N	DRILLING DATE:	MARCH 10, 2021
	618,218.1 E	INSTALLATION DATE:	MARCH 10, 2021
GROUND ELEVATION:	74.5 m	LEAD LENGTH:	0.3 m
CABLE LENGTH:	8.0 m	1ST BEAD ELEVATION:	73.3 m
NUMBER OF BEADS:	4	HOLE DEPTH:	9.1 m



SBT NO.	DEPTH BELOW OG (m)	TEMPERATURE CALIBRATION CORRECTION (°C)
38	1.2	0.00
39	2.7	0.00
1140	5.2	−0.06
1141	7.7	0.00

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

CULVERT CROSSING C29
SBT INSTALLATION DIAGRAM

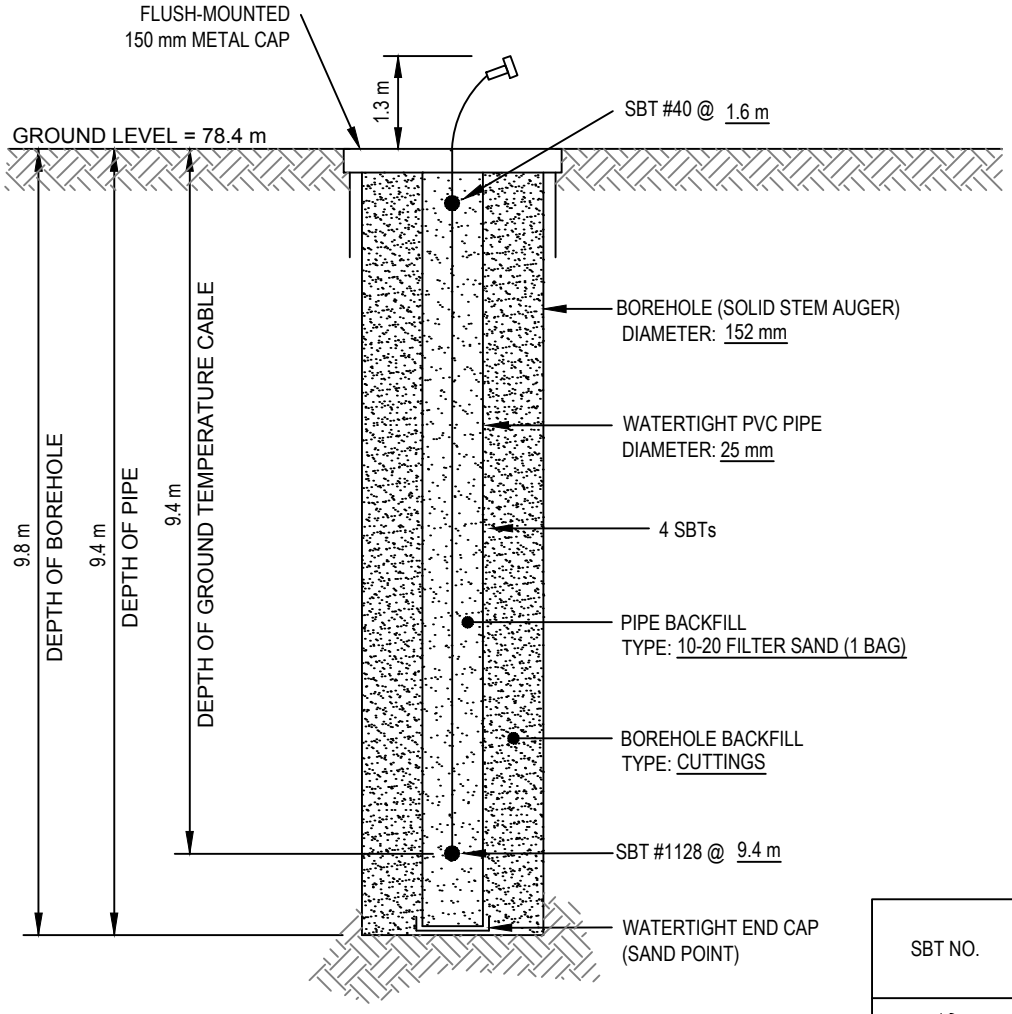
PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

B4

Q:\Edmonton\Engineering\E141\Projects\ENG.YARC03354-02\Production Drawings\PCAR\ENG.YARC03354-02_B4.dwg [B4] October 25, 2021 - 4:47:59 pm (BY: LEE, ELVIN)

SITE:	PCAR CULVERT CROSSING C33	BOREHOLE NO.:	PCARBH-C33-1
LOCATION:	MVWR km 1007.2	CABLE SERIAL NO.:	40, 1143, 1135, 1128
COORDINATES:	7,234,794.9 N	DRILLING DATE:	MARCH 11, 2021
	617,439.0 E	INSTALLATION DATE:	MARCH 11, 2021
GROUND ELEVATION:	78.4 m	LEAD LENGTH:	1.3 m
CABLE LENGTH:	10.7 m	1ST BEAD ELEVATION:	76.8 m
NUMBER OF BEADS:	4	HOLE DEPTH:	9.8 m



SBT NO.	DEPTH BELOW OG (m)	TEMPERATURE CALIBRATION CORRECTION (°C)
40	1.6	0.00
1143	4.2	−0.03
1135	6.8	0.00
1128	9.4	0.11

NOTES:
1. ALL DIMENSIONS ARE IN METRIC.
2. DRAWING NOT TO SCALE.

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

CULVERT CROSSING C33
SBT INSTALLATION DIAGRAM

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU
OFFICE: EDMONTON	DATE: MAY 2021		

B5

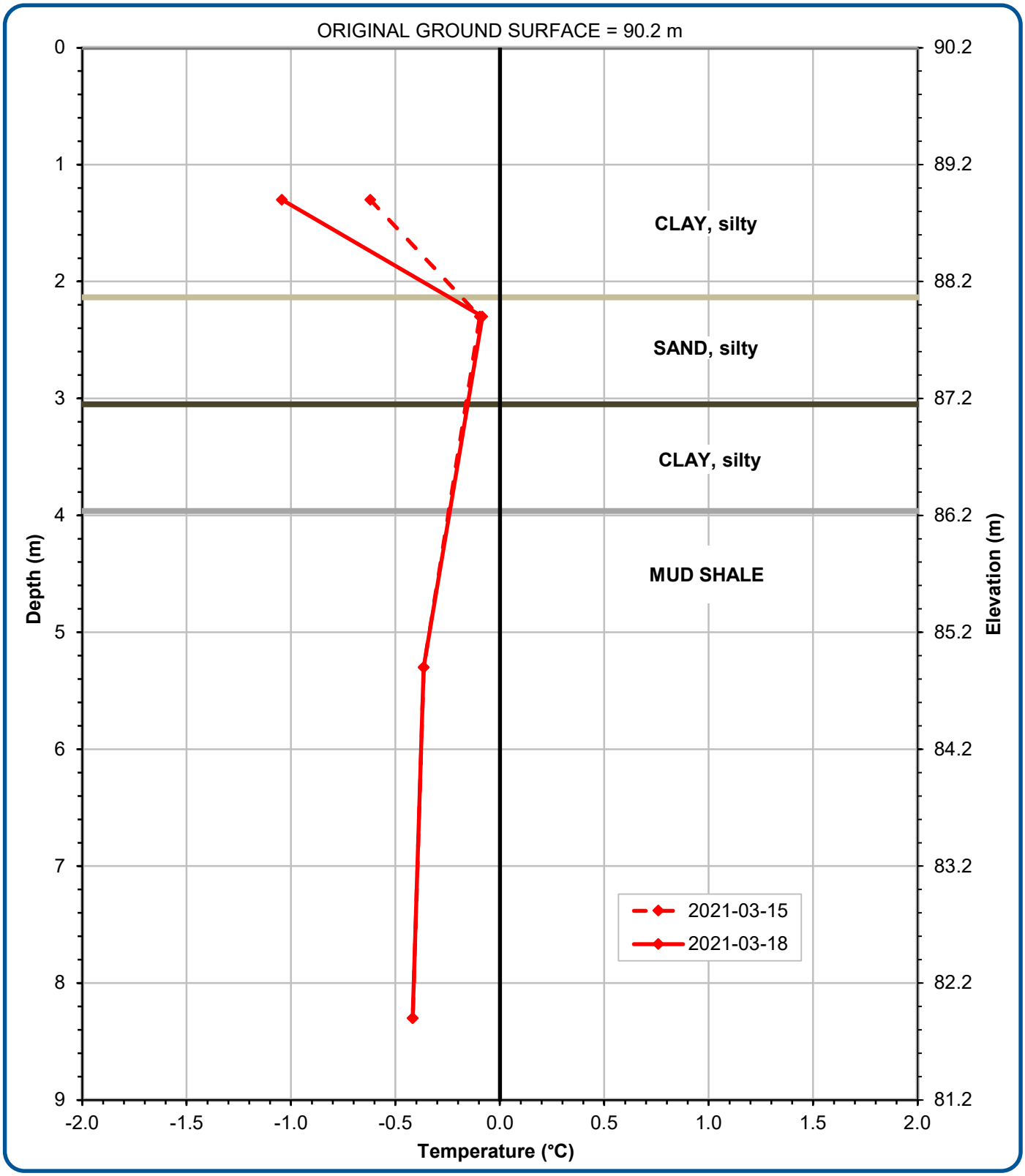
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APPENDIX C

GROUND TEMPERATURE PROFILES

Prohibition Creek Access Road

Culvert Crossing C3 (MVWR km 997.0)



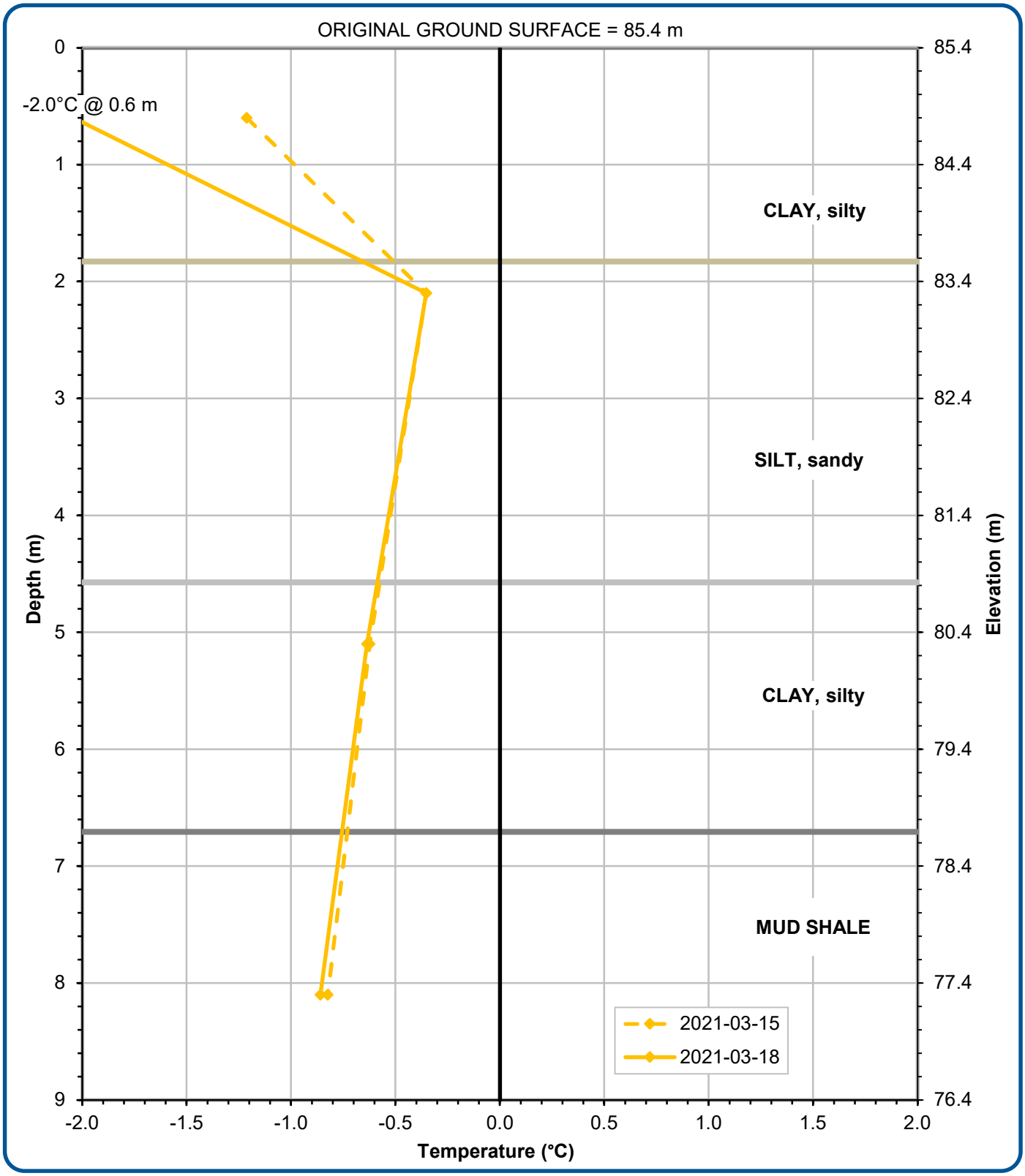
SBT Serial No. 1B, 17, 1A, 492
Date Installed: March 7, 2021

Borehole PCARBH-C3-1
Ground Temperature Profile

TETRA TECH

Prohibition Creek Access Road

Culvert Crossing C9 (MVWR km 999.0)



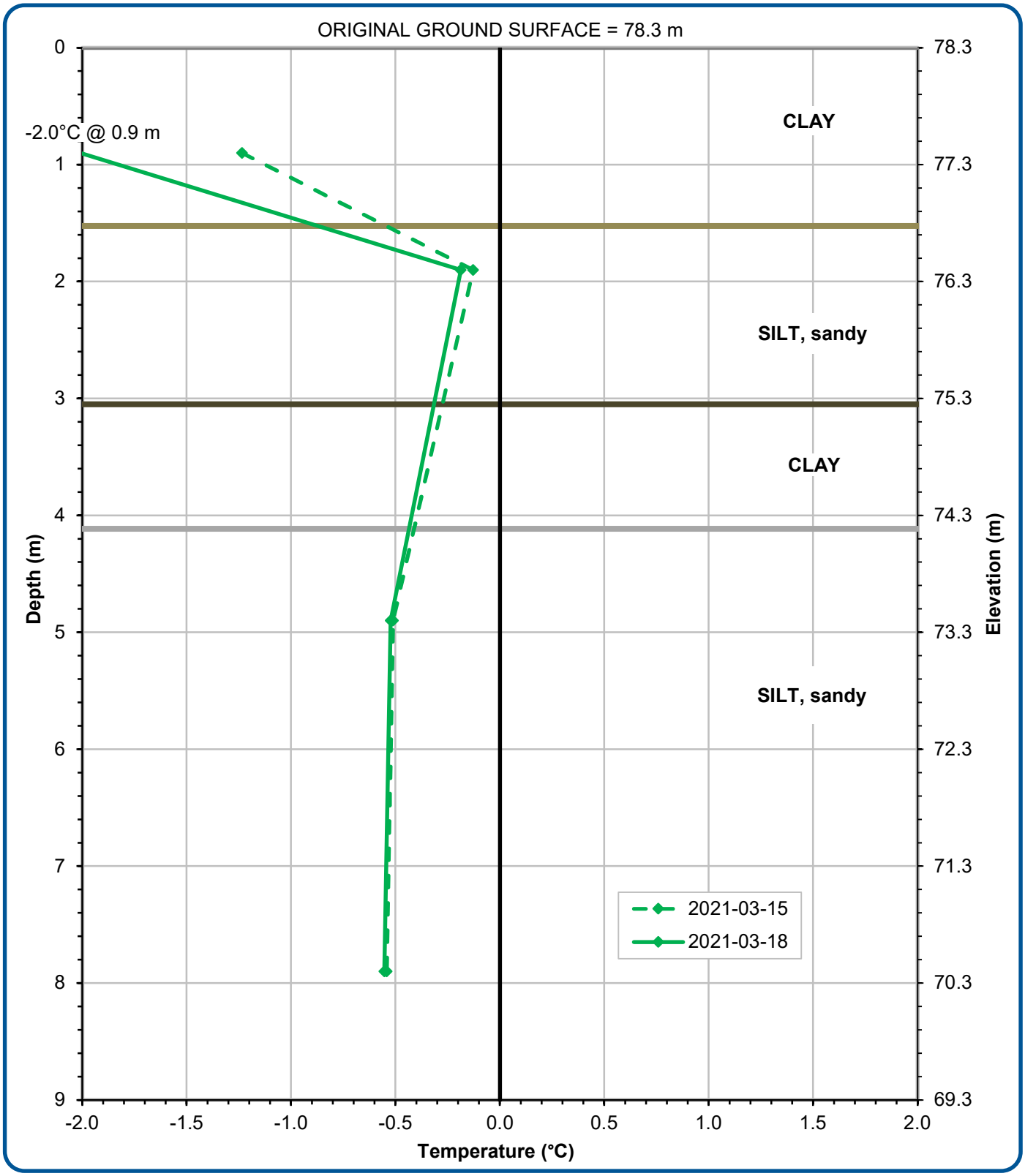
SBT Serial No. 34, 35, 1C, 3
Date Installed: March 8, 2021

Borehole PCARBH-C9-2
Ground Temperature Profile

TETRA TECH

Prohibition Creek Access Road

Culvert Crossing C24 (MVWR km 1004.6)



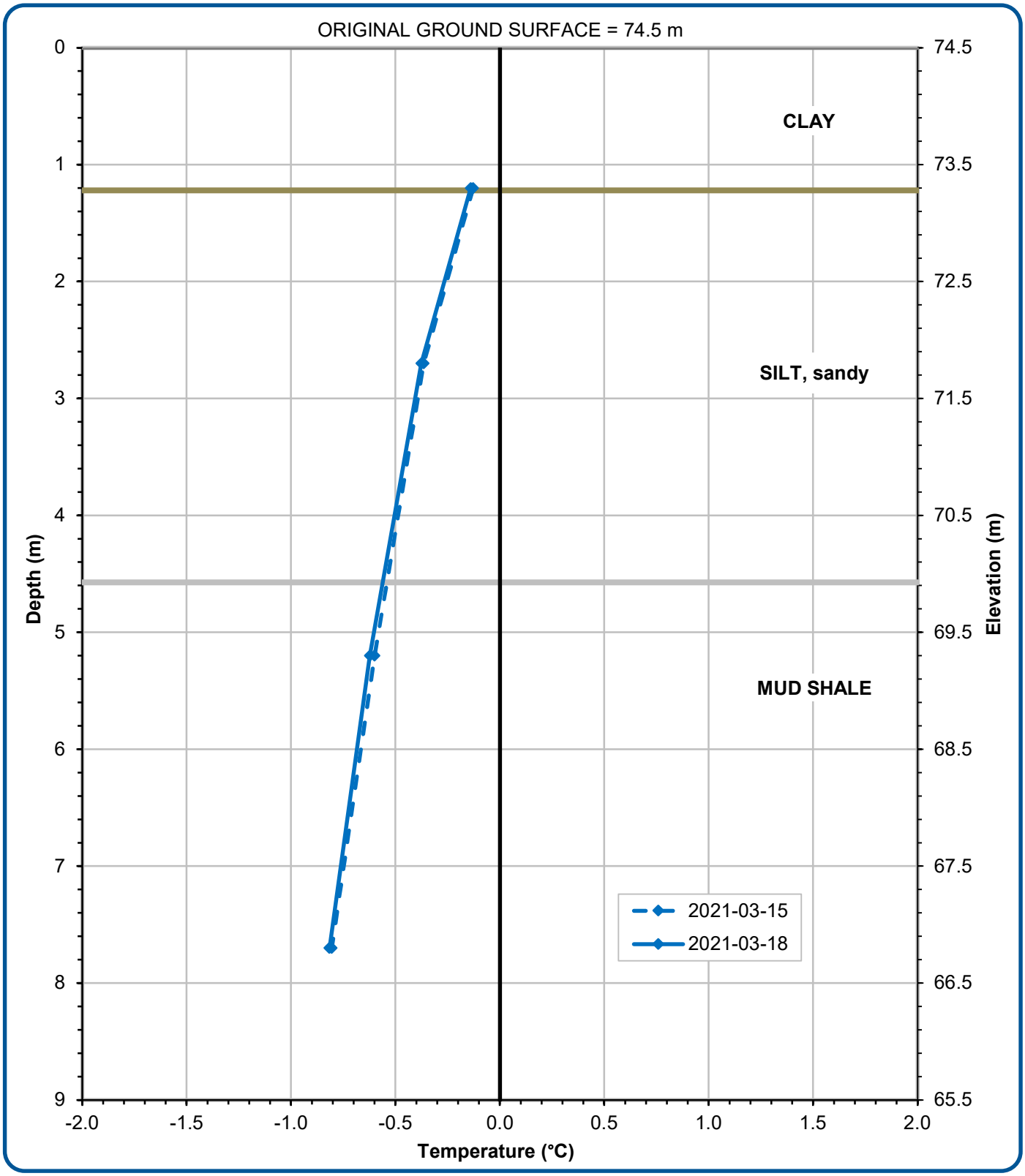
SBT Serial No. 36, 37, 1133, 1134
Date Installed: March 9, 2021

Borehole PCARBH-C24-1
Ground Temperature Profile

TETRA TECH

Prohibition Creek Access Road

Culvert Crossing C29 (MVWR km 1006.2)



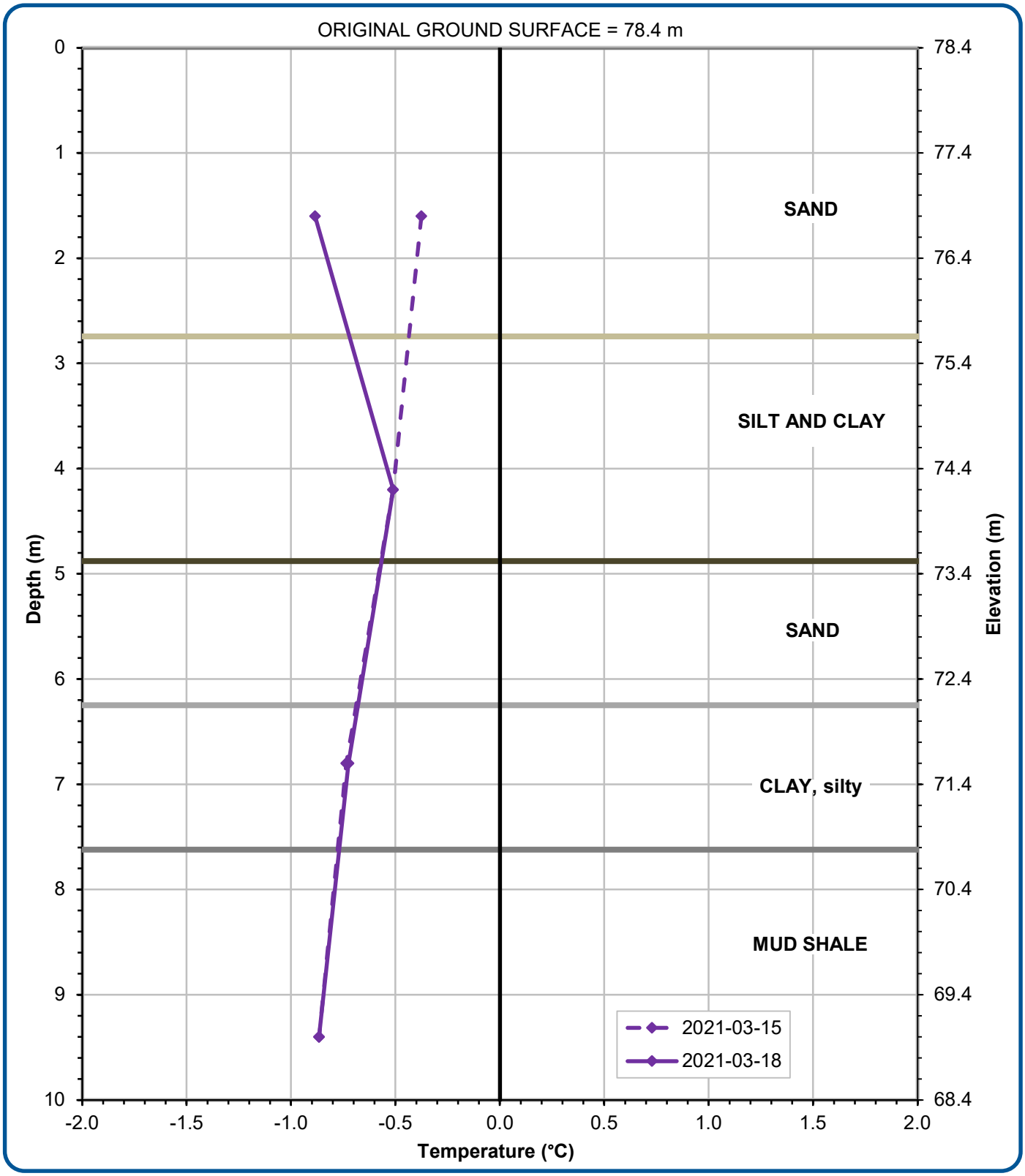
SBT Serial No. 38, 39, 1140, 1141
Date Installed: March 10, 2021

Borehole PCARBH-C29-2
Ground Temperature Profile

TETRA TECH

Prohibition Creek Access Road

Culvert Crossing C33 (MVWR km 1007.2)



SBT Serial No. 40, 1143, 1135, 1128
Date Installed: March 11, 2021

Borehole PCARBH-C33-1
Ground Temperature Profile

TETRA TECH

APPENDIX D

GEOTECHNICAL LABORATORY TEST RESULTS

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Prohibition Creek Access Road Culvert Crossings	Sample No.:	7577
Project No.:	ENG.YARC03354-05.001	Date Tested:	March 20, 2021
Client:	K'alo-Stantec Limited	Tested By:	SI/JPC
Address:	PCARBH-C3-1, MVWR km 997, NT	Page:	1 of 5

B.H. Number	Depth (m)	Moisture Content (%)	Visual Description of Soil
C3-1	1.2 - 1.5	32.0	CLAY, silty, trace sand, organics, brown mottled black
C3-1	1.5 - 2.0	21.4	CLAY, silty, trace sand, brown
C3-1	2.6 - 2.9	12.9	SAND and SILT, some gravel, trace clay, brown with orange streaks
C3-1	3.0 - 3.5	15.2	CLAY, silty, trace sand, brown mottled black
C3-1	3.7 - 4.0	13.4	CLAY, silty, some sand, brown
C3-1	4.6 - 5.0	11.9	CLAY, silty, light grey
C3-1	5.2 - 5.5	11.7	CLAY, silty, trace sand, light grey
C3-1	6.1 - 6.3	9.7	CLAY, silty, light grey
C3-1	7.0 - 7.3	8.1	CLAY, silty, light grey
C3-1	7.6 - 7.9	9.7	CLAY, silty, light grey
C3-1	8.5 - 8.8	9.4	CLAY, silty, light grey

Reviewed By: _____ P.Eng.

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TETRA TECH

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Prohibition Creek Access Road Culvert Crossings	Sample No.:	7577
Project No.:	ENG.YARC03354-05.001	Date Tested:	March 20, 2021
Client:	K'alo-Stantec Limited	Tested By:	SI/JPC
Address:	PCARBH-C9-1, MVWR km 999, NT	Page:	2 of 5

B.H. Number	Depth (m)	Moisture Content (%)	Visual Description of Soil
C9-1	1.2 - 1.5	60.7	CLAY, silty, dark brownish black
C9-1	1.5 - 2.0	43.6	CLAY, some silt, dark brown
C9-1	2.4 - 2.7	17.7	SILT, sandy, gravelly, some clay, brown mottled orange
C9-1	3.0 - 3.5	23.0	CLAY, silty, brown with black spots
C9-1	4.1 - 4.4	17.6	CLAY, silty, trace sand, dark grey
C9-1	4.6 - 5.0	16.9	CLAY, silty, grey
C9-1	5.3 - 5.6	11.2	CLAY, silty, trace sand, light grey
C9-1	6.1 - 6.2	12.1	CLAY, silty, light grey

Reviewed By: _____ P.Eng.

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TETRA TECH

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Prohibition Creek Access Road Culvert Crossings	Sample No.:	7577
Project No.:	ENG.YARC03354-05.001	Date Tested:	March 20, 2021
Client:	K'alo-Stantec Limited	Tested By:	SI/JPC
Address:	PCARBH-C24-1, MVWR km 1004.6, NT	Page:	3 of 5

B.H. Number	Depth (m)	Moisture Content (%)	Visual Description of Soil
C24-1	1.2 - 1.5	17.0	SILT, some sand, trace clay, brown
C24-1	1.5 - 2.0	17.6	SILT, sandy, some clay, brown
C24-1	2.3 - 2.6	21.2	SILT, sandy, some clay, trace gravel, brown
C24-1	3.0 - 3.7	17.2	CLAY, silty, trace gravel, trace sand, brown
C24-1	4.3 - 4.6	11.8	SILT, sandy, some clay, trace gravel, grey
C24-1	4.6 - 4.9	10.6	CLAY, silty, trace sand, trace gravel, grey
C24-1	5.5 - 5.8	10.0	CLAY, silty, trace sand, trace gravel, brownish grey
C24-1	6.1 - 6.4	9.5	CLAY, silty, trace sand, trace gravel, dark brownish grey
C24-1	6.6 - 6.9	7.5	CLAY, silty, trace sand, trace gravel, black
C24-1	7.3 - 7.6	6.2	CLAY, silty, trace sand, trace gravel, black
C24-1	7.6 - 8.0	7.9	CLAY, silty, some sand, some gravel, dark grey
C24-1	8.5 - 8.8	9.5	CLAY, silty, trace sand, trace gravel, dark grey

Reviewed By: _____ P.Eng.

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TETRA TECH

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Prohibition Creek Access Road Culvert Crossings	Sample No.:	7577
Project No.:	ENG.YARC03354-05.001	Date Tested:	March 20, 2021
Client:	K'alo-Stantec Limited	Tested By:	SI/JPC
Address:	PCARBH-C29-1, MVWR km 1006.2, NT	Page:	4 of 5

B.H. Number	Depth (m)	Moisture Content (%)	Visual Description of Soil
C29-1	1.1 - 1.2	58.9	CLAY, some silt, trace sand, dark brown
C29-1	1.2 - 1.7	49.6	SAND, silty, trace clay, trace gravel, brown
C29-1	2.3 - 2.6	12.7	SAND, silty, trace clay, trace gravel, dark brown
C29-1	2.7 - 3.0	13.5	SAND, trace silt, brown
C29-1	3.7 - 4.0	19.1	CLAY, silty, trace sand, brown
C29-1	4.3	23.6	CLAY, silty, trace sand, brown with black spots
C29-1	5.2 - 5.5	9.4	SILT and SAND, some clay, trace gravel, brownish grey
C29-1	5.8 - 6.0	12.9	CLAY, silty, trace sand, trace gravel, grey

Reviewed By: _____ P.Eng.

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TETRA TECH

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Prohibition Creek Access Road Culvert Crossings	Sample No.:	7577
Project No.:	ENG.YARC03354-05.001	Date Tested:	March 20, 2021
Client:	K'alo-Stantec Limited	Tested By:	SI/JPC
Address:	PCARBH-C33-1, MVWR km 1007.2, NT	Page:	5 of 5

B.H. Number	Depth (m)	Moisture Content (%)	Visual Description of Soil
C33-1	0.9 - 1.2	21.2	CLAY, silty, brown
C33-1	1.5 - 2.0	14.5	SAND, gravelly, silty, trace clay, brown
C33-1	2.1 - 2.4	12.6	SAND, silty, some gravel, trace clay, brown
C33-1	2.7 - 2.9	9.0	SAND, silty, some gravel, brown
C33-1	4.0 - 4.3	15.7	SILT, sandy, some clay, trace gravel, brown
C33-1	4.6 - 4.7	19.0	CLAY, silty, trace sand, brown mottled black
C33-1	5.5 - 5.8	9.6	SAND, gravelly, some silt, trace clay, brown
C33-1	6.1 - 6.6	15.3	CLAY, silty, some sand, grey
C33-1	7.0 - 7.3	9.2	CLAY, silty, some gravel, some sand, brownish grey
C33-1	7.6 - 7.9	10.1	CLAY, silty, trace sand, grey
C33-1	8.5 - 8.8	8.4	CLAY, silty, some gravel, trace sand, greyish brown

Reviewed By: _____ P.Eng.

Data presented hereon is for the sole use of the stipulated client. Tetra Tech is not responsible, nor can be held liable, for use made of this report by any other party, with or without the knowledge of Tetra Tech. The testing services reported herein have been performed to recognized industry standards, unless noted. No other warranty is made. These data do not include or represent any interpretation or opinion of specification compliance or material suitability. Should engineering interpretation be required, Tetra Tech will provide it upon written request.

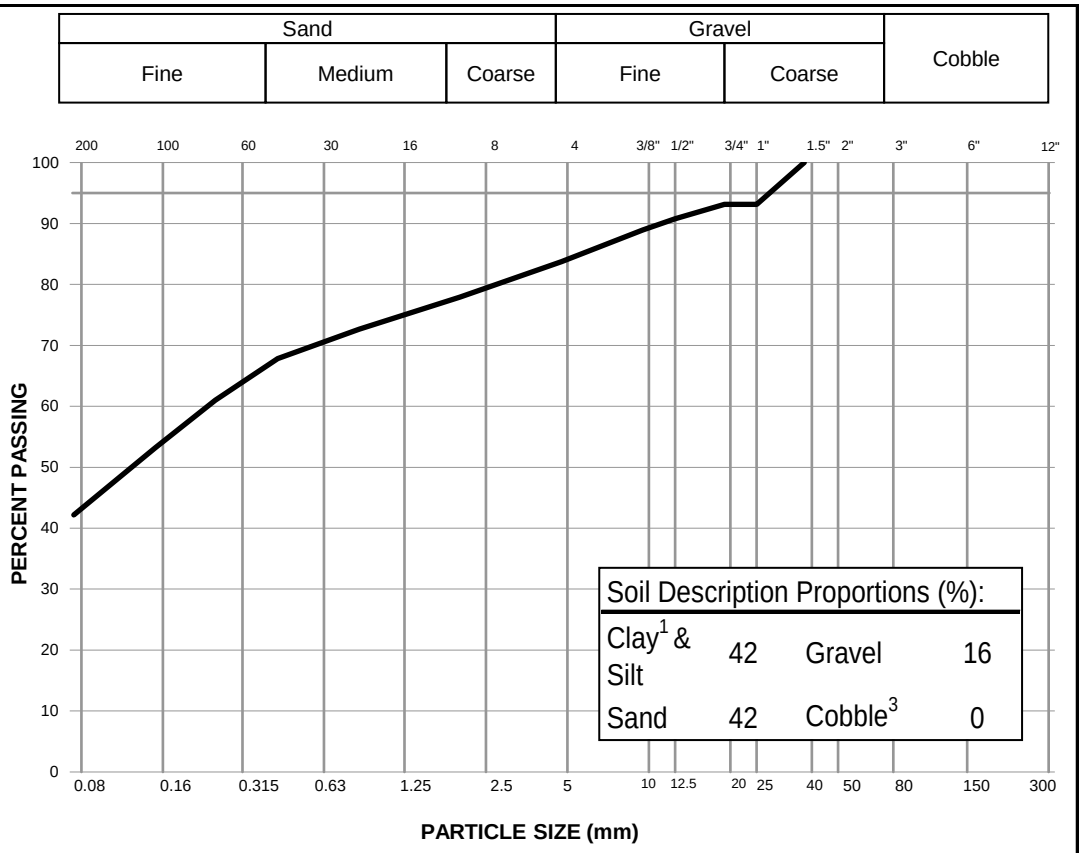
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A3
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 997	Sample Loc.:	PCARBH-C3-1
Client:	K'alo-Stantec Limited	Sample Depth:	2.6 - 2.9 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 23, 2021 By: JPC	Date sampled:	March 7, 2021
Soil Description[2]:	SAND and SILT, some gravel, trace clay, brown with orange streaks	Sampled By:	TAB
		USC Classification:	SM Cu: #N/A
Moisture Content:	12.9%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	
50	
37.5	100
25	93
19	93
12.5	91
9.5	89
4.75	84
2	78
0.85	73
0.425	68
0.25	61
0.15	53
0.075	42.2



Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to Tt WM4400 description protocols
[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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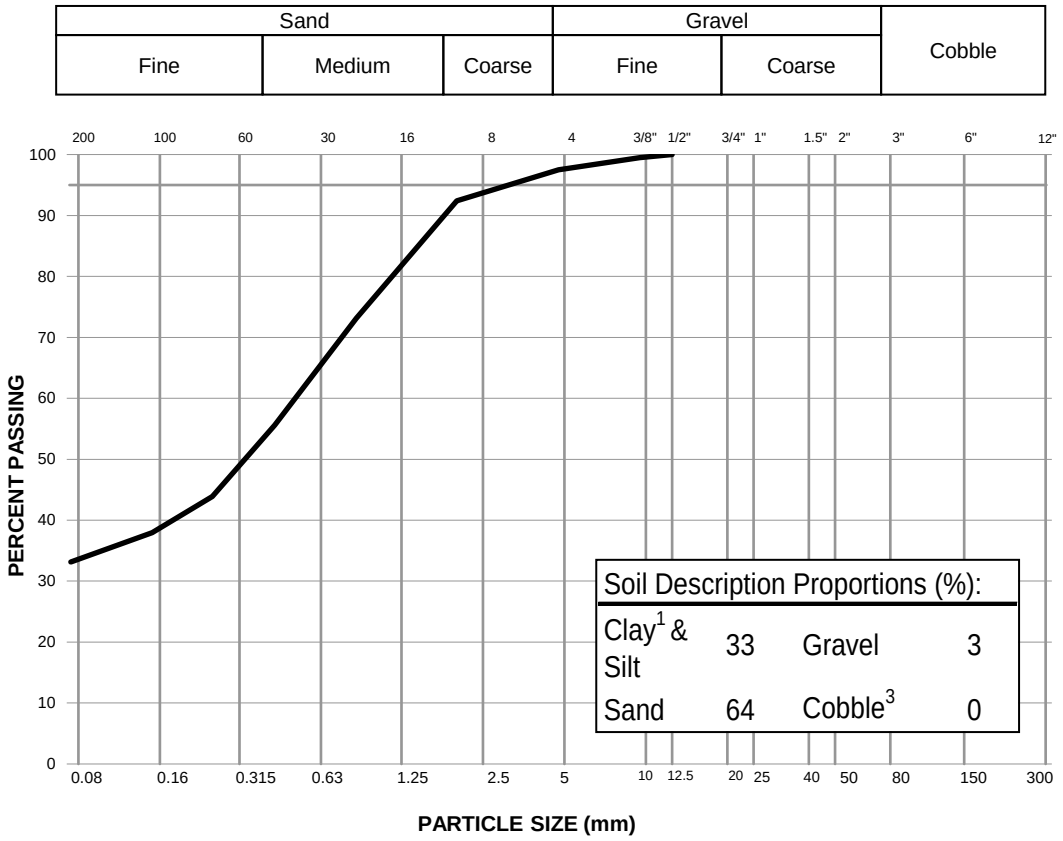
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A36
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 1006.2	Sample Loc.:	PCARBH-C29-1
Client:	K'alo-Stantec Limited	Sample Depth:	2.3 - 2.6 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 23, 2021 By: JPC	Date sampled:	March 10, 2021
Soil Description[2]:	SAND, silty, trace clay, trace gravel, dark brown	Sampled By:	TAB
		USC Classification:	SM Cu: #N/A
Moisture Content:	12.7%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	
50	
37.5	
25	
19	
12.5	100
9.5	99
4.75	97
2	92
0.85	73
0.425	56
0.25	44
0.15	38
0.075	33.1



Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to Tt WM4400 description protocols
[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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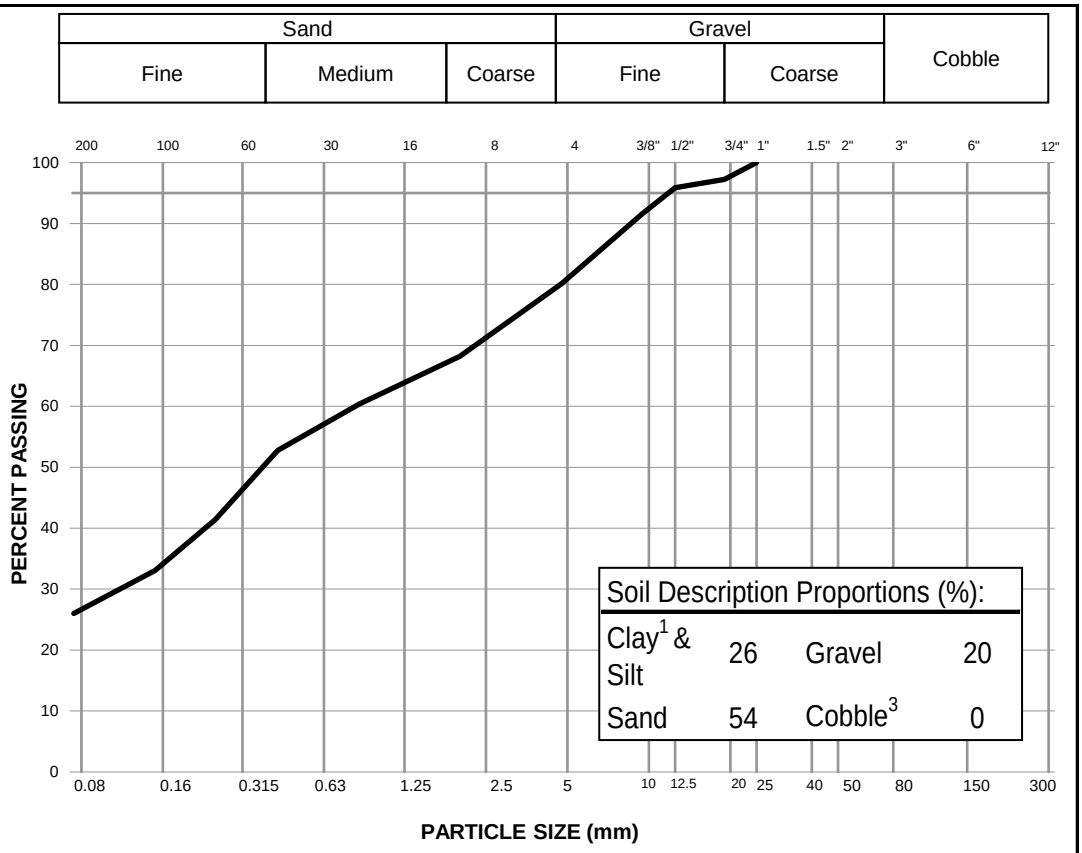
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A45
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 1006.2	Sample Loc.:	PCARBH-C33-1
Client:	K'alo-Stantec Limited	Sample Depth:	2.1 - 2.4 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 23, 2021 By: JPC	Date sampled:	March 11, 2021
Soil Description[2]:	SAND, silty, some gravel, trace clay, brown	Sampled By:	TAB
		USC Classification:	SM Cu: #N/A
Moisture Content:	12.6%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	
50	
37.5	
25	100
19	97
12.5	96
9.5	92
4.75	80
2	68
0.85	60
0.425	53
0.25	41
0.15	33
0.075	26.0



Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to Tt WM4400 description protocols
[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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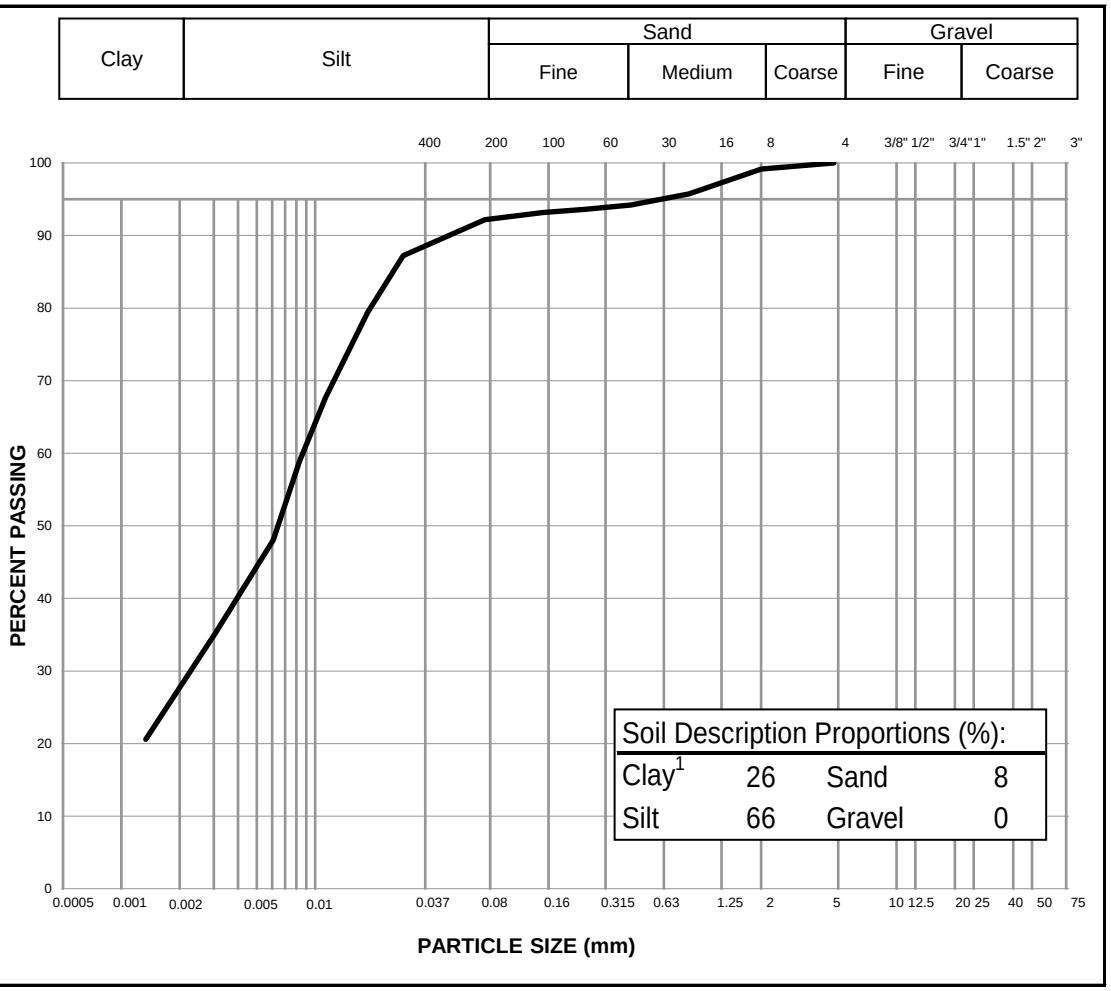
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A7
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 997	Sample Loc.:	PCARBH-C3-1
Client:	K'alo-Stantec Limited	Sample Depth:	5.2 - 5.5 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 7, 2021
Soil Description[2]:	CLAY, silty, trace sand, light grey	Sampled By:	TAB
		USC Classification:	CL-CI Cu: #N/A
Moisture Content:	11.7%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
37.5	
25	
19	
12.5	
9.5	
4.75	100
2	99
0.85	96
0.425	94
0.25	94
0.15	93
0.075	92.2
0.0285	87.2
0.0187	79.4
0.0113	67.6
0.0083	58.8
0.0061	48.0
0.0031	35.3
0.0013	20.6



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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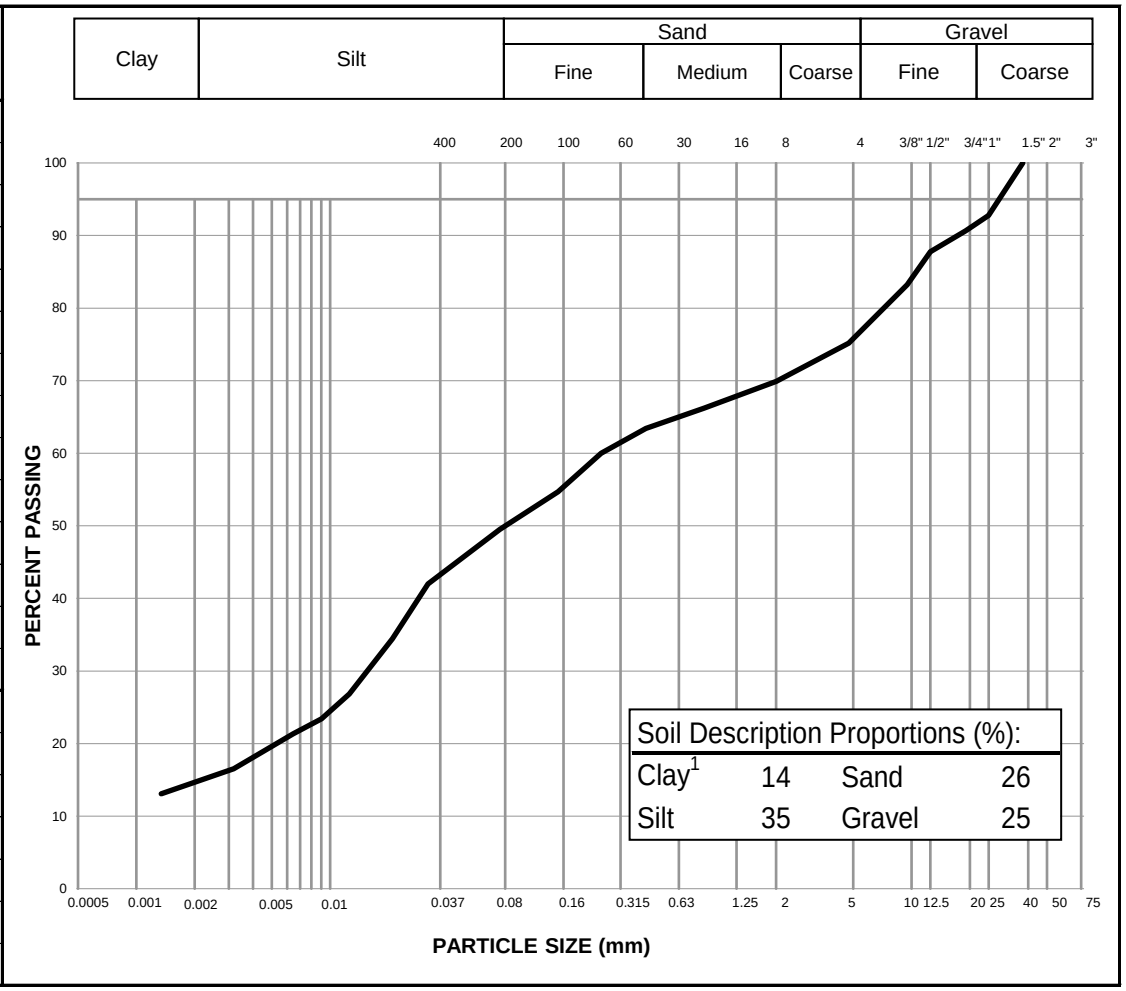
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A14
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 999	Sample Loc.:	PCARBH-C9-1
Client:	K'alo-Stantec Limited	Sample Depth:	2.4 - 2.7 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 8, 2021
Soil Description[2]:	SILT, sandy, gravelly, some clay, brown mottled orange	Sampled By:	TAB
		USC Classification:	ML Cu: #N/A
Moisture Content:	17.7%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
37.5	100
25	93
19	91
12.5	88
9.5	83
4.75	75
2	70
0.85	66
0.425	63
0.25	60
0.15	55
0.075	49.5
0.0319	42.0
0.0210	34.4
0.0126	26.8
0.0090	23.4
0.0064	21.3
0.0032	16.5
0.0013	13.1



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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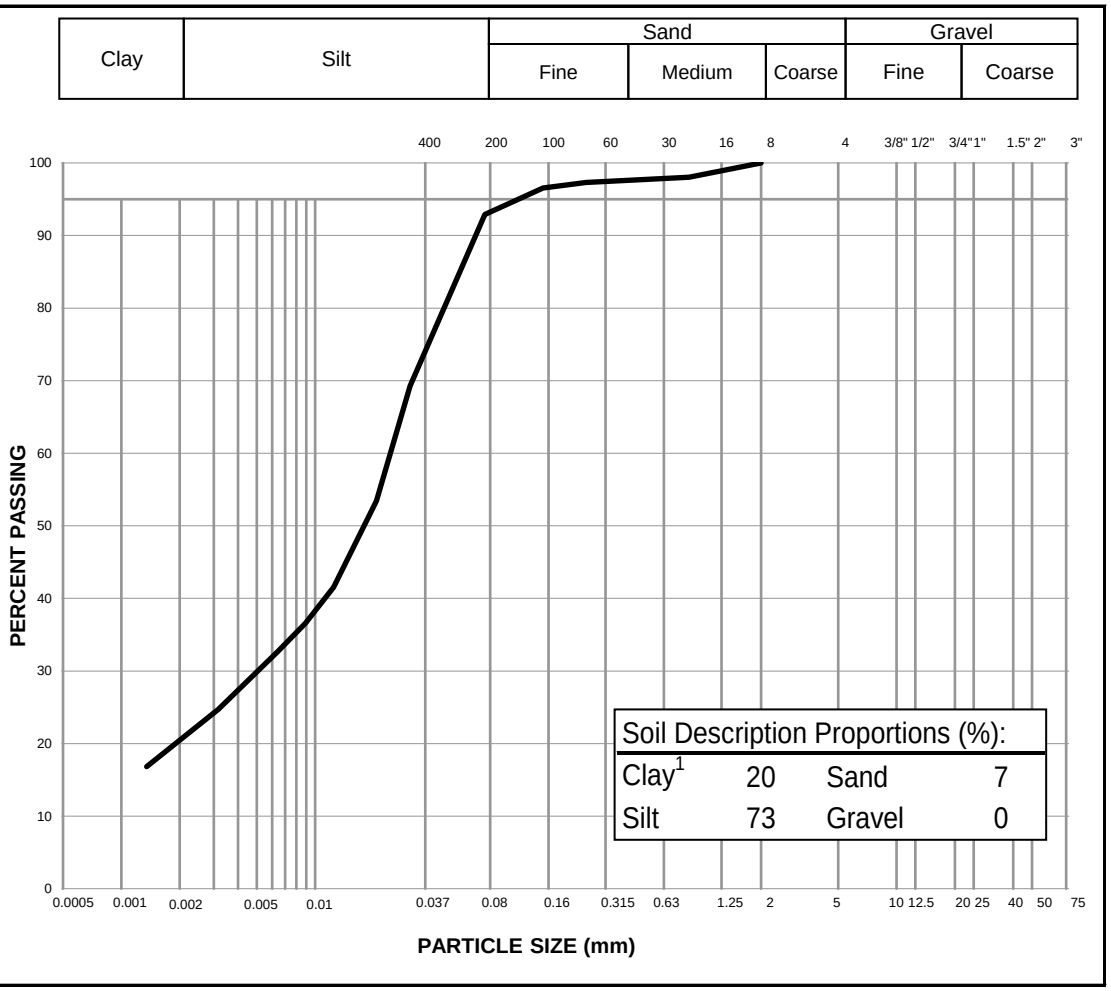
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A18
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 999	Sample Loc.:	PCARBH-C9-1
Client:	K'alo-Stantec Limited	Sample Depth:	5.3 - 5.6 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 8, 2021
Soil Description[2]:	CLAY, silty, trace sand, light grey	Sampled By:	TAB
		USC Classification:	CI Cu: #N/A
Moisture Content:	11.2%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
37.5	
25	
19	
12.5	
9.5	
4.75	
2	100
0.85	98
0.425	98
0.25	97
0.15	97
0.075	92.9
0.0309	69.3
0.0207	53.4
0.0125	41.6
0.0089	36.6
0.0064	32.7
0.0032	24.7
0.0014	16.8



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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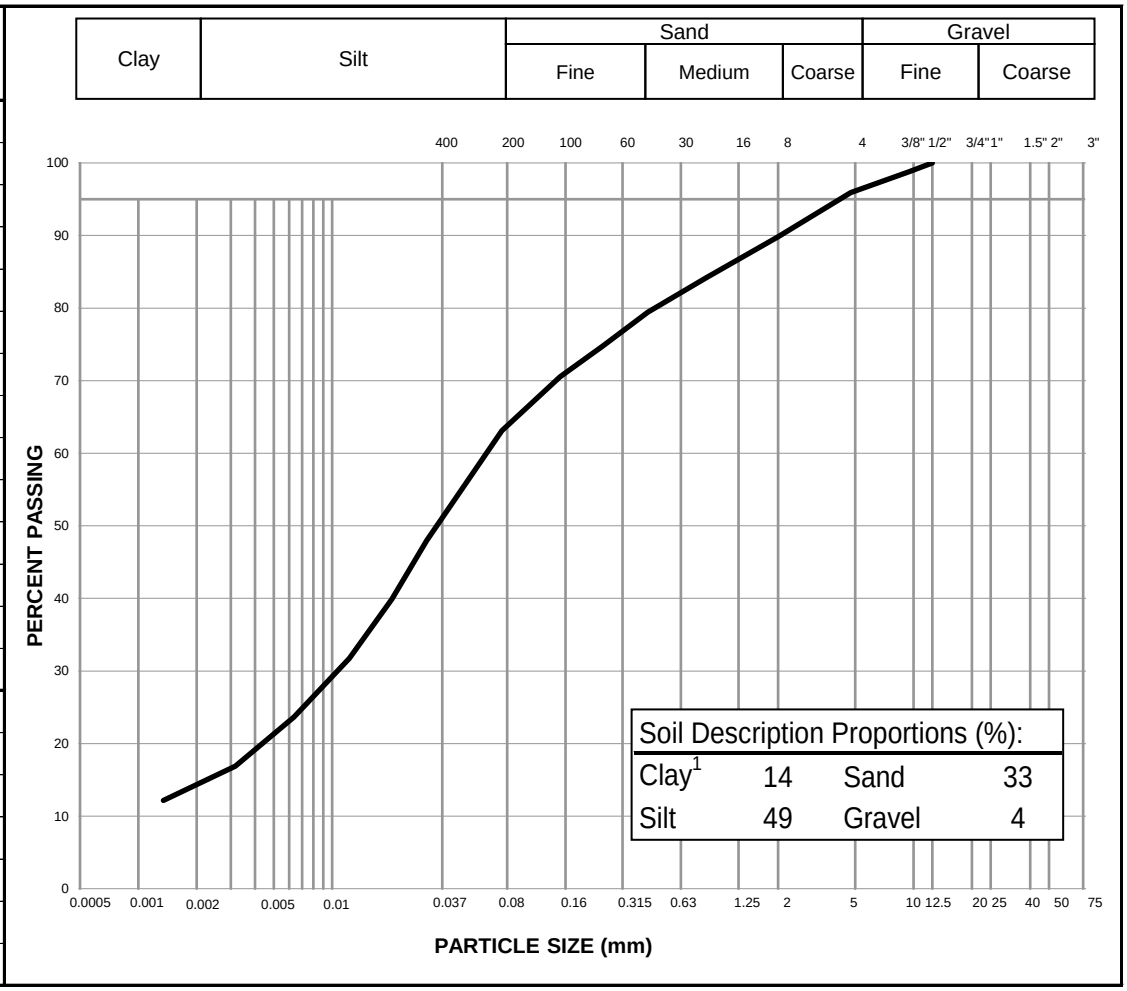
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A23
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 1004.6	Sample Loc.:	PCARBH-C24-1
Client:	K'alo-Stantec Limited	Sample Depth:	2.3 - 2.6 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 9, 2021
Soil Description[2]:	SILT, sandy, some clay, trace gravel, brown	Sampled By:	TAB
		USC Classification:	ML Cu: #N/A
Moisture Content:	21.2%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
37.5	
25	
19	
12.5	100
9.5	99
4.75	96
2	90
0.85	84
0.425	79
0.25	75
0.15	71
0.075	63.1
0.0308	48.0
0.0203	39.9
0.0122	31.8
0.0088	27.7
0.0064	23.6
0.0032	16.9
0.0013	12.2



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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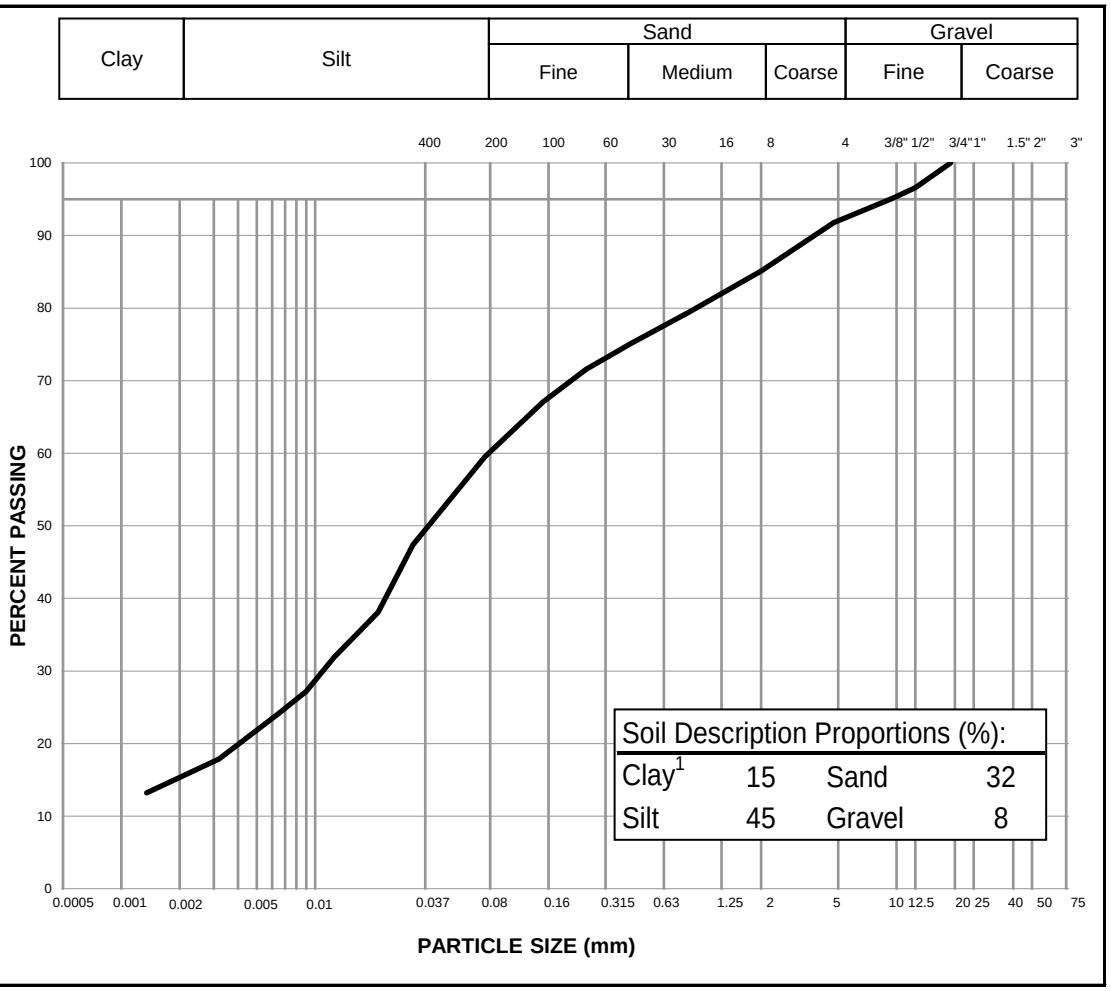
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A25
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 1004.6	Sample Loc.:	PCARBH-C24-1
Client:	K'alo-Stantec Limited	Sample Depth:	4.3 - 4.6 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 9, 2021
Soil Description[2]:	SILT, sandy, some clay, trace gravel, grey	Sampled By:	TAB
		USC Classification:	CL-CI Cu: #N/A
Moisture Content:	11.8%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
37.5	
25	
19	100
12.5	97
9.5	95
4.75	92
2	85
0.85	79
0.425	75
0.25	72
0.15	67
0.075	59.5
0.0319	47.4
0.0211	38.1
0.0125	31.9
0.0090	27.2
0.0064	24.1
0.0032	17.9
0.0014	13.2



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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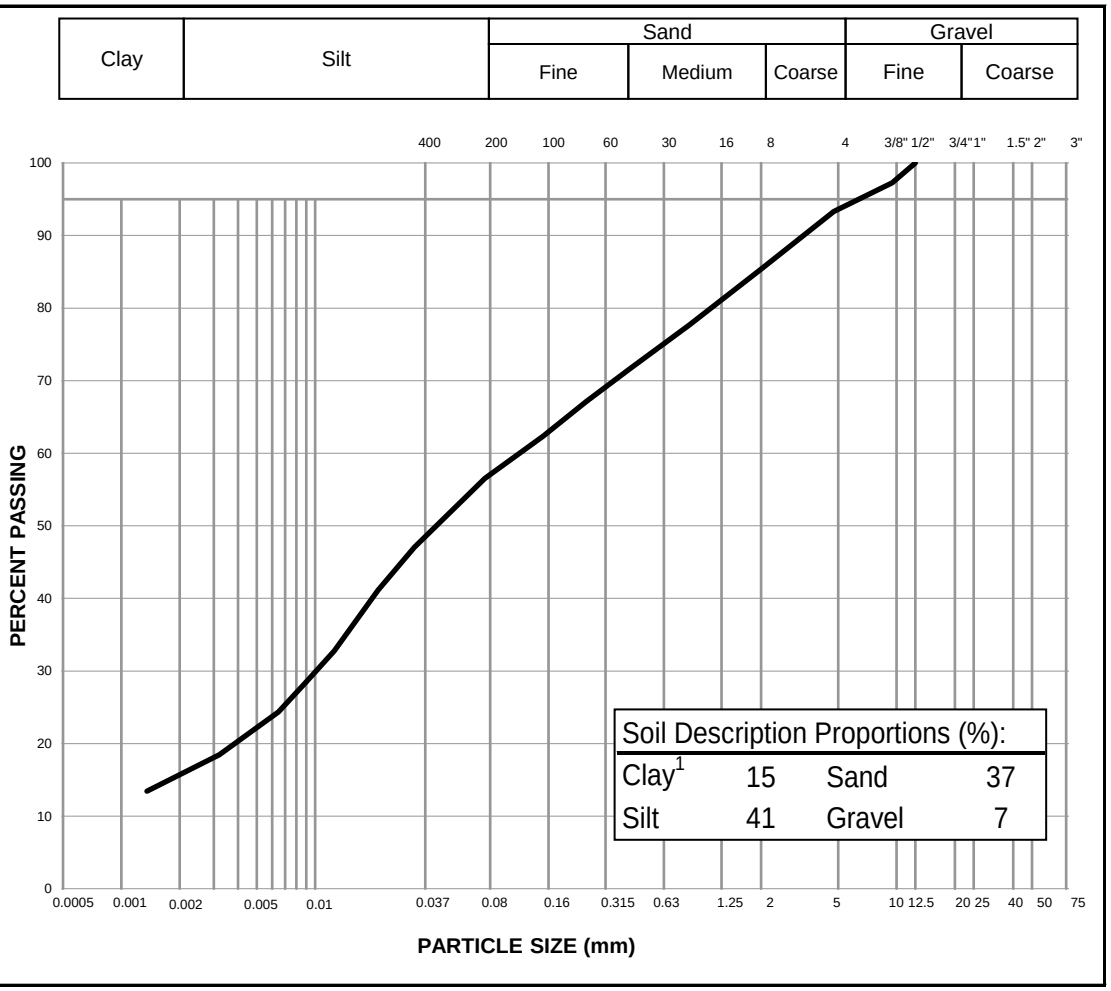
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A40
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 1006.2	Sample Loc.:	PCARBH-C29-1
Client:	K'alo-Stantec Limited	Sample Depth:	5.2 - 5.5 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 10, 2021
Soil Description[2]:	SILT and SAND, some clay, trace gravel, brownish grey	Sampled By:	TAB
		USC Classification:	ML Cu: #N/A
Moisture Content:	9.8%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
37.5	
25	
19	
12.5	100
9.5	97
4.75	93
2	85
0.85	78
0.425	72
0.25	67
0.15	62
0.075	56.5
0.0325	47.0
0.0211	41.2
0.0126	32.8
0.0090	28.6
0.0065	24.4
0.0032	18.5
0.0014	13.4



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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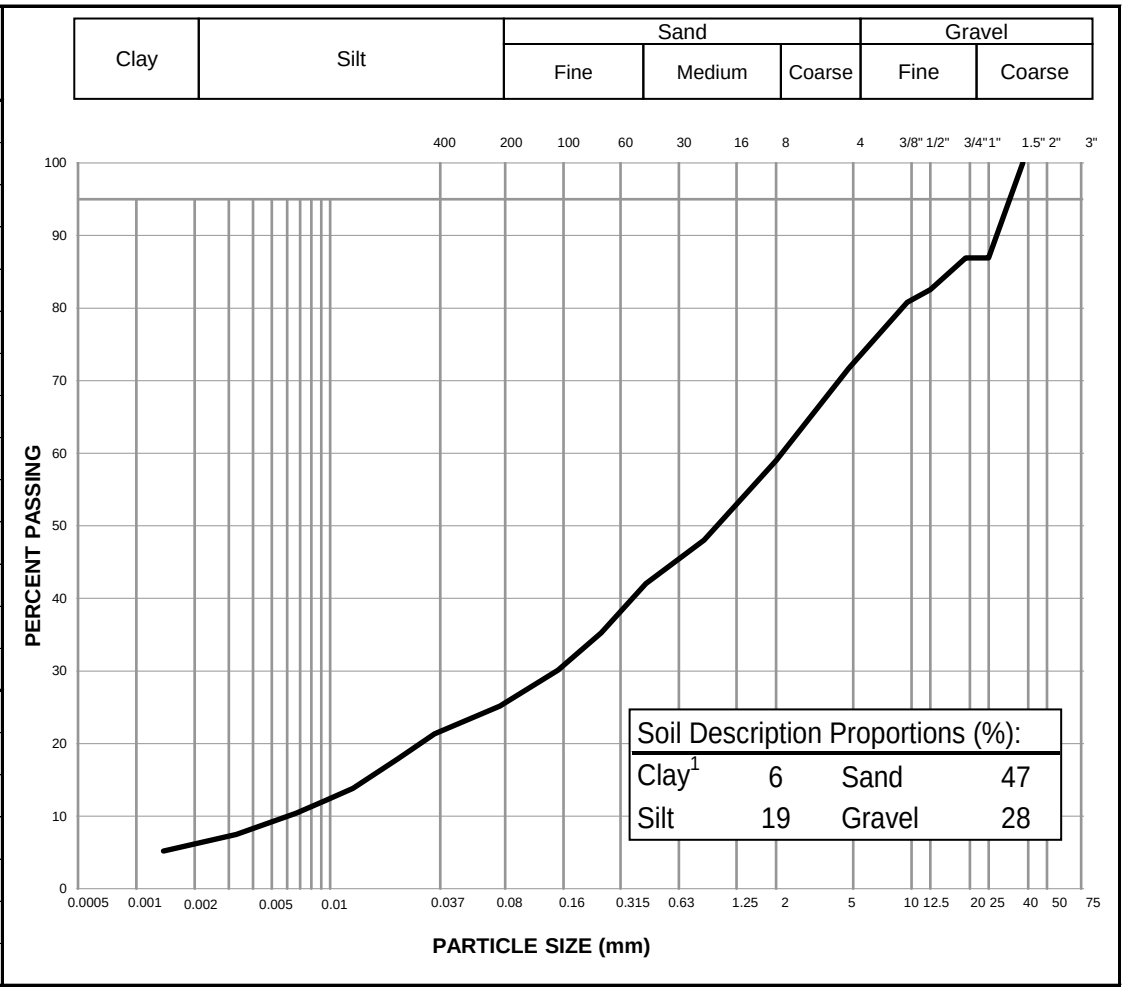
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D7928

Project:	PCAR Culvert Crossings Investigation	Sample No.:	7577-A49
Project No.:	ENG.YARC03354-02	Material Type:	In Situ
Site:	MVWR km 1007.2	Sample Loc.:	PCARBH-C33-1
Client:	K'alo-Stantec Limited	Sample Depth:	5.5 - 5.8 m
Client Rep.:	Warren McLeod	Sampling Method:	Grab
Date Tested:	March 27, 2021 By: SI	Date sampled:	March 11, 2021
Soil Description[2]:	SAND, gravelly, some silt, trace clay, brown	Sampled By:	TAB
		USC Classification:	SM Cu: 355.8
Moisture Content:	9.6%		Cc: 1.6

Particle Size (mm)	Percent Passing
75	
50	
37.5	100
25	87
19	87
12.5	83
9.5	81
4.75	72
2	59
0.85	48
0.425	42
0.25	35
0.15	30
0.075	25.2
0.0346	21.3
0.0223	17.9
0.0131	13.8
0.0094	12.1
0.0067	10.4
0.0033	7.5
0.0014	5.2



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

[2] The description is visually based & subject to Tetra Tech description protocols

Specification: _____

Remarks: _____

_____

Reviewed By: _____ P.Eng.

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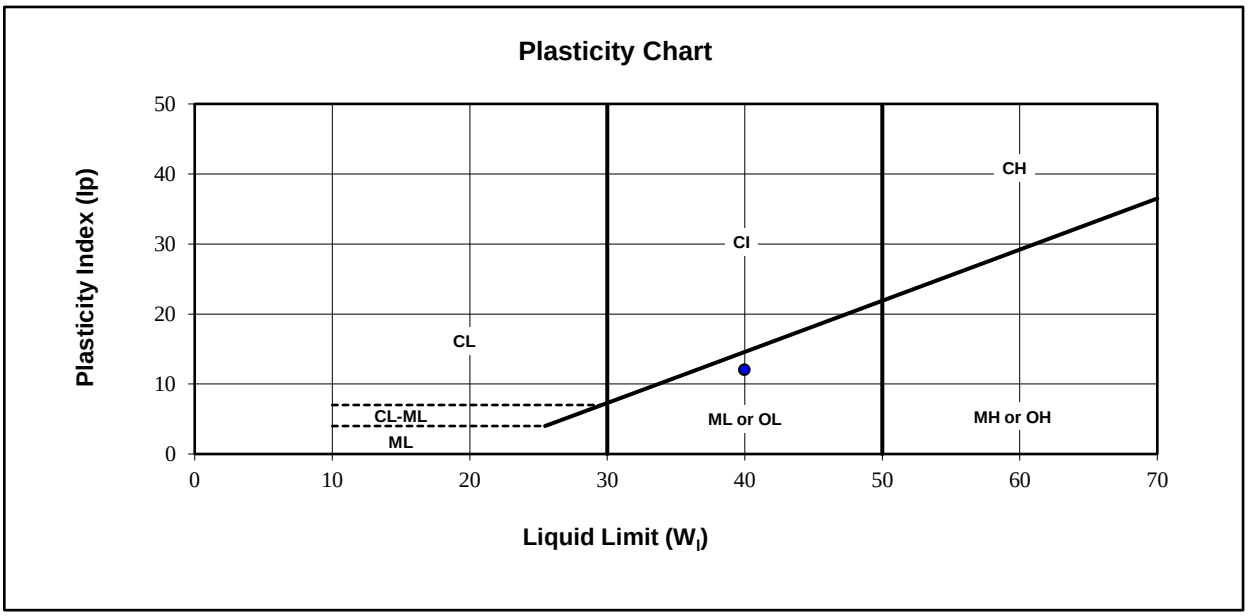
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A1
	MVWR km 997	Borehole Number:	PCARBH-C3-1
Project No:	ENG.YARC03354-05	Depth:	1.2 - 1.5 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 7, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 3, 2021

Sample Description: CLAY, silty, trace sand, organics, brown mottled black



Liquid Limit ($W_{1)}$:	40	Natural Moisture (%)	32.0
Plastic Limit :	28	Soil Plasticity:	Low
Plasticity Index (Ip) :	**12**	Mod.USCS Symbol:	OL

Remarks:

Reviewed By: P.Eng.

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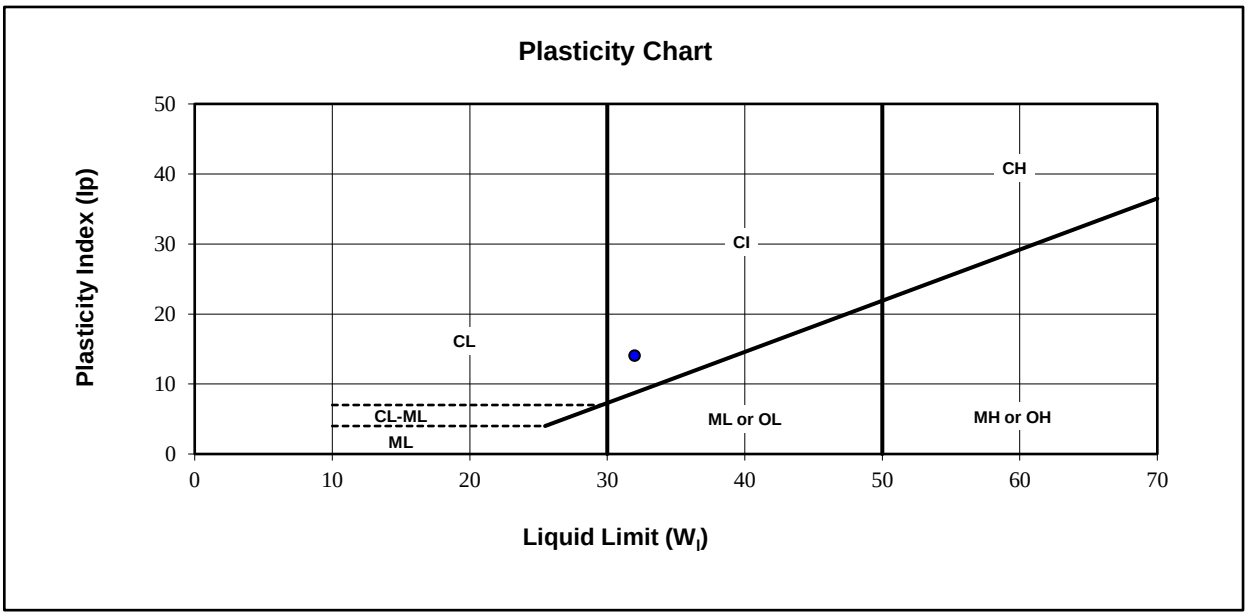
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A5
	MVWR km 997	Borehole Number:	PCARBH-C3-1
Project No:	ENG.YARC03354-05	Depth:	3.7 - 4.0 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 7, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 4, 2021

Sample Description: CLAY, silty, some sand, brown



Liquid Limit ($W_{1)}$) :	32	Natural Moisture (%)	13.4
Plastic Limit :	18	Soil Plasticity:	Low to Medium
Plasticity Index (Ip) :	**14**	Mod.USCS Symbol:	CL-CI

Remarks:

Reviewed By: _____ P.Eng.

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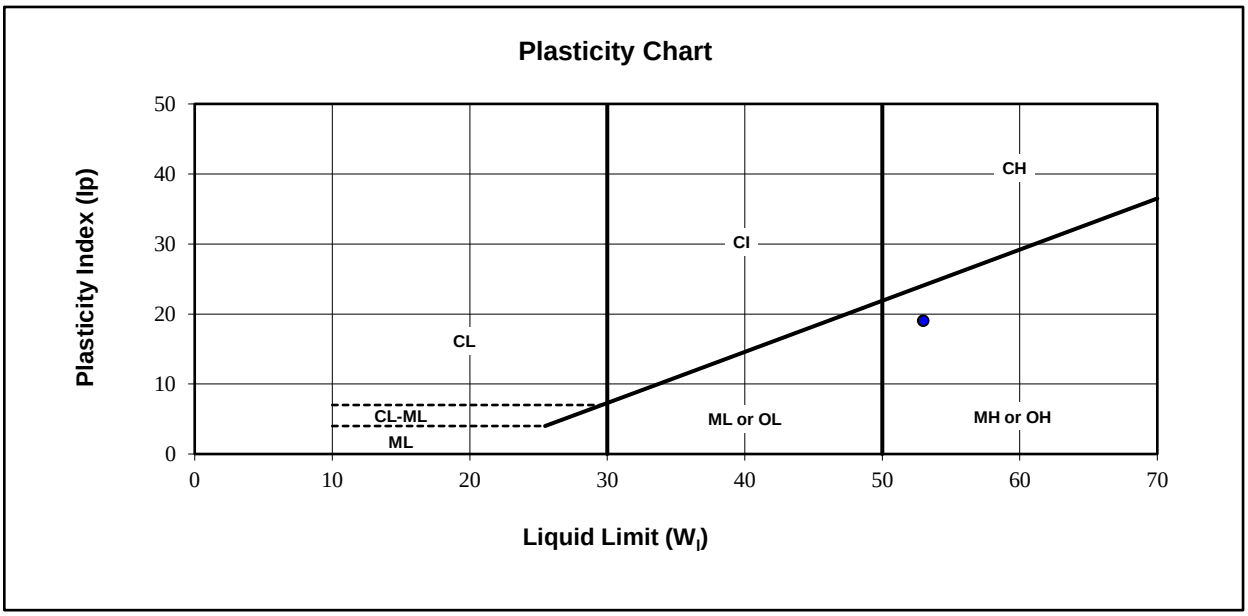
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-SS13
	MVWR km 999	Borehole Number:	PCARBH-C9-1
Project No:	ENG.YARC03354-05	Depth:	1.5 - 2.0 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 8, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 3, 2021

Sample Description: CLAY, some silt, dark brown



Liquid Limit ($W_{1)}$:	53	Natural Moisture (%)	43.6
Plastic Limit :	34	Soil Plasticity:	High
Plasticity Index (Ip) :	**19**	Mod.USCS Symbol:	OH

Remarks:

Reviewed By: P.Eng.

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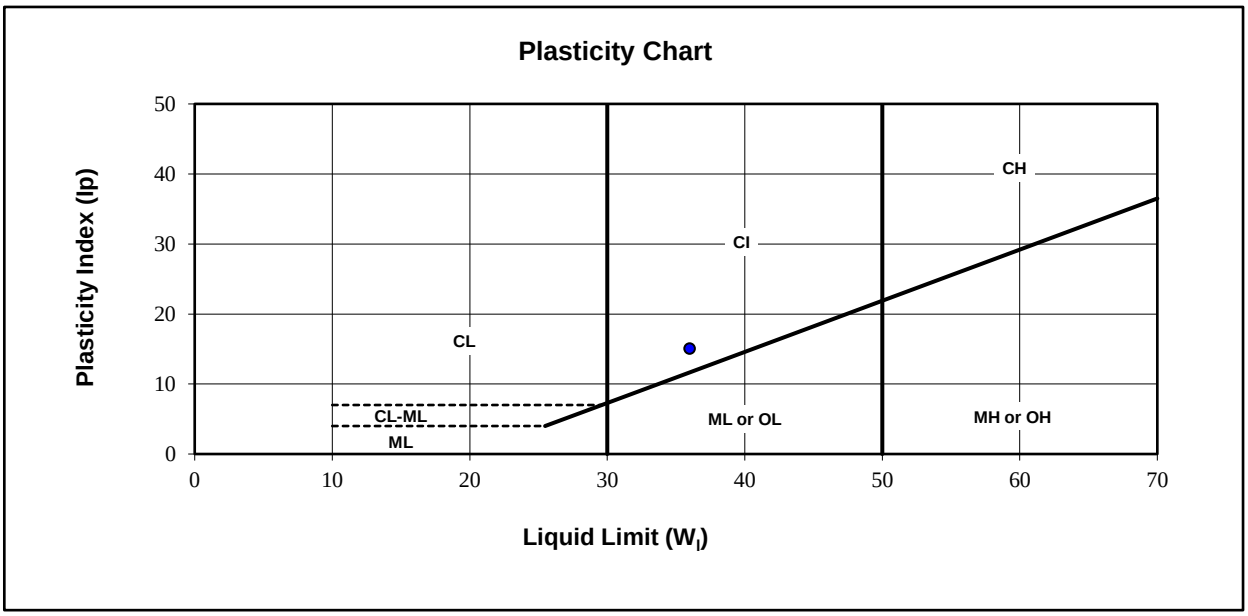
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A16
	MVWR km 999	Borehole Number:	PCARBH-C9-1
Project No:	ENG.YARC03354-05	Depth:	4.1 - 4.4 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 8, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 4, 2021

Sample Description: CLAY, silty, trace sand, dark grey



Liquid Limit ($W_{1)}$:	36	Natural Moisture (%)	17.6
Plastic Limit :	21	Soil Plasticity:	Medium
Plasticity Index (Ip) :	**15**	Mod.USCS Symbol:	CI

Remarks:

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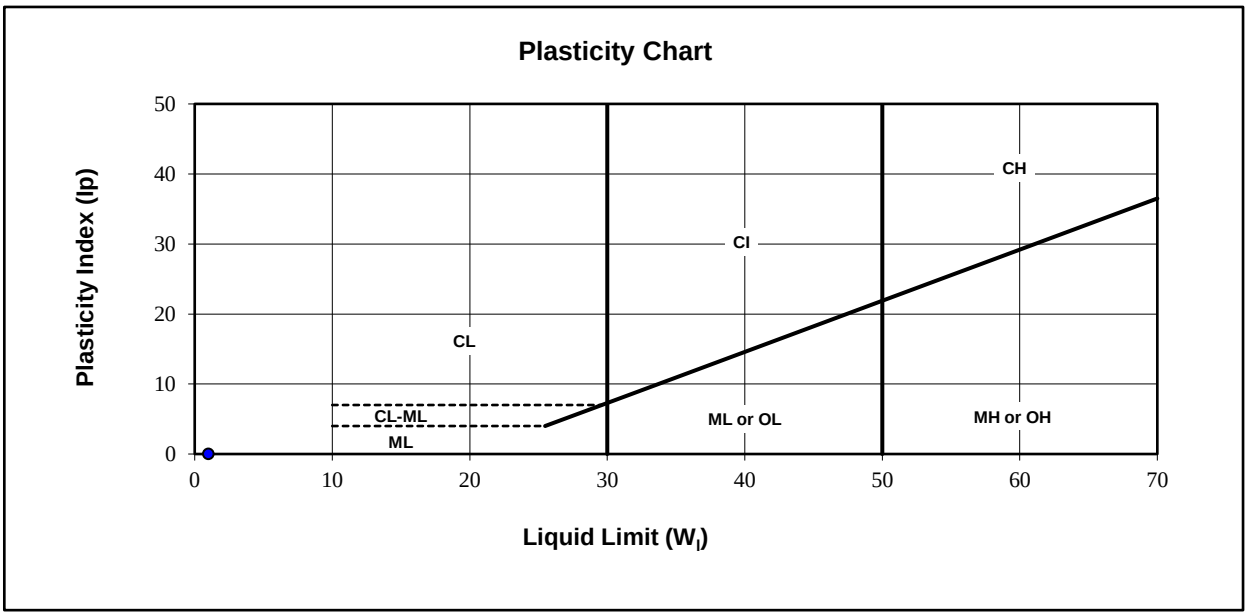
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-SS22
	MVWR km 1004.6	Borehole Number:	PCARBH-C24-1
Project No:	ENG.YARC03354-05	Depth:	1.5 - 2.0 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM/SI
Attention:	Warren McLeod	Date Sampled:	March 9, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 4, 2021

Sample Description: SILT, sandy, some clay, brown



Liquid Limit ($W_{1)}$:		Natural Moisture (%)	17.6
Plastic Limit :		Soil Plasticity:	Non-Plastic
Plasticity Index (Ip) :		Mod.USCS Symbol:	SM

Remarks: Sample is non-plastic. Unable to obtain liquid limit.

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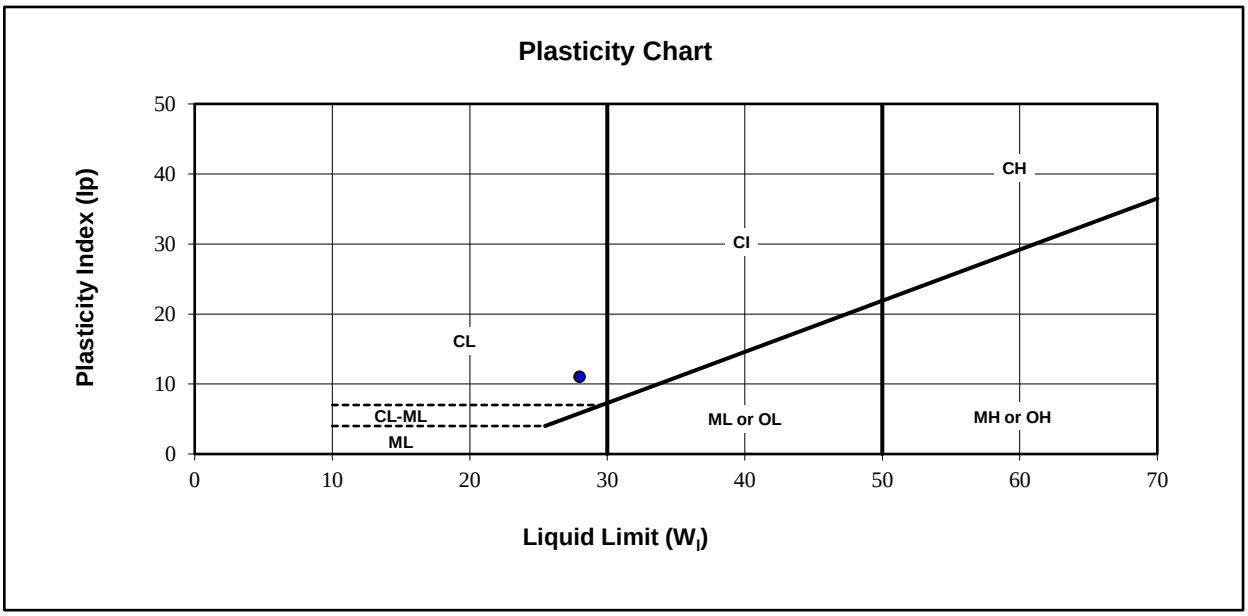
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-SS24
	MVWR km 1004.6	Borehole Number:	PCARBH-C24-1
Project No:	ENG.YARC03354-05	Depth:	3.0 - 3.7 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 9, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 4, 2021

Sample Description: CLAY, silty, trace gravel, trace sand, brown



Liquid Limit ($W_{1)}$:	28	Natural Moisture (%)	17.2
Plastic Limit :	17	Soil Plasticity:	Low to Medium
Plasticity Index (Ip) :	**11**	Mod.USCS Symbol:	CL-CI

Remarks:

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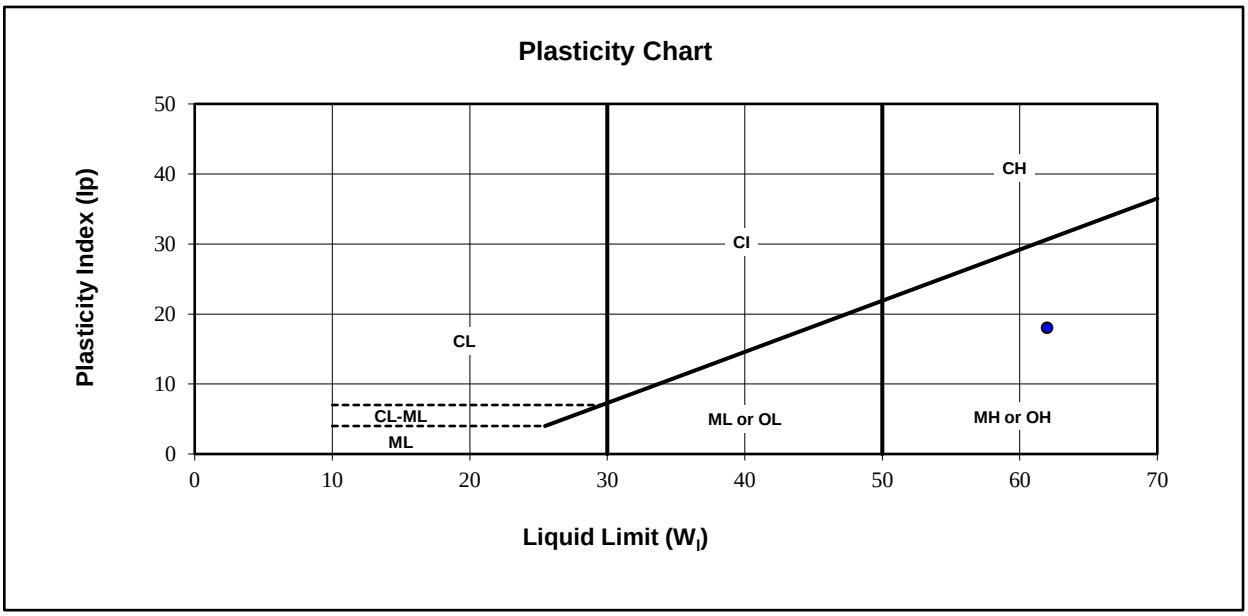
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A34
	MVWR km 1006.2	Borehole Number:	PCARBH-C29-1
Project No:	ENG.YARC03354-05	Depth:	1.1 - 1.2 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 10, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 3, 2021

Sample Description: CLAY, some silt, trace sand, dark brown



Liquid Limit ($W_{1)}$:	62	Natural Moisture (%)	58.9
Plastic Limit :	44	Soil Plasticity:	High
Plasticity Index (Ip) :	**18**	Mod.USCS Symbol:	OH

Remarks:

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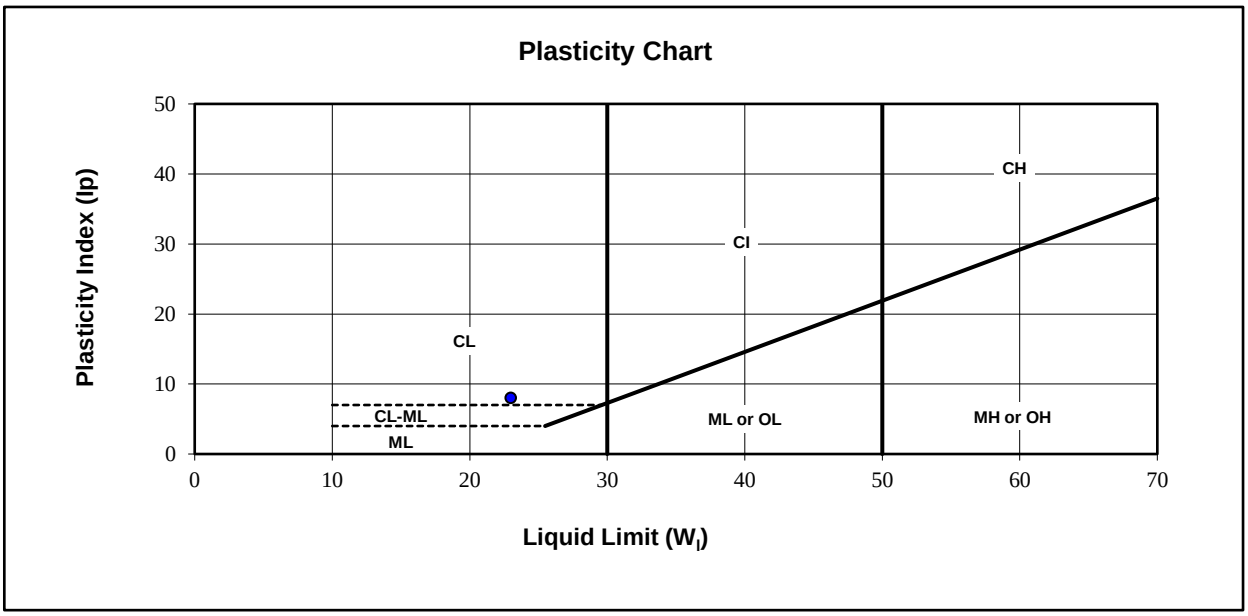
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A38
	MVWR km 1006.2	Borehole Number:	PCARBH-C29-1
Project No:	ENG.YARC03354-05	Depth:	3.7 - 4.0 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 10, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 3, 2021

Sample Description: CLAY, silty, trace sand, brown



Liquid Limit ($W_{1)}$:	23	Natural Moisture (%)	19.1
Plastic Limit :	15	Soil Plasticity:	Low
Plasticity Index (Ip) :	**8**	Mod.USCS Symbol:	CL

Remarks:

Reviewed By: P.Eng.

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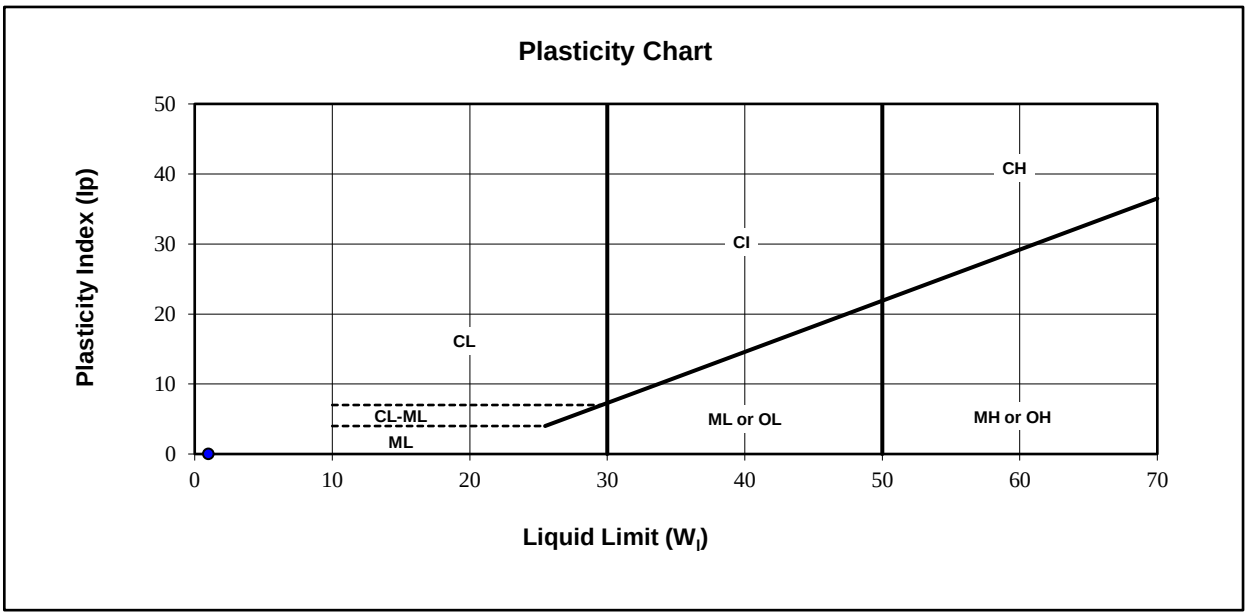
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A47
	MVWR km 1007.2	Borehole Number:	PCARBH-C33-1
Project No:	ENG.YARC03354-05	Depth:	4.0 - 4.3 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM/SI
Attention:	Warren McLeod	Date Sampled:	March 11, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 4, 2021

Sample Description: SILT, sandy, some clay, trace gravel, brown



Liquid Limit ($W_{1)}$) :		Natural Moisture (%)	15.7
Plastic Limit :		Soil Plasticity:	Non-Plastic
Plasticity Index (Ip) :		Mod.USCS Symbol:	ML

Remarks: Sample is non-plastic. Slight apparent plasticity, dilatancy on hand.

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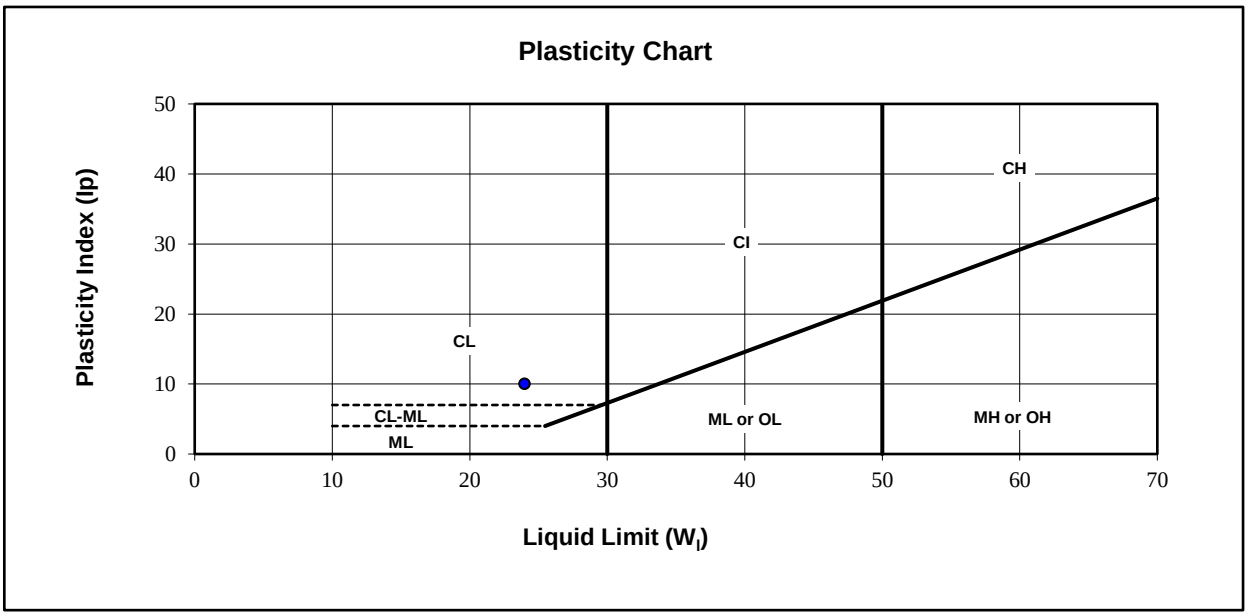
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	PCAR Culvert Crossings Investigation	Sample Number:	7577-A51
	MVWR km 1007.2	Borehole Number:	PCARBH-C33-1
Project No:	ENG.YARC03354-05	Depth:	7.0 - 7.3 m
Client:	K'alo-Stantec Limited	Sampled By:	TAB Tested By: WM
Attention:	Warren McLeod	Date Sampled:	March 11, 2021
Email:	warren.mcleod@stantec.com	Date Tested:	April 4, 2021

Sample Description: CLAY, silty, some gravel, some sand, brownish grey



Liquid Limit ($W_{1)}$:	24	Natural Moisture (%)	9.2
Plastic Limit :	14	Soil Plasticity:	Low
Plasticity Index (Ip) :	**10**	Mod.USCS Symbol:	CL

Remarks:

Reviewed By: P.Eng.

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APPENDIX E

GEOCHEMICAL LABORATORY TEST RESULTS

Measurement of Soil or Aggregate Resistivity using Two-Electrode Soil Box Method

AASHTO T 288

Project No:	704-ENG.YARC03354-05	**Sample Nos.:**	SS4
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	March 7, 2021
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	March 26, April 5-8, 2021
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd. SE, Calgary, AB T2C 3G3

Description:	CLAY, some silt, trace sand, trace gravel, trace organics (rootlets)	Temperature of sample;	
Source:	PCARBH-C3-1	As collected :	°C
Sample Location:	MVWR km 997	As Tested :	21 °C
Depth:	3.0-3.5m		
Model of meter:	Miller 400A		

Resistivity of Aggregate (as-received moisture content)

Resistivity = R x S / L

Box Used: **TB 2**

Sample Temperature: **21.0 °C**

Where :	L = Length of sample box (cm)	L =	22.2 cm
	h = height of sample in box	h =	3.2 cm
	S = Cross-sectional area of sample (cm^2)	S =	12.80 cm^2
	R = Resistance (Ohms)	R =	6200 Ohms

Resistivity = 6200 x 12.80 ÷ 22.2

Resistivity = **3,575** Ohm•cm

Remarks: pH (AASHTO T-289) = 8.18; Chloride (AASHTO T-291) = 110 ppm; Sulphate (AASHTO T-290) = 45 ppm

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Measurement of Soil or Aggregate Resistivity using Two-Electrode Soil Box Method

AASHTO T 288

Project No:	704-ENG.YARC03354-05	**Sample Nos.:**	SS15
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	March 8, 2021
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	March 26, April 5-8, 2021
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd. SE, Calgary, AB T2C 3G3

Description:	CLAY, some silt, trace sand, trace organics	Temperature of sample;	
Source:	PCARBH-C9-1	As collected :	°C
Sample Location:	MVWR km 999	As Tested :	21 °C
Depth:	3.0-3.5m		
Model of meter:	Miller 400A		

Resistivity of Aggregate (as-received moisture content)

Resistivity = R x S / L

Box Used: **TB 1**

Sample Temperature: **21.0 °C**

Where :	L = Length of sample box (cm)	L =	10.8 cm
	h = height of sample in box	h =	2.4 cm
	S = Cross-sectional area of sample (cm^2)	S =	7.20 cm^2
	R = Resistance (Ohms)	R =	3800 Ohms

Resistivity = 3800 x 7.20 ÷ 10.8

Resistivity = **2,533** Ohm•cm

Remarks: pH (AASHTO T-289) = 8.10; Chloride (AASHTO T-291) = 32 ppm; Sulphate (AASHTO T-290) = 64 ppm

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TETRA TECH

Measurement of Soil or Aggregate Resistivity using Two-Electrode Soil Box Method

AASHTO T 288

Project No:	704-ENG.YARC03354-05	**Sample Nos.:**	A23
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	March 9, 2021
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	March 26, April 5-8, 2021
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd. SE, Calgary, AB T2C 3G3

Description:	SILT, clayey, trace sand, trace gravel	Temperature of sample;	
Source:	PCARBH-C24-1	As collected :	°C
Sample Location:	MVWR km 1004.6	As Tested :	21 °C
Depth:	2.3-2.6m		
Model of meter:	Miller 400A		

Resistivity of Aggregate (as-received moisture content)

Resistivity = R x S / L

Box Used: **TB 2**

Sample Temperature: **21.0 °C**

Where :	L = Length of sample box (cm)	L =	22.2 cm
	h = height of sample in box	h =	3.2 cm
	S = Cross-sectional area of sample (cm^2)	S =	12.80 cm^2
	R = Resistance (Ohms)	R =	6500 Ohms

Resistivity = 6500 x 12.80 ÷ 22.2

Resistivity = **3,748** Ohm•cm

Remarks: pH (AASHTO T-289) = 8.12; Chloride (AASHTO T-291) = 35 ppm; Sulphate (AASHTO T-290) = 95 ppm

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TETRA TECH

Measurement of Soil or Aggregate Resistivity using Two-Electrode Soil Box Method

AASHTO T 288

Project No:	704-ENG.YARC03354-05	**Sample Nos.:**	SS37
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	March 10, 2021
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	March 26, April 5-8, 2021
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd. SE, Calgary, AB T2C 3G3

Description:	SAND, some silt, trace clay, trace gravel	Temperature of sample;	
Source:	PCARBH-C29-1	As collected :	°C
Sample Location:	MVWR km 1006.2	As Tested :	21 °C
Depth:	2.7-3.0m		
Model of meter:	Miller 400A		

Resistivity of Aggregate (as-received moisture content)

Resistivity = R x S / L

Box Used: **TB 1**

Sample Temperature: **21.0 °C**

Where :	L = Length of sample box (cm)	L =	10.8 cm
	h = height of sample in box	h =	2.4 cm
	S = Cross-sectional area of sample (cm^2)	S =	7.20 cm^2
	R = Resistance (Ohms)	R =	15000 Ohms

Resistivity = 15000 x 7.20 ÷ 10.8

Resistivity = **10,000** Ohm•cm

Remarks: pH (AASHTO T-289) = 8.17; Chloride (AASHTO T-291) = 45 ppm;
Sulphate (AASHTO T-290) = 88 ppm

Reviewed By: _____ P. Eng.

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TETRA TECH

Measurement of Soil or Aggregate Resistivity using Two-Electrode Soil Box Method

AASHTO T 288

Project No:	704-ENG.YARC03354-05	**Sample Nos.:**	SS44
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	March 11, 2021
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	March 26, April 5-8, 2021
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd. SE, Calgary, AB T2C 3G3

Description:	SAND, some gravel, trace silt	Temperature of sample;	
Source:	PCARBH-C33-1	As collected :	°C
Sample Location:	MVWR km 1007.2	As Tested :	21 °C
Depth:	1.5-2.0m		
Model of meter:	Miller 400A		

Resistivity of Aggregate (as-received moisture content)

Resistivity = R x S / L

Box Used: **TB 1**

Sample Temperature: **21.0 °C**

Where :	L = Length of sample box (cm)	L =	10.8 cm
	h = height of sample in box	h =	2.4 cm
	S = Cross-sectional area of sample (cm^2)	S =	7.20 cm^2
	R = Resistance (Ohms)	R =	13000 Ohms

Resistivity = 13000 x 7.20 ÷ 10.8

Resistivity = **8,667** Ohm•cm

Remarks: pH (AASHTO T-289) = 8.21; Chloride (AASHTO T-291) = 44 ppm;
Sulphate (AASHTO T-290) = 33 ppm

Reviewed By: _____ P. Eng.

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TETRA TECH

Organic Content in Soils by Loss on Ignition

AASHTO T267

Project No:	704-ENG.YARC03354-05	**Sample No.:**	SS4
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	7-Mar-21
Client:	Government of Northern Territories	**Sampled By:**	TB
		Date Tested:	6-Apr-21
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd SE, Calgary, AB T2C 3G3

Description: CLAY, some silt, trace sand, trace gravel, trace organics (rootlets)

Source: PCARBH-C3-1

Sample Location: MVWR km 997

Supplier: -

A	Mass of dish + sample, before Ignition	(g)	127.382	132.148
B	Mass of dish + sample, after ignition	(g)	124.442	129.115
C	Mass of dish	(g)	56.672	62.070

*Furnace Temperature: **455 °C**

$$\textbf{ORGANIC MATTER} = \frac{A - B}{A - C} \times 100$$

4.2%	**4.3%**
4.2%	

Remarks: Depth: 3.0-3.5m

Reviewed By: _____ P.Eng.

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TETRA TECH

Organic Content in Soils by Loss on Ignition

AASHTO T267

Project No:	704-ENG.YARC03354-05	**Sample No.:**	SS15
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	8-Mar-21
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	6-Apr-21
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd SE, Calgary, AB T2C 3G3

Description: CLAY, some silt, trace sand, trace organics

Source: PCARBH-C9-1

Sample Location: MVWR km 999

Supplier: -

A	Mass of dish + sample, before Ignition	(g)	139.514	126.835
B	Mass of dish + sample, after ignition	(g)	136.183	123.730
C	Mass of dish	(g)	64.050	50.982

*Furnace Temperature: **455 °C**

$$\textbf{ORGANIC MATTER} = \frac{A - B}{A - C} \times 100$$

4.4%	**4.1%**
4.3%	

Remarks: Depth: 3.0-3.5m

Reviewed By: _____ P.Eng.

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Organic Content in Soils by Loss on Ignition

AASHTO T267

Project No:	704-ENG.YARC03354-05	**Sample No.:**	A23
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	9-Mar-21
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	6-Apr-21
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd SE, Calgary, AB T2C 3G3

Description:	SILT, clayey, trace sand, trace gravel
Source:	PCARBH-C24-1
Sample Location:	MVWR km 1004.6
Supplier:	-

A	Mass of dish + sample, before Ignition	(g)	157.139	146.803
B	Mass of dish + sample, after ignition	(g)	154.978	144.652
C	Mass of dish	(g)	66.953	54.932

*Furnace Temperature: **455 °C**

$$\textbf{ORGANIC MATTER} = \frac{A - B}{A - C} \times 100$$

2.4%	**2.3%**
2.4%	

Remarks: Depth: 2.3-2.6m

Reviewed By: Cromelie P.Eng.

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Organic Content in Soils by Loss on Ignition

AASHTO T267

Project No:	704-ENG.YARC03354-05	**Sample No.:**	SS37
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	10-Mar-21
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	6-Apr-21
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd SE, Calgary, AB T2C 3G3

Description: SAND, some silt, trace clay, trace gravel

Source: PCARBH-C29-1

Sample Location: MVWR km 1006.2

Supplier: -

A	Mass of dish + sample, before Ignition	(g)	112.978	112.288
B	Mass of dish + sample, after ignition	(g)	111.487	110.843
C	Mass of dish	(g)	50.646	48.203

*Furnace Temperature: **455 °C**

$$\textbf{ORGANIC MATTER} = \frac{A - B}{A - C} \times 100$$

2.4%	**2.3%**
2.3%	

Remarks: Depth: 2.7-3.0m

Reviewed By: _____ P.Eng.

Data presented hereon is for the sole use of the stipulated client. Tetra Tech is not responsible, nor can be held liable, for use made of this report by any other party, with or without the knowledge of Tetra Tech. The testing services reported herein have been performed to recognized industry standards, unless noted. No other warranty is made. These data do not include or represent any interpretation or opinion of specification compliance or material suitability. Should engineering interpretation be required, Tetra Tech will provide it upon written request.

TETRA TECH

Organic Content in Soils by Loss on Ignition

AASHTO T267

Project No:	704-ENG.YARC03354-05	**Sample No.:**	SS44
Project:	Prohibition Creek Access Road Culvert Crossings	**Date Sampled:**	11-Mar-21
Client:	Government of the Northwest Territories	**Sampled By:**	TB
		Date Tested:	6-Apr-21
Attention:	**Ph:**	**Tested By:**	EM
Email:		**Office:**	Suite 110, 140 Quarry Park Blvd SE, Calgary, AB T2C 3G3

Description: SAND, some gravel, trace silt

Source: PCARBH-C33-1

Sample Location: MVWR km 1007.2

Supplier: -

A	Mass of dish + sample, before Ignition	(g)	122.418	129.118
B	Mass of dish + sample, after ignition	(g)	121.015	127.379
C	Mass of dish	(g)	55.637	56.846

*Furnace Temperature: **455 °C**

$$\textbf{ORGANIC MATTER} = \frac{A - B}{A - C} \times 100$$

2.1%	**2.4%**
2.3%	

Remarks: Depth: 1.5-2.0m

Reviewed By: _____ P.Eng.

Data presented hereon is for the sole use of the stipulated client. Tetra Tech is not responsible, nor can be held liable, for use made of this report by any other party, with or without the knowledge of Tetra Tech. The testing services reported herein have been performed to recognized industry standards, unless noted. No other warranty is made. These data do not include or represent any interpretation or opinion of specification compliance or material suitability. Should engineering interpretation be required, Tetra Tech will provide it upon written request.

TETRA TECH

APPENDIX F

CROSSING C9 ENVIRONMENTAL SOIL ANALYSIS TECHNICAL MEMO

TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	Warren McLeod, P.Eng. Senior Project Leader – Northern Canada K'alo-Stantec Limited	**Date:**	October 25, 2021
From:	Michael Blanchette, P.Eng. Environmental Engineer Tetra Tech Canada Inc.	**File:**	704-ENG.YARC03354-05.001

Subject: PCAR Culvert Crossing C9 Environmental Soil Sampling Results
Prohibition Creek Access Road, Northwest Territories

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by K'alo-Stantec Limited (K'alo-Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to undertake geotechnical investigations for five anticipated bridge-sized culvert crossings along the proposed Prohibition Creek Access Road (PCAR), Northwest Territories (NT). The PCAR is a 14 km-long section of the Mackenzie Valley Winter Road (MVWR) that is expected to be upgraded to an all-season road as part of the proposed extension to the Mackenzie Valley Highway (MVH).

Hydrocarbon odours were detected in Borehole PCARBH-C9-2 at a depth of 7.3 m, during the geotechnical investigation of Crossing C9. Potential hydrocarbon impacts were not anticipated in the area during the drilling work. Due to the purpose of the drilling work being for a geotechnical investigation and not for an environmental investigation, appropriate environmental sampling containers were not available on-site. A soil bag sample was collected from the depth of 7.3 m for later sub-sampling into environmental sampling containers.

2.0 METHODS

The soil bag sample was later sub-sampled into environmental soil sampling containers, provided by ALS Limited (ALS) in Yellowknife, NT, and labelled as sample 001. The sample was then submitted to ALS for the analysis of benzene, toluene, ethylbenzene, xylenes (BTEX), petroleum hydrocarbon fractions (PHC) F1 to F4, and particle size analysis.

The analytical results were compared to the GNWT *Environmental Guideline for Contaminated Site Remediation*, 2003, herein referred to as the NT CSR guidelines.

Tetra Tech Canada Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
Tel 867.920.2287 Fax 867.873.3324

3.0 RESULTS AND RECOMMENDATIONS

The original certificate of analysis for the lab results are included in Appendix A. The analytical results are compared to the NT CSR guidelines in Table 1.

The F2 value of 607 mg/kg was above the NT CSR guideline of 250 mg/kg. The F3 and F4G-SG values of 2,280 mg/kg and 3,900 mg/kg, respectively were elevated but below the NT CSR guidelines of 3,500 mg/kg and 10,000 mg/kg. All other values were below the NT CSR guidelines.

Tetra Tech recommends that additional environmental soil sampling and groundwater sampling be completed in the vicinity of Borehole PCARBH-C9-2, to at least the depth that the F2 impacts were encountered (7.3 m). Additional sampling should not be limited to F2. Although the other BTEX and PHC F1-F4 values were below the referenced NT CSR guidelines, soil sample 001 was only sub-sampled into environmental soil sampling containers at a later date in Yellowknife, and not onsite during the original geotechnical investigations. This may have contributed to a loss of PHC constituents which would result in underestimating of parameter concentrations when samples were tested. In addition, samples should be collected at multiple depths to better refine the area and depth of impact.

4.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of K'alo-Stantec, the GNWT, and their agents. Tetra Tech does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than K'alo-Stantec and the GNWT, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix B or Contractual Terms and Conditions executed by both parties.

5.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

FILE: 704-ENG.YARC03354-05.001
FILE: 704-ENG.YARC03354-05.001
FILE: 704-ENG.YARC03354-05.001

Prepared by:
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FILE: 704-ENG.YARC03354-05.001

Reviewed by:
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Principal Consultant
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Brian.Adeney@tetratech.com

/cee

Enclosure: Table 1: Soil Analytical Results
Appendix A: Laboratory Analysis Results
Appendix B: Tetra Tech's Limitations on the Use of this Document

TABLE

Table 1 Soil Analytical Results

Table 1: Soil Analytical Results

			001
			16/Mar/2021
			L2489080
			L2489080-1
Paramater	**Unit**	**NWT CSR [1] Residential / Parkland Fine**	
Salinity			
Moisture	%	-	8
Soil Texture			
>75um	%	-	30.0
General Texture Class	N/A	-	Fine
Hydrocarbons			
Benzene	mg/kg	0.5	<0.0050
Toluene	mg/kg	0.8	<0.050
Ethylbenzene	mg/kg	1.2	<0.010
Xylenes (m & p)	mg/kg	-	<0.050
Xylene (o)	mg/kg	-	<0.050
Xylenes Total	mg/kg	1	<0.10
F1 (C_6-C_{10})	mg/kg	180	20
F1 (C_6-C_{10}) - BTEX	mg/kg	180	20
F2 (C_{10}-C_{16})	mg/kg	250	607
F3 (C_{16}-C_{34})	mg/kg	3500	2280
F4 (C_{34}-C_{50})	mg/kg	10000	953
F4G-SG (GHH-Silica)	mg/kg	10000	3900
Chrom. to baseline at nC_{50}	N/A	-	No

Notes:

[1] Environmental Guideline for Contaminated Site Remediation. November 2003. Tables A4 and A7. Criteria listed are for fine textures soils subsoil (>1.5 m depth) under Residential/Parkland land use, "-" No applicable guideline or not analyzed

Shaded - Greater than NWT CSR Guideline

N/A - Not Applicable

APPENDIX A

LABORATORY ANALYSIS RESULTS

TETRA TECH CANADA INC..
ATTN: Michael Blanchette
14940 123 Ave NW
North Bldg.
Edmonton AB T5V 1B4

Date Received: 19-MAR-21
Report Date: 30-MAR-21 19:13 (MT)
Version: FINAL

Client Phone: 780-451-2121

Certificate of Analysis

Lab Work Order #: L2568753

Project P.O. #: NOT SUBMITTED
Job Reference: 704-ENE.YARC03351-03
C of C Numbers: 17-818549
Legal Site Desc:

Nicole Thibault, B.Sc. (Hons)
Account Manager

[This report shall not be reproduced except in full without the written authority of the Laboratory.]

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2568753-1 001							
Sampled By: CLIENT on 16-MAR-21 @ 14:10							
Matrix:							
ABT1 BTEX + Styrene, F1 to F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	16-MAR-21	23-MAR-21	R5362917
Toluene	<0.050		0.050	mg/kg	16-MAR-21	23-MAR-21	R5362917
Ethylbenzene	<0.010		0.010	mg/kg	16-MAR-21	23-MAR-21	R5362917
m+p-Xylene	<0.050		0.050	mg/kg	16-MAR-21	23-MAR-21	R5362917
o-Xylene	<0.050		0.050	mg/kg	16-MAR-21	23-MAR-21	R5362917
Styrene	<0.050		0.050	mg/kg	16-MAR-21	23-MAR-21	R5362917
Xylenes	<0.10		0.10	mg/kg	16-MAR-21	23-MAR-21	R5362917
Surrogate: 1,4-Difluorobenzene (SS)	94.8		70-130	%	16-MAR-21	23-MAR-21	R5362917
Surrogate: 4-Bromofluorobenzene (SS)	129.2		70-130	%	16-MAR-21	23-MAR-21	R5362917
Surrogate: 3,4-Dichlorotoluene (SS)	96.0		70-130	%	16-MAR-21	23-MAR-21	R5362917
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	103.4		70-130	%	20-MAR-21	20-MAR-21	R5409836
Chrom. to baseline at nC50	NO				20-MAR-21	20-MAR-21	R5409836
Prep/Analysis Dates					20-MAR-21	20-MAR-21	R5409836
CCME Total Hydrocarbons							
F1 (C6-C10)	20		10	mg/kg		24-MAR-21	
F1-BTEX	20		10	mg/kg		24-MAR-21	
F2 (C10-C16)	607		20	mg/kg		24-MAR-21	
F3 (C16-C34)	2280		20	mg/kg		24-MAR-21	
F4 (C34-C50)	953		20	mg/kg		24-MAR-21	
F4G-SG (GHH-Silica)	3900		500	mg/kg		24-MAR-21	
Miscellaneous Parameters							
% Moisture	8.00		0.25	%		22-MAR-21	R5408019
F4G Prep/Analysis Dates					20-MAR-21	24-MAR-21	R5413257
% Particles > 75um (Coarse/Fine)							
% >75um	30.0		1.0	%		30-MAR-21	R5417385
General Texture Class	Fine					30-MAR-21	R5417385

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
BTXS,F1-MEOH-ED	Soil	BTEX and F1	EPA 8260C/5021A and CWS PHC Tier 1

This analysis involves the extraction of a subsample of the sediment/soil with methanol added in the field at the time of subsampling. The soil methanol extract is added to water and reagents, then heated in a sealed vial to equilibrium. The headspace from the vial is transferred into a gas chromatograph. BTX Target compound concentrations are measured using mass spectrometry detection. The instrumental portion of F1 analysis is carried out in accordance with the Canada Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method (2001).

F1-4-CALC-ED	Soil	CCME Total Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001

Analytical methods used for analysis of CCME Petroleum Hydrocarbons have been validated and comply with the Reference Method for the CWS PHC.

Hydrocarbon results are expressed on a dry weight basis.

In cases where results for both F4 and F4G are reported, the greater of the two results must be used in any application of the CWS PHC guidelines and the gravimetric heavy hydrocarbons cannot be added to the C6 to C50 hydrocarbons.
In samples where BTEX and F1 were analyzed , F1-BTEX represents a value where the sum of Benzene, Toluene, Ethylbenzene and total Xylenes has been subtracted from F1.

In samples where PAHs, F2 and F3 were analyzed, F2-Naphth represents the result where Naphthalene has been subtracted from F2. F3-PAH represents a result where the sum of Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene has been subtracted from F3.

Unless otherwise qualified, the following quality control criteria have been met for the F1 hydrocarbon range:
1. All extraction and analysis holding times were met.
2. Instrument performance showing response factors for C6 and C10 within 30% of the response factor for toluene.
3. Linearity of gasoline response within 15% throughout the calibration range.

Unless otherwise qualified, the following quality control criteria have been met for the F2-F4 hydrocarbon ranges:
1. All extraction and analysis holding times were met.
2. Instrument performance showing C10, C16 and C34 response factors within 10% of their average.
3. Instrument performance showing the C50 response factor within 30% of the average of the C10, C16 and C34 response factors.
4. Linearity of diesel or motor oil response within 15% throughout the calibration range.

F2-4-TMB-ED	Soil	CCME Total Extractable Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment" For C10 to C50 hydrocarbons (F2, F3, F4) and gravimetric heavy hydrocarbons (F4G-sg), a subsample of the sediment/soil is extracted with 1:1 hexane:acetone using a rotary extractor. The extract undergoes a silica-gel clean-up to remove polar compounds. F2, F3 & F4 are analyzed by on-column GC/FID, and F4G-sg is analyzed gravimetrically.

Notes:
1. F2 (C10-C16): Sum of all hydrocarbons that elute between nC10 and nC16.
2. F3 (C16-C34): Sum of all hydrocarbons that elute between nC16 and nC34.
3. F4 (C34-C50): Sum of all hydrocarbons that elute between nC34 and nC50.
4. F4G: Gravimetric Heavy Hydrocarbons
5. F4G-sg: Gravimetric Heavy Hydrocarbons (F4G) after silica gel treatment.
6. Where F4 (C34-C50) and F4G-sg results are reported for a sample, the larger of the reported values is used for comparison against the relevant CCME standard for F4.
7. The gravimetric heavy hydrocarbon results (F4G-sg), cannot be added to the C6 to C50 hydrocarbon results.
8. This method is validated for use.
9. Data from analysis of quality control samples is available upon request.
10. Reported results are expressed as milligrams per dry kilogram.

F4G-TMB-ED	Soil	CCME Gravimetric Heavy Hydrocarbons (SG)	CCME CWS-PHC, Pub #1310, Dec 2001
PREP-MOISTURE-ED	Soil	% Moisture	CCME PHC in Soil - Tier 1 (mod)

The weighed portion of soil is placed in a 105°C oven to dry to a constant weight; the drying time will vary based on the moisture content of the soil. The dried soil weight is then used to calculate % moisture.

PSA-75UM-SIEVE-ED	Soil	% Particles > 75um (Coarse/Fine)	ASTM D422-63-SIEVE

An air-dried sample is reduced to < 2 mm size and mixed with a dispersing agent (Calgon solution). The sample is washed through a 200 mesh (75 µm) sieve. The retained weight of sample is used to determine % sand fraction.
Reference: ASTM D422-63

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ED		ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA	

Chain of Custody Numbers:

17-818549

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L2568753 Report Date: 30-MAR-21

Client: TETRA TECH CANADA INC..
14940 123 Ave NW North Bldg.
Edmonton AB T5V 1B4
Contact: Michael Blanchette

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
BTXS,F1-MEOH-ED	**Soil**							
Batch R5362917								
WG3505882-4 DUP		**L2568753-1**						
Benzene		<0.0050	<0.0050	RPD-NA	mg/kg	N/A	30	23-MAR-21
Toluene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	23-MAR-21
Ethylbenzene		<0.010	<0.010	RPD-NA	mg/kg	N/A	30	23-MAR-21
m+p-Xylene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	23-MAR-21
o-Xylene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	23-MAR-21
Styrene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	23-MAR-21
WG3505882-2 LCS								
Benzene			96.9		%		70-130	22-MAR-21
Toluene			89.6		%		70-130	22-MAR-21
Ethylbenzene			89.0		%		70-130	22-MAR-21
m+p-Xylene			101.1		%		70-130	22-MAR-21
o-Xylene			95.6		%		70-130	22-MAR-21
Styrene			91.1		%		70-130	22-MAR-21
WG3505882-1 MB								
Benzene			<0.0050		mg/kg		0.005	22-MAR-21
Toluene			<0.050		mg/kg		0.05	22-MAR-21
Ethylbenzene			<0.010		mg/kg		0.01	22-MAR-21
m+p-Xylene			<0.050		mg/kg		0.05	22-MAR-21
o-Xylene			<0.050		mg/kg		0.05	22-MAR-21
Styrene			<0.050		mg/kg		0.05	22-MAR-21
Surrogate: 1,4-Difluorobenzene (SS)			94.3		%		70-130	22-MAR-21
Surrogate: 4-Bromofluorobenzene (SS)			87.4		%		70-130	22-MAR-21
Surrogate: 3,4-Dichlorotoluene (SS)			102.0		%		70-130	22-MAR-21
F2-4-TMB-ED	**Soil**							
Batch R5409836								
WG3505534-4 DUP		**L2568753-1**						
F2 (C10-C16)		607	563		mg/kg	7.5	40	20-MAR-21
F3 (C16-C34)		2280	2120		mg/kg	7.3	40	20-MAR-21
F4 (C34-C50)		953	900		mg/kg	5.7	40	20-MAR-21
WG3505534-3 IRM		**ALS PHC RM3**						
F2 (C10-C16)			107.1		%		70-130	20-MAR-21
F3 (C16-C34)			104.9		%		70-130	20-MAR-21
F4 (C34-C50)			119.2		%		70-130	20-MAR-21
WG3505534-2 LCS		**DIESEL / MOTOR OIL**						
F2 (C10-C16)			112.3		%		70-130	20-MAR-21

Quality Control Report

Workorder: L2568753 Report Date: 30-MAR-21

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
F2-4-TMB-ED	**Soil**							
Batch R5409836								
WG3505534-2 LCS		**DIESEL / MOTOR OIL**						
F3 (C16-C34)			111.2		%		70-130	20-MAR-21
F4 (C34-C50)			113.2		%		70-130	20-MAR-21
WG3505534-1 MB								
F2 (C10-C16)			<20		mg/kg		20	20-MAR-21
F3 (C16-C34)			<20		mg/kg		20	20-MAR-21
F4 (C34-C50)			<20		mg/kg		20	20-MAR-21
Surrogate: 2-Bromobenzotrifluoride			98.5		%		70-130	20-MAR-21
F4G-TMB-ED	**Soil**							
Batch R5413257								
WG3507778-4 DUP		**L2568753-1**						
Gravimetric Heavy Hydrocarbons (Silica)		3900	3290		mg/kg	17	40	24-MAR-21
WG3507778-3 IRM		**ALS PHC RM3**						
Gravimetric Heavy Hydrocarbons (Silica)			92.4		%		70-130	24-MAR-21
WG3507778-2 LCS		**DIESEL/MOTOR OIL**						
Gravimetric Heavy Hydrocarbons (Silica)			111.9		%		70-130	24-MAR-21
WG3507778-1 MB								
Gravimetric Heavy Hydrocarbons (Silica)			<500		mg/kg		500	24-MAR-21
PREP-MOISTURE-ED	**Soil**							
Batch R5408019								
WG3505911-2 LCS								
% Moisture			100.4		%		90-110	22-MAR-21
WG3505911-1 MB								
% Moisture			<0.25		%		0.25	22-MAR-21
PSA-75UM-SIEVE-ED	**Soil**							
Batch R5417385								
WG3510858-3 DUP		**L2568753-1**						
% >75um		30.0	30.9		%	3.2	20	30-MAR-21
WG3510858-2 IRM		**ALS SAL 2019**						
% >75um			33.3		%		29.1-39.1	30-MAR-21
WG3510858-1 MB								
% >75um			<1.0		%		1	30-MAR-21

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

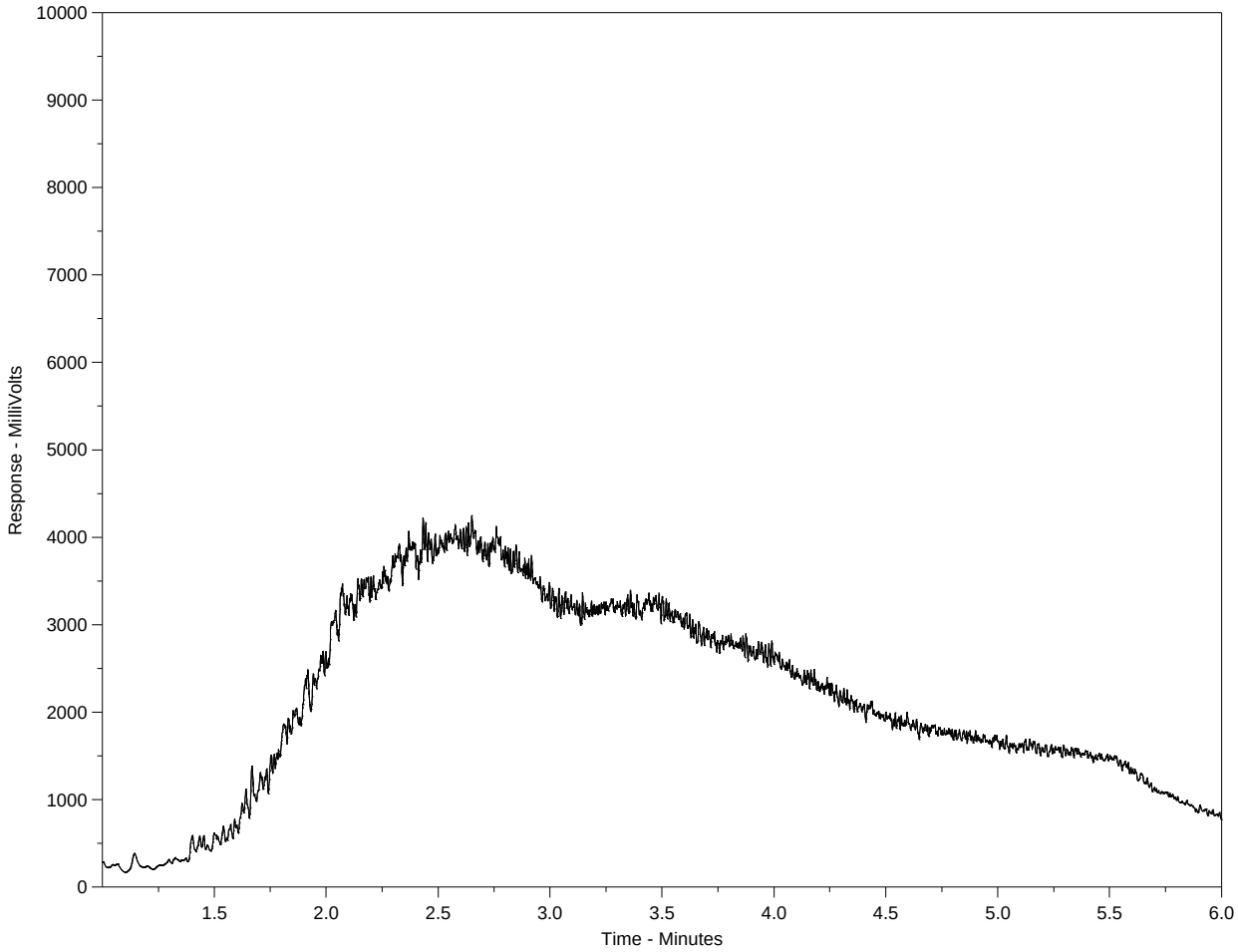
ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

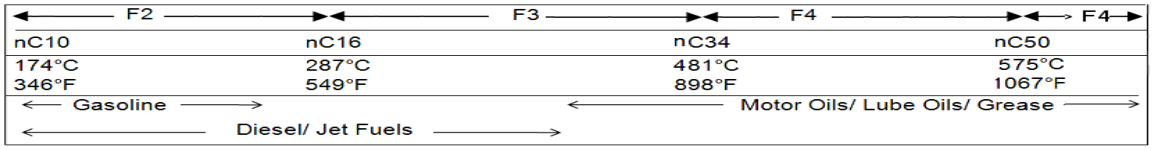
The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Hydrocarbon Distribution Report

ALS Sample ID: L2568753-1
Client ID: 001





The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

ALS Environmental

www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L2568753-COFC

COC Number: 17 - 818549

Page of

Report To	Contact and company name below will appear on the final report	Report Format / Distribution	Select Service Level Below - Contact your AM to confirm all E&P TATs (surcharges may apply)
Company:	Tetra Tech Canada	Select Report Format: [X] PDF [X] EXCEL [X] EDD (DIGITAL)	Regular [R] [X] Standard TAT if received by 3 pm - business days - no surcharges apply
Contact:	Michael Blanchette	Quality Control (QC) Report with Report [X] YES [ ] NO	PRIORITY (Business Days): 4 day [P4-20%] [ ] / 3 day [P3-25%] [ ] / 2 day [P2-50%] [ ]
Phone:	780 699 9600	[ ] Compare Results to Criteria on Report - provide details below if box checked	EMERGENCY: 1 Business day [E - 100%] [ ] / Same Day, Weekend or Statutory holiday [E2 -200% (Laboratory opening fees may apply)] [ ]
	Company address below will appear on the final report	Select Distribution: [X] EMAIL [ ] MAIL [ ] FAX	Date and Time Required for all E&P TATs: dd-mmm-yy hh:mm
Street:	~~138 Cuppy Drive~~ 14940-123 Ave	Email 1 or Fax: Michael.Blanchette@Tetratech.com	For tests that can not be performed according to the service level selected, you will be contacted.
City/Province:	~~Yellowknife NT~~ Edmonton, AB	Email 2	
Postal Code:	~~X1A 0G4~~ T5V 1B4	Email 3	
Invoice To	Same as Report To [X] YES [ ] NO	Invoice Distribution	Analysis Request
	Copy of Invoice with Report [X] YES [ ] NO	Select Invoice Distribution: [X] EMAIL [ ] MAIL [ ] FAX	
Company:		Email 1 or Fax	
Contact:		Email 2	

Project Information		Oil and Gas Required Fields (client use)	
ALS Account # / Quote #:		AFE/Cost Center:	PO#:
Job #:	704-ENG.YARC03354-01	Major/Minor Code:	Routing Code:
PO / AFE:		Requisitioner:	
LSD:		Location:	
ALS Lab Work Order # (lab use only):	L2568753	ALS Contact:	Sampler:

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	NUMBER OF CONTAINERS: BTEX F1-F4	PSA	SAMPLES ON HOLD	SUSPECTED HAZARD (see Special Instructions)
	001	Mar 16, 2021	14:00		1	1		
	002	↓	14:00		1	1		
	003		14:10		1	1		

Drinking Water (DW) Samples[1] (client use)	Special Instructions / Specify Criteria to add on report by clicking on the drop-down list below (electronic COC only)
Are samples taken from a Regulated DW System? [ ] YES [ ] NO	
Are samples for human consumption/ use? [ ] YES [ ] NO	

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen [ ] SIF Observations Yes [ ] No [ ]

Ice Packs [ ] Ice Cubes [X] Custody seal intact Yes [ ] No [ ]

Cooling Initiated [ ]

INITIAL COOLER TEMPERATURES °C	FINAL COOLER TEMPERATURES °C
16.9	

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by: Jacob Cooyut	Date:	Time:	Received by:	Date: 13.10	Time: 17 Mar 21	Received by:	Date:	Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

JUNE 2018 FRONT

1. If any water samples are taken from a **Regulated Drinking Water (DW) System**, please submit using an **Authorized DW COC form**.

GENERAL TERMS AND CONDITIONS:

These terms and conditions are incorporated in and form part of the Agreement between ALS Group's Environmental Division and the party named in the Offer (the "Client").

1. Definitions. Capitalized Terms not defined in these Terms and Conditions have the definitions set out in the other Agreement documents.
2. The Services. ALS will provide the Services to the Client as described in the Offer and in any chain of custody form provided with any sample.
3. Prices. ALS may review and change all prices, fees, surcharges or other charges set out in the Agreement if there are changes to ALS's cost beyond ALS's control, including changes in legislative requirements, Client variations of sample numbers and Client requests for changes to standard reporting requirements. Notwithstanding Condition 3, all quotations expire after three years.
4. Payment Terms. The Client shall pay ALS within 30 days of the invoice date OAC. ALS may, for reasonable business reasons, require the Client to arrange for payment in advance.
5. Quotation Numbers. The Client shall provide the quotation number to ALS (where applicable) to ensure correct pricing.
6. Taxes. Applicable taxes are not included in prices. Applicable surcharges and additional fees will be added at the time of invoicing.
7. Quality Control. ALS has an extensive QA/QC program. Clients' samples are analyzed using approved, referenced procedures followed by thorough data validation prior to reporting of the analytical results.
8. Test Results. Results are obtained from analytical measurements that are subject to inherent variability. Measurement results reflect characteristics of submitted test samples at time of analysis. The Client is responsible for informing itself on the limitation of test results and acknowledges that test results are not guaranteed. When statements of conformity are requested on test reports (e.g. within Criteria Reports), measurement uncertainty is not applied to test results prior to the evaluation.
9. Standard of Care. ALS will use reasonable care and diligence as required by the laws of the province or territory where the sample is tested.
10. Storage. Where possible, ALS will store; soil and water samples for 45 days from date of receipt, tissue/biota samples for 6 months from date of receipt, air samples or re-usable media for 14 days from date of receipt, and microbiological samples for 3 days from date of receipt.
11. Holds. If the Client requests a sample to be placed on hold, ALS will store the samples according to paragraph 10, after which ALS will invoice the Client and discard the sample. Each sample is subject to a minimum $5.00 hold fee. Longer hold periods are available upon request. See paragraph 12.
12. Archives. If the Client requests a sample be archived, ALS will invoice in advance and store the sample for the period requested, after which ALS may discard the sample.
13. Legal Sample Handling Protocol. Legal sample handling protocol must be arranged before samples are collected. ALS charges a surcharge on the list price plus the hourly technologist or chemist rates for legal sample protocol. Additional charges will apply for samples that require storage by ALS.
14. Samples. The quality, condition, content and source of samples stored and tested are not known to ALS except as declared and described on the chain of custody form completed and submitted by the Client and accompanying the sample.
15. Risk of Loss. ALS will use reasonable care to protect samples during storage, however all samples are stored at the Client's risk and the Client is responsible for obtaining appropriate insurance, if desired. The Client acknowledges that during the performance of the Services samples may be altered, lost, damaged, or destroyed and the Client releases ALS from any claim the Client may have for any loss or damage to the sample.
16. Environmental. The Client must comply with all applicable environment legislation, including labeling all hazardous samples to comply with GHS and TDG regulations, and must provide appropriate Safety Data that include the nature of the hazard and a contact name and phone number to call for information. The Client will indemnify ALS for all loss or damages, including any fine or cost of complying with an order of any government authority, resulting from the Client's breach of this paragraph.
17. Hazardous Materials Disposal. ALS may return, at the Client's cost, hazardous material to the Client for disposal.
18. Hazardous Materials Surcharge. ALS may apply an additional surcharge for handling of hazardous samples or samples with Naturally Occurring Radioactive Materials (NORM), H2S, CN, etc.
19. Sample Containers. ALS may ship sample containers to the Client's location by the most cost effective means using ALS preferred courier suppliers, within the specified project timeline.
20. Additional Charges. ALS may charge the Client (a) its cost for emergency bottle shipments and shipments to and from a remote site, and (b) where pick up and delivery services are provided, subject in each instance to a minimum charge of $25.00.
21. Re-Tests. ALS reserves the right to re-test any samples that remain in its possession. Re-tests requested by the Client may be subject to charges.
22. Waiver. The Client is responsible for making any assessment regarding the suitability of the Services and the intended results for the Client's purposes and waives any claims against ALS it may have as a result of the interpretation of the results. The Client shall indemnify ALS for all claims made by any third party against ALS in respect of all losses however arising from the performance of the Services or the use of any report provided in the performance of the Services.
23. Limitation of Liability. In no event shall ALS be liable for any consequential, indirect, incidental, special, exemplary, or punitive damages, whether foreseeable or unforeseeable (including claims for loss of profits or revenue or losses caused by stoppage of other work or impairment of other assets), incurred by the Client arising out of breach or failure of express or implied warranty, breach of contract, breach of warranty, misrepresentation, negligence, strict liability in tort or otherwise. In any event, the liability of ALS to the Client shall be limited to the cost of testing the sample as requested in the chain of custody form under which the sample was originally deposited. For the purposes of this paragraph and paragraphs 8, 15, 16, 22 and 24, as applicable, "ALS" includes without limitations its directors, officers, employees and affiliates and the "Client" includes without limitation any third party that may have a claim against ALS through the Client.
24. Notice of Liability. Notwithstanding paragraph 23, ALS shall not be liable to the Client unless the Client provides notice in writing to ALS of such loss or damage, together with full particulars thereof, within 30 days of the Client's receipt of the report of the analysis of the sample giving rise to such liability. The provisions of this paragraph allocate the risk under the Agreement between the Client and ALS, and the fees to be paid by the Client to ALS reflect this allocation of risks and the limitations of liability in this Agreement.
25. Third Party Service Provider Indemnity. For testing not performed at ALS, and where the Client requires ALS to forward samples to a third party service provider, the Client indemnifies ALS against any breach of this Agreement, all liabilities or losses incurred in connection with the third party service provider, including but not limited to courier services, testing turn-around time, and any additional costs associated with such third party.
26. Third Party Service Provider Indemnity. If ALS is required to engage a third party service provider for whatever reason, the Client indemnifies ALS against any breach of this Agreement, liabilities, or losses incurred in connection with the third party service provider, including but not limited to courier services, testing turn-around time, and any additional costs associated with such third party.
27. Entire Agreement. The Agreement is the entire agreement between the parties and supersedes and takes precedence over any terms and conditions contained in any documentation provided by the Client. ALS's execution of any subsequent documentation from the Client only acknowledges receipt and not acceptance of any terms or conditions therein. If there is a conflict between these terms and conditions and any other Agreement document, these terms and conditions prevail.
28. Term. Providing the first batch of samples to which this tender refers is submitted within three months of the starting date of this quotation, the following prices, terms and conditions will remain firm until the closing date. This offer, and its terms and conditions will automatically lapse if the offer has not been accepted and samples not delivered to ALS by the Closing Date.
29. Termination. (a) Either party may terminate this Agreement for any reason by giving the other party thirty (30) days written notice (Notice Period). (b) If the Agreement is terminated pursuant to clause (a), then the Client must pay ALS for all Services performed up to the expiry of the Notice Period.

APPENDIX B

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOENVIRONMENTAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an "Authorized Party"), consideration for such authorization is the Authorized Party's acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the "Limitations on Liability"). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party's express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH's professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

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

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by persons other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by TETRA TECH in its reasonably exercised discretion.

APPENDIX G

SEISMIC HAZARD INFORMATION

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 65.202N 126.448W **User File Reference:** Prohibition Creek Access Road, NT 2021-05-27 15:49 UT

Requested by: Thomas Bradshaw, Tetra Tech Canada Inc.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.447	0.265	0.168	0.061
Sa (0.1)	0.667	0.397	0.253	0.092
Sa (0.2)	0.683	0.432	0.288	0.111
Sa (0.3)	0.578	0.371	0.253	0.101
Sa (0.5)	0.441	0.279	0.187	0.073
Sa (1.0)	0.236	0.150	0.101	0.041
Sa (2.0)	0.104	0.067	0.046	0.019
Sa (5.0)	0.031	0.020	0.014	0.005
Sa (10.0)	0.011	0.007	0.005	0.002
PGA (g)	0.336	0.207	0.134	0.049
PGV (m/s)	0.255	0.156	0.102	0.039

Notes: Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

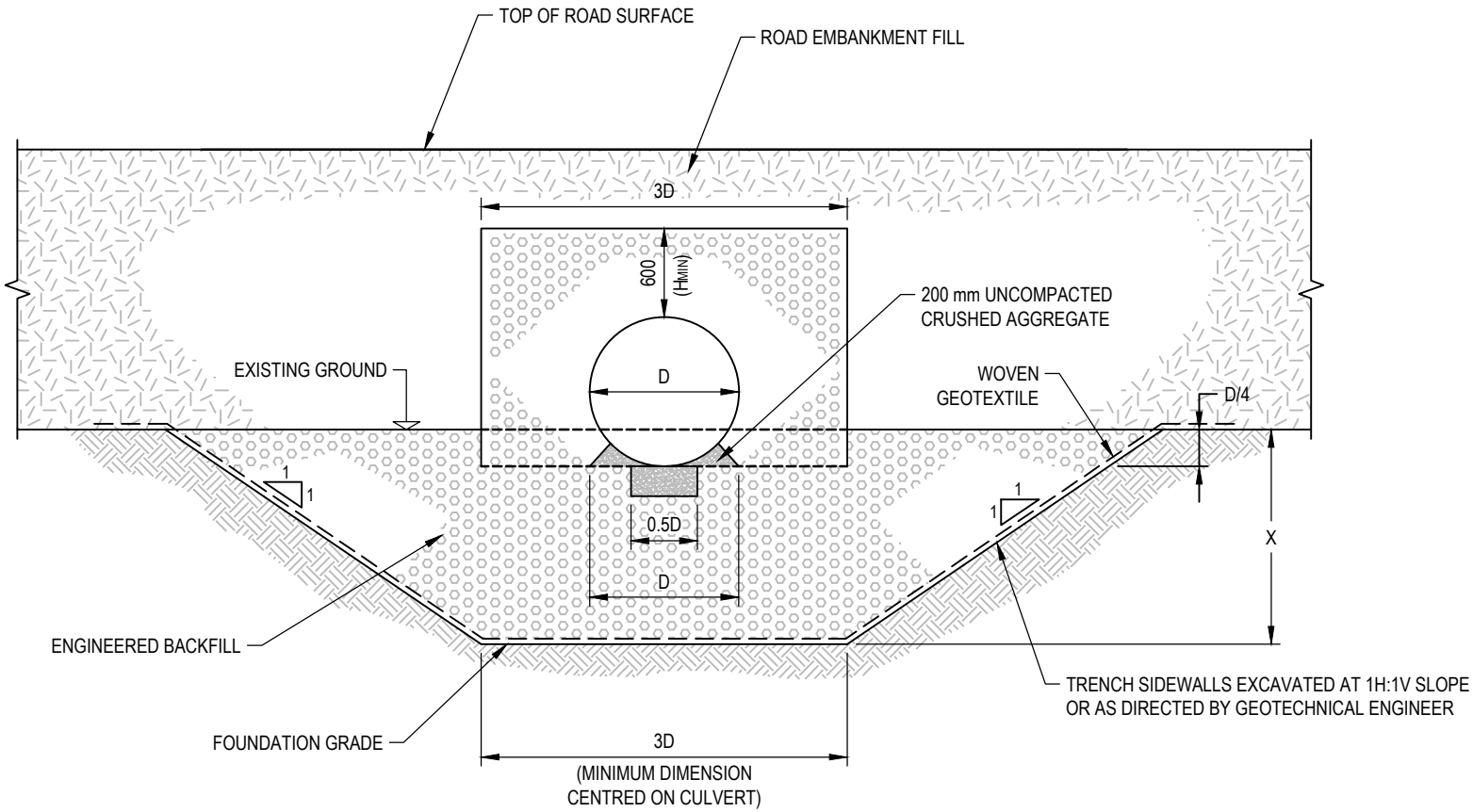
Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

APPENDIX H

TYPICAL CULVERT INSTALLATION DRAWINGS



NOTES:

1. MINIMUM RECOMMENDED DEPTH OF CULVERT INVERT BELOW GROUND SURFACE.
2. MINIMUM RECOMMENDED DEPTH OF EXCAVATION BELOW GROUND SURFACE.
3. MINIMUM RECOMMENDED BOTTOM WIDTH OF EXCAVATION CENTRED ON CULVERT.
4. ALL DIMENSIONS IN MILLIMETRES.
5. CROSS-SECTION NOT TO SCALE.

LEGEND:

D = CULVERT DIAMETER (mm)
X = EXCAVATION DEPTH (mm)
H_{MIN} = MINIMUM HEIGHT OF COVER (mm)

CULVERT CROSSING	PROPOSED CULVERT DIAMETER (D)	CULVERT INVERT BURIAL DEPTH[1] (D/4)	EXCAVATION DIMENSIONS		
			DEPTH[2] (X)	WIDTH[3] (3D)	SIDESLOPES
C9	2,280	570	2,000	6,840	1H:1V
C33	1,200 (x 2)	300	600	4,800	

CLIENT

Kálo-Stantec

TETRA TECH

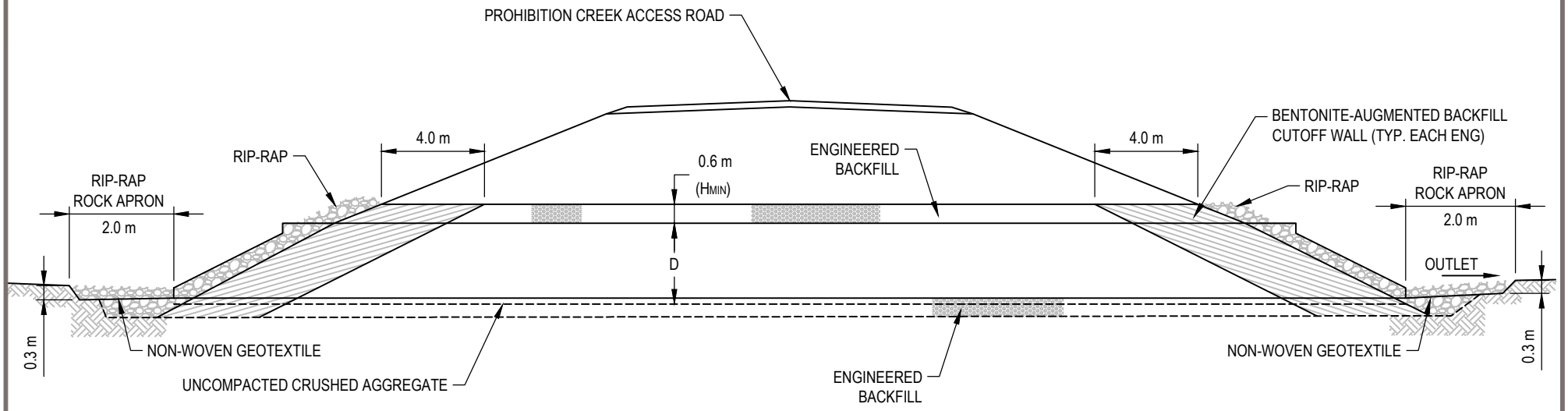
PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

TYPICAL CULVERT CROSS-SECTION

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-05	EL	TB	IFU

OFFICE	DATE
EDMONTON	MAY 2021

H1



NOTES:

1. D = CULVERT DIAMETER
2. X = MINIMUM RECOMMENDED DEPTH OF EXCAVATION
3. ALL DIMENSIONS IN METRES.
4. SECTION NOT TO SCALE.

CLIENT

Kálo-Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD
CULVERT CROSSINGS GEOTECHNICAL

TYPICAL CULVERT PROFILE

PROJECT NO.	DWN	CKD	REV	
ENG.YARC03354-05	EL	TB	IFU	**H2**
OFFICE	DATE			
EDMONTON	MAY 2021			

APPENDIX I

LIMITATIONS ON USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

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The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

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

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards 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. TETRA TECH 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.

1.9 LOGS OF TESTHOLES

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.

1.10 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 historical environment. TETRA TECH 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 exploration and review may be necessary.

1.11 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.

1.12 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.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact 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, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and 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.

1.15 DRAINAGE SYSTEMS

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. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters 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 used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH 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.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

Prohibition Creek Access Road
Thermal Assessment Report

MVWR km 995.3 to km 1009.3, Northwest Territories





PRESENTED TO
Kãlo Stantec Limited

JUNE 10, 2021
ISSUED FOR USE
FILE: 704-ENG.YARC03354-02

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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was retained by Kãlo Stantec Limited (Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to provide thermal assessment support for advancing design and engineering of the Prohibition Creek Access Road (PCAR) south of Norman Wells, Northwest Territories (NT). The PCAR is a section of the Mackenzie Valley Winter Road (MVWR) that is expected to be replaced with an all-season, two-lane, gravel highway as part of a future extension to the Mackenzie Valley Highway (MVH). The objective of this thermal assessment is to inform the MVH design of the geothermal and subsurface conditions expected along the PCAR alignment. This report should be read in conjunction with Tetra Tech's 2020 geotechnical and geophysical evaluation report titled *Geotechnical and Geophysical Evaluation for Prohibition Creek Access Road, Near Norman Wells, NT* (Tetra Tech 2020).

The PCAR alignment starts from the Prohibition Creek Bridge (MVWR km 995.3) and extends northwest to the end of the Canyon Creek All-Season Access Road at the Canyon Creek Bridge (MVWR km 1009.3). The proposed alignment also traverses three intermediate bridges at Christina Creek (MVWR km 1001.7), Hellava Creek (MVWR km 1002.7), and Francis Creek (MVWR km 1005.0). A total of 25 boreholes (BH-01 to BH-25) were drilled to depths ranging from 5.5 m to 8.1 m and both unfrozen and frozen soils, including visible ground ice, were encountered at depth. The soils recovered were predominantly glacial till consisting of clays and silts with sand and gravel components. The PCAR is located within a zone of extensive, discontinuous permafrost, meaning permafrost is expected to be present along 50% to 90% of the alignment (NRC 2009). Seasonally frozen (active) layers were observed in all 25 boreholes drilled and frozen conditions beneath the estimated active layer were observed in 23 of 25 boreholes. Generally, ground ice contents were higher closer to the surface and decreased with depth.

During Tetra Tech's 2020 geotechnical investigation, PVC conduit pipes were installed in five select boreholes along the PCAR alignment to facilitate the installation of ground temperature instrumentation up to depths of 8.0 m. Tetra Tech returned to the PCAR in August 2020 and successfully installed ground temperature cables (GTCs) in all five boreholes (BH-02, BH-08, BH-14, BH-19, BH-25). Ground temperature readings were initially taken following the installation of the GTCs and further readings were taken in October 2020 and March 2021. Readings ranged from -2.9°C to 0.1°C, below the measured active layer depth which varied from 0.6 m to 1.5 m thick. Using information from the investigation programs as well as the ground temperature data, the PCAR was divided into three generalized sections based on thermal conditions: South, Middle, and North.

The South Section of the PCAR alignment spans from the Prohibition Creek Bridge to MVWR km 999.2. Six geotechnical boreholes (BH-20 to BH-25) were drilled along this section of the alignment and one GTC was installed at MVWR km 996.0 (Borehole BH-25). The South Section's subgrade is expected to be thaw-stable as it generally consists of ice-poor permafrost above shallow sedimentary bedrock. Thaw settlement due to thermal disturbances caused by construction of the PCAR are not expected to be significant.

The Middle Section of the PCAR alignment extends from MVWR km 999.2 to Christina Creek (MVWR km 1001.7). Five geotechnical boreholes (BH-15 to BH-19) were drilled along this section of the PCAR and one GTC was installed at MVWR km 999.2 (Borehole BH-19). The subgrade along the Middle Section is likely thaw-sensitive as it contains frequently visible ground ice within fine-grained, warm permafrost soils. Thaw settlement is expected due to the construction of the PCAR, especially in areas where visible ground ice is greater than 20% by volume, such as around Borehole BH-17 (approximately MVWR km 999.5 to km 1000.5).

The North Section of the PCAR alignment ranges from Christina Creek to Canyon Creek (MVWR km 1001.7 to km 1009.3). Fourteen geotechnical boreholes (BH-01 to BH-14) were drilled during the geotechnical investigation and three GTCs were installed (Boreholes BH-02, BH-08, and BH-14) to monitor thermal conditions. The subgrade within this section is expected to be thaw-stable and the potential for settlement due to permafrost degradation is

expected to be minor. Although frozen materials were identified from the ground temperature readings, the investigation program confirmed that the permafrost is ice-poor and not likely to experience significant thaw settlement.

Permafrost and thermal considerations for each section of the PCAR are provided based on Tetra Tech's experience on similar road projects and engineering judgement. Settlement along the PCAR alignment was estimated based on two mechanisms: thaw settlement and self-weight settlement of placed embankment fill during winter construction as well as thaw settlement and consolidation of the underlying subgrade. Significant thaw settlement is expected in the Middle Section of the PCAR where ice-rich permafrost has been identified throughout the subgrade. Embankment fill settlement is expected to be up to 0.3 m along the PCAR and consideration should be given to overbuilding the road embankments by 0.3 m to allow for this. Thaw settlement and consolidation of the subgrade due to permafrost warming and degradation over many years could be up to 0.9 m along the Middle Section of the PCAR.

Additional monitoring is recommended to better understand permafrost conditions at the PCAR site and all GTCs should be read two times each year, at a minimum. Subsequent readings should be taken in spring (early April) when ground temperatures are the coldest for the year and in the fall (late September) when ground temperatures are warmest for the year. Tetra Tech will continue to update and track ground temperatures as data is collected from the PCAR.

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APPENDICES

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ACRONYMS & ABBREVIATIONS

Acronyms/Abbreviations	Definition
CSA	Canadian Standards Association
GNWT	Government of the Northwest Territories, Department of Infrastructure
GTC	Ground Temperature Cable
km	Kilometres
m	Metres
mm	Millimetres
MVH	Mackenzie Valley Highway
MVWR	Mackenzie Valley Winter Road
NAD83	North American Datum of 1983
NT	Northwest Territories
PCAR	Prohibition Creek Access Road
Stantec	Kālo Stantec Ltd.
TAC	Transportation Association of Canada
Tetra Tech	Tetra Tech Canada Inc.
UTM	Universal Transverse Mercator

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Kālo Stantec Limited, the Government of the Northwest Territories, and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Kālo Stantec Limited and the Government of the Northwest Territories or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached in Appendix A.

1.0 INTRODUCTION

1.1 General

Tetra Tech Canada Inc. (Tetra Tech) was retained by Kãlo Stantec Limited (Stantec), on behalf of the Government of the Northwest Territories, Department of Infrastructure (GNWT), to provide thermal assessment support for advancing design and engineering of the Prohibition Creek Access Road (PCAR) near Norman Wells, Northwest Territories (NT). The PCAR is a section of the Mackenzie Valley Winter Road (MVWR) that is expected to be replaced with an all-season, two-lane, gravel highway as part of a future extension to the Mackenzie Valley Highway (MVH). Tetra Tech recently completed geotechnical and geophysical investigations along the proposed PCAR alignment in March 2020.

The objective of this thermal assessment is to inform the MVH design of the geothermal and subsurface conditions expected along the PCAR alignment. This report includes an assessment of the site's thermal conditions based on data gathered from the investigation programs and subsequent ground temperature monitoring. It includes road construction considerations and recommendations on the PCAR design as well as future monitoring. This assessment report should be read in conjunction with Tetra Tech's geotechnical and geophysical evaluation report titled *Geotechnical and Geophysical Evaluation for Prohibition Creek Access Road, Near Norman Wells, NT* (Tetra Tech 2020).

Tetra Tech was initially requested by the GNWT to conduct a thermal assessment of the PCAR via email on April 1, 2020. Authorization to proceed with this work was provided through a standing offer agreement in place between the GNWT and the team of Stantec and Tetra Tech, via a subconsultant agreement signed on August 11, 2020.

1.2 Project Description

The MVWR extends from Wrigley (km 690) to Fort Good Hope (km 1173), with supplementary access roads connecting to Déljne (106 km) and Colville Lake (165 km). The winter road is constructed and maintained by the GNWT on an annual basis and typically operates from late December to late March. The GNWT is currently advancing a project to replace the MVWR by extending the MVH from Wrigley to Norman Wells, connecting the Sahtu Region with an all-season, two-lane, gravel highway.

One section of the existing MVWR alignment to be upgraded, between Tulita (km 938) and Norman Wells (km 1026), is the PCAR located near Latitude 65°11'14.6" N and Longitude 126°24'12.5" W. It starts from the Prohibition Creek Bridge (km 995.3) and extends northwest to the end of the Canyon Creek All-Season Access Road at the Canyon Creek Bridge (km 1009.3). The proposed PCAR alignment also traverses three intermediate bridges at Christina Creek (km 1001.7), Hellava Creek (km 1002.7), and Francis Creek (km 1005.0). The road route is near to Enbridge's Line 21 pipeline and the Mackenzie Valley Fibre Link. The project location is shown in Figure 1.

1.3 Scope of Work

Tetra Tech's scope of work, in accordance with the proposal submitted on July 7, 2020, included the following tasks:

- Conduct a site visit to the PCAR and install multi-bead ground temperature cables (GTCs) in existing boreholes with PVC conduit;
- Complete a desktop thermal assessment based on the data collected during the geotechnical and geophysical investigation programs as well as recent ground temperature data; and
- Prepare a report summarizing the collected ground temperature data and provide an assessment of the thermal regime along the PCAR alignment, including a description of present permafrost conditions and thermal considerations for embankment design and engineering of the MVH.

2.0 SITE DESCRIPTION

2.1 Surface Conditions

Surface conditions along the PCAR alignment predominantly consist of grass, peat, and other organics, as visible from satellite imagery of the area. The treeline begins approximately 10 m to 20 m from the edge of the road surface on both sides of the right-of-way. The trees encountered were predominantly Black Spruce (*picea mariana*) trees with heights upwards of 10 m and trunk diameters of approximately 0.1 m. The road alignment runs in a straight line from southeast to northwest, perpendicular to the nearby Franklin Mountains.

Surficial materials along the PCAR alignment generally consist of glacial till veneer and blanket deposits, based on surficial mapping for areas southeast of Norman Wells (Duk-Rodkin 2002). The till deposits typically consist of unsorted silts and clays with sands and coarser clasts, ranging from 2 m to 6 m thick. The PCAR alignment also parallels along the boundary of a glaciolacustrine deposit between MVWR km 1004 to km 1005. It is expected that the road route is underlain by sedimentary rocks, including mud shale or siltstone, both of the Imperial Formation (Fallas and MacNaughton 2013).

2.2 Subsurface Conditions

Subsurface conditions were classified following Tetra Tech's 2020 geotechnical and geophysical investigations (Tetra Tech 2020). A total of 25 boreholes (BH-01 to BH-25) were drilled along the access road alignment, spaced approximately 500 m apart. For reference, copies of the PCAR borehole logs are provided in Appendix B.

Drilling depths ranged from 5.5 m to 8.1 m and both unfrozen and frozen soils, including visible ground ice, were encountered at depth. The soils recovered were predominantly glacial till consisting of clays and silts with sand and gravel components, consistent with the heterogeneous characteristics of glacial deposits. Groundwater was encountered in one borehole near MVWR km 1004 at a depth of 2.5 m; however, this was the only instance where groundwater was encountered along the PCAR alignment.

2.3 Climate

Environment and Climate Change Canada operates several meteorological stations at the nearby town of Norman Wells with public records available from 1950 to the present (ECCC 2021). The mean annual air temperature for the period of record is -6.6°C, which has been gradually increasing from the start of data collection. The average

rate of annual temperature increase has been 0.04°C/year over the period of record, with the biggest increase occurring in the winter months between October to April. Over the past 10 years, the mean annual air temperature has averaged -5.6°C with an average rate of increase of 0.15°C/year.

Using published data from the Climate Atlas of Canada, it was determined that Norman Wells has an average number of freezing degree days of 3,996°C-days from 1950 to the present (CAC 2021). The number of freezing degree days has decreased by an average of 11°C-days/year during that time. Over the past 10 years, the number of freezing degree days has averaged 3,737°C-days with an average rate of decrease of 35°C-days/year.

The mean annual precipitation over the period of record (1950 to 2020) was determined to be 341 mm/year. Over the past 10 years, the annual precipitation in Norman Wells averaged 350 mm/year.

2.4 Permafrost Conditions

The PCAR is located within a zone of extensive, discontinuous permafrost, meaning permafrost is expected to be present along 50% to 90% of the alignment (NRC 2009). Ground temperature readings collected from the nearby Canyon Creek All-Season Access Road indicate permafrost temperatures range between 0°C and -2.0°C (Tetra Tech EBA 2016).

Seasonally frozen (active) layers were observed in all 25 boreholes drilled and frozen conditions beneath the estimated active layer were observed in 23 of 25 boreholes (Tetra Tech 2020). Generally, ground ice contents were higher closer to the surface and decreased with depth. As presented in Section 3.0, ground temperature data collected along the PCAR alignment indicates that permafrost temperatures are typically -1.0°C to -1.5°C and unfrozen (non-permafrost) conditions exist.

3.0 THERMAL DATA

3.1 Ground Temperature Instrumentation

Previously during Tetra Tech's 2020 geotechnical investigation, PVC conduit pipes (25 mm diameter) were installed in five select boreholes along the PCAR alignment to facilitate the installation of ground temperature instrumentation up to depths of 8.0 m. Boreholes were selected based on subsurface and thermal conditions encountered during the investigation program to represent typical ground conditions along the alignment. The borehole locations with ground temperature instrumentation are presented in Figures 1 to 4.

Tetra Tech returned to the PCAR in August 2020 and successfully installed GTCs in all five boreholes (BH-02, BH-08, BH-14, BH-19, BH-25). Table 3-1 summarizes the ground temperature instrumentation that was installed along the PCAR alignment.

Table 3-1: Ground Temperature Cables Installed

Borehole Number	MVWR Milepost (km)	Coordinates (m, UTM Zone 9: NAD83, [CSRS] Epoch 2010)		Ground Surface Elevation (m)	Installation Depth (m)	Number of Thermistor Beads*	Date Installed
		Northing	Easting				
BH-02	1008.2	7,235,343.0	616,665.0	79.5	7.8	8	August 5, 2020
BH-08	1005.0	7,233,631.0	619,056.0	82.3	8.0	8	August 5, 2020
BH-14	1001.8	7,231,839.0	621,558.0	80.1	7.7	8	August 5, 2020
BH-19	999.2	7,230,411.0	623,533.0	85.6	7.3	8	August 7, 2020
BH-25	996.0	7,228,649.0	625,986.0	95.0	7.2	8	August 7, 2020

** Depth below ground of each thermistor bead shown on Ground Temperature Profiles in Appendix C.*

The five GTCs are all manual read installations. A switch box and multimeter need to be connected to the cables in the field to obtain readings. Resistances are recorded at the thermistor beads along each cable which are then converted to ground temperatures using an equation.

3.2 Ground Temperature Data

Ground temperature readings were initially collected in August 2020, following the installation of the GTCs, to confirm that they were all functioning. The ground temperatures from Boreholes BH-19 and BH-25 had not yet equilibrated to natural background temperatures at that time, so August 2020 data for these two installations are not presented. A second set of ground temperature readings were collected in October 2020 and a third set of readings were collected in March 2021. A summary of the March 2021 ground temperature data collected is in Table 3-2.

Table 3-2: Ground Temperature Data Summary

Borehole Number	BH-02	BH-08*	BH-14	BH-19	BH-25
MVWR Milepost (km)	1008.2	1005.0	1001.8	999.2	996.0
Permafrost Encountered	Yes	No	Yes	Yes	Yes
Depth of Active Layer	0.8 m	0.9 m	0.6 m	1.2 m	1.5 m
Minimum Temperature below Active Layer (March 2021)	-0.9 °C @ 7.8 m	0.2°C @ 1.0 m	-0.2°C @ 1.2 m	-2.9°C @ 1.3 m	-1.1°C @ 7.2 m
Maximum Temperature below Active Layer (March 2021)	-0.5°C @ 2.8 m	2.9°C @ 8.0 m	0.1°C @ 4.7 m	-1.3°C @ 3.8 m	-0.2°C @ 1.7 m

** Ground temperature readings incorrectly high in Borehole BH-08, likely due to an issue at the Amphenol connector on the GTC.*

Ground temperature profiles to depth for each GTC are included in Appendix C. A combined ground temperature profile for all sites, except Borehole BH-08, is also presented in the appendix.

Ground temperatures generally decreased with depth in all boreholes, except Borehole BH-14 where ground temperatures were the warmest. The depth of the active layer generally increased in the boreholes advancing from north to south on the PCAR alignment, ranging from 0.6 m to 1.5 m thick. Boreholes BH-02, BH-19, and BH-25 were frozen below the active layer to depth. Ground temperatures at depth ranged from -0.9°C in

Borehole BH-02 to -1.6°C in Borehole BH-19. Borehole BH-14 was frozen below the active layer to a depth of 2.2 m. The remainder of the borehole was unfrozen with a ground temperature of 0.1°C at depth.

Readings from Borehole BH-08 in August and October 2020 were incorrectly high and inconsistent with the other ground temperature data collected along the PCAR; however, recent readings from March 2021, although still abnormally high, indicate that the ground temperatures are trending closer to the other PCAR ground temperature data. These anomalous readings are likely due to a connectivity issue with the GTC's Amphenol connector. The connector should be inspected during the next site visit and repaired, if possible. Based on this issue, the data from Borehole BH-08 has not been presented in the combined ground temperature profile and was omitted from the thermal assessment in this report.

4.0 THERMAL ASSESSMENT

The factors affecting the sensitivity of permafrost ground to thermal degradation are mainly based on soil type, ground ice content, and ground temperature. Ice-rich permafrost soils are generally described as soils where the amount of water contained in the soil in a frozen state is higher than would be retained in a thawed (unfrozen) state. When frozen ground contains excess ground ice, the soil is susceptible to significant settlement and loss of soil strength when thawed (i.e., thaw-sensitive). Ice-poor permafrost is described as frozen soil that contains little frozen water and when thawed will not experience significant settlement or loss of soil strength (i.e., thaw-stable).

The PCAR has been divided into three generalized sections based on thermal conditions observed during the 2020 investigation programs and supported by subsequent ground temperature monitoring. PCAR thermal characterization sections are presented in Table 4-1 and in the following subsections.

Table 4-1: PCAR Thermal Characterization Sections

PCAR Section	MVWR Milepost (km)		Permafrost Conditions	GTCs within Section	Boreholes within Section
	From	To			
South (Prohibition Creek to MVWR km 999)	995.3	999.2	Frozen, Ice-Poor Unfrozen	1 (BH-25)	6 (BH-20 to BH-25)
Middle (MVWR km 999 to Christina Creek)	999.2	1001.7	Frozen, Ice-Poor Frozen, Ice-Rich	1 (BH-19)	5 (BH-15 to BH-19)
North (Christina Creek to Canyon Creek)	1001.7	1009.3	Unfrozen Frozen, Ice-Poor	3 (BH-02, BH-08, BH-14)	14 (BH-01 to BH-14)

Subsurface conditions are not uniform and it is expected that the thermal conditions will vary within each PCAR section; however, the data collected provides a good indication of the range of thermal properties to be expected along the PCAR alignment.

4.1 South Section (Prohibition Creek to MVWR km 999)

The PCAR's South Section spans from the Prohibition Creek Bridge at MVWR km 995.3 to km 999.2, as shown in Figure 2. Six geotechnical boreholes (BH-20 to BH-25) were drilled along this section of the alignment and one GTC was installed at MVWR km 996.0 (Borehole BH-25).

Subsurface conditions generally consisted of frozen silts and clays with some sand layers overlying mud shale bedrock (Tetra Tech 2020). Bedrock was encountered at depths ranging from 3.5 m to 5.0 m. Based on the boreholes, most of the South Section had minimal organic cover of less than 0.2 m. Visible ice crystals (V_x) and random ice formations (V_r) were observed below the estimated active layer in five of the six boreholes, ranging from 1% to 40% by volume. A 10 mm-thick ice lens was noted in one borehole (BH-23) at a depth of 1.7 m. Unfrozen conditions were noted in one borehole (BH-21) below 2 m depth to the end of the borehole. Thawed moisture contents ranged from dry to moist below the active layer, with an average moisture content of 15%.

Ground temperature readings from MVWR km 996.0 (Borehole BH-25) indicate warm permafrost beneath a measured active layer of 1.5 m. The active layer was found to be thickest within the South Section which is expected given that it is the most southern section of the PCAR and has minimal organic cover. Temperature readings below the active layer were frozen and decreased with depth, ranging from -0.2°C at 1.7 m to -1.1°C at 7.2 m.

Based on the above, the South Section's subgrade is expected to be thaw-stable as it generally consists of ice-poor permafrost soils overlying shallow bedrock. Thaw settlement and consolidation is not expected to be significant if thermally disturbed by construction of the PCAR.

4.2 Middle Section (MVWR km 999 to Christina Creek)

The Middle Section of the PCAR extends from MVWR km 999.2 to Christina Creek (MVWR km 1001.7), as shown in Figure 3. Five geotechnical boreholes (BH-15 to BH-19) were drilled along this section of the PCAR and one GTC was installed at MVWR km 999.2 (Borehole BH-19).

The Middle Section's subsurface predominantly consisted of frozen silty clays with trace sand and gravel components. All boreholes were overlain by a layer of organic peat ranging from 0.2 m to 0.9 m thick. Visible ice crystals (V_x), random ice formations (V_r), and stratified ice formations (V_s), up to 30% by volume, were observed below the estimated active layer to depth in all boreholes. Ice lenses, up to 20 mm thick, were also encountered below the estimated active layer in all boreholes. Moisture contents within the PCAR's Middle Section were damp to wet when thawed, with values averaging 23%.

Ground temperatures measured from the start of the Middle Section (Borehole BH-19) indicate warm permafrost conditions; however, readings below the active layer from the Middle Section were consistently colder compared to other sections of the PCAR. Temperature readings indicate an active layer thickness of about 1.2 m underlain by warm permafrost. Ground temperatures below the active layer decreased with depth, ranging from -1.3°C at 3.8 m to -2.9°C at 1.3 m. Based on this and the amount of visible ground ice observed, it is likely that permafrost soils containing excess ice exist below the depths drilled within this section (Tetra Tech 2020).

The subgrade for the Middle Section of the PCAR contains frequent ground ice within fine-grained, warm permafrost soils (i.e., ground temperatures warmer than -2°C). Settlement resulting from permafrost degradation over time is likely to occur due to construction of the PCAR. Areas where visible ground ice is greater than 20% by volume, such as around Borehole BH-17 (approximately MVWR km 999.5 to km 1000.5), will be prone to greater thaw settlement.

4.3 North Section (Christina Creek to Canyon Creek)

The PCAR's North Section ranges from Christina Creek to Canyon Creek (MVWR km 1001.7 to 1009.3), as depicted in Figure 4. The section consists of 14 geotechnical boreholes (BH-01 to BH-14) drilled during the geotechnical investigation and three GTCs were installed (Boreholes BH-02, BH-08, and BH-14) to monitor thermal conditions.

The North Section's ground conditions primarily consisted of unfrozen to frozen silts and clays with some sand and gravel layers. All boreholes were overlain with organic topsoil ranging from 0.1 m to 0.5 m thick. Warm permafrost was observed to depth in 13 of the 14 boreholes drilled along this section, including visible ice crystals (V_x) and random ice formations (V_r) up to 30% by volume below the estimated active layer. A 2 mm-thick ice lens was noted at depth in one borehole (BH-11). Moisture contents, when thawed, ranged from dry to moist below the active layer, averaging 16%. Unfrozen soils were observed below 2.4 m depth near MVWR km 1004.5 (Borehole BH-09) and a groundwater level of 2.5 m was inferred.

Measured ground temperatures along the North Section of the PCAR indicate discontinuous permafrost is present with an active layer thickness ranging from 0.6 m to 0.9 m. Ground temperatures below the active layer in Borehole BH-02 were frozen and decreased with depth, ranging from -0.5°C at 2.8 m to -0.9°C at 7.8 m. Unfrozen conditions were recorded in Borehole BH-14 between depths of 2.2 m and 5.6 m, indicating discontinuous permafrost. Frozen temperatures were recorded from the active layer depth to the top of the unfrozen zone as well as below the unfrozen zone to depth. Ground temperature readings from the middle of the North Section (Borehole BH-08) were incorrectly high and inconsistent with the rest of the section. Ground temperature data from Borehole BH-08 was omitted during this assessment. Given that visible ground ice was encountered in the borehole, it is expected that permafrost is also present at that location.

Based on the above, the PCAR subgrade within this section is expected to be generally thaw-stable and settlement due to permafrost degradation is not anticipated to be significant.

5.0 ROAD DESIGN CONSIDERATIONS

For road construction in areas of warm, discontinuous permafrost, any changes to the ground surface condition will unavoidably result in changes to the subgrade's thermal regime. This potentially triggers permafrost degradation and thaw settlement of the subgrade. The thermal and mechanical response of the frozen subgrade to the construction of road embankments may be very slow (i.e., thaw consolidation, creep). It is estimated that subgrade thermal regimes can take up to three years to equilibrate in the case of summer construction, or up to five years if constructed in winter conditions (Lingnau 1985). Thaw settlement and differential settlement of the road embankment and subgrade will occur, and regular road maintenance should be expected, particularly the first few years following construction.

The approach for embankment design is to protect the integrity of the structural core of the road where it is subject to traffic (TAC 2010). In thaw-sensitive permafrost areas, it is essential to anticipate thaw and to design the embankment to mitigate the effects of thaw and settlement. In thaw-stable permafrost areas, it is reasonable to manage permafrost thaw with suitable embankment design or specific protection techniques. The most common way to protect embankments against permafrost degradation is by increasing the thickness of the embankment fill, as these materials typically have low thermal conductivity. The objective is to use embankment fill as thermal resistance to slow the rate of heat flowing into the embankment foundation. Wide shoulders and flattened sideslopes should also be considered during the design of the PCAR as this provides an overall wider road configuration, which serves to move settlement away from the structural core of the embankment and reduces snow accumulation.

Permafrost and thermal considerations for the design of the PCAR should be based on guidance from the Transportation Association of Canada (TAC) *Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions* (TAC 2010) and the Canadian Standards Association (CSA) *Technical Guide: Infrastructure in permafrost: A guideline for climate change adaption* (CSA 2019).

Embankment design recommendations for the PCAR follow the generalized design approach outlined by TAC (2010). Three different embankment designs are outlined in the below subsections based on the thermal conditions

and generalized road sections described in Section 4.0. Thermal considerations for design and engineering of the PCAR embankments are summarized in Section 5.4, based on Tetra Tech's experience on similar road projects and engineering judgement. Estimated magnitudes of embankment settlement for each section of the PCAR are provided in Section 5.5.

5.1 South Section (Prohibition Creek to MVWR km 999)

The South Section of the proposed PCAR is expected to be thaw-stable as it generally contains ice-poor permafrost soils overlying shallow bedrock. Embankment thicknesses are likely to be governed by conventional pavement structure considerations; however, sideslopes are recommended to have a gradient of 2H:1V or flatter. Cuts within this section can be considered, if necessary.

5.2 Middle Section (MVWR km 999 to Christina Creek)

Permafrost soils along the PCAR's Middle Section are anticipated to be thaw-sensitive, based on the increased moisture contents and frequent occurrence of visible ground ice, particularly between MVWR km 999.5 and km 1000.5. Excess ground ice is also expected below the current borehole depths (8.0 m). It is recommended that embankment fills be a minimum of 1.6 m thick with sideslope gradients of 3H:1V or flatter. It is recommended that woven geotextile be installed between the road embankment and the subgrade from MVWR km 999.5 to km 1000.5 to preserve the road structure's integrity. Cuts within this section should be avoided.

5.3 North Section (Christina Creek to Canyon Creek)

The North Section of the PCAR alignment is expected to be thaw-stable as the frozen soils observed were consistently ice-poor below the active layer; however, permafrost is present under this section of the alignment based on the ground temperature readings and the observances of ground ice. Embankments within this section are recommended to have a minimum thickness of 1.4 m to help sustain permafrost conditions. Sideslopes are recommended to have a minimum gradient of 2.5H:1V within the North Section. Cuts within this section can be considered, if necessary; however, embankment fill settlements similar to that in the Middle Section should be anticipated (see Section 5.2). If cuts are required, a woven geotextile is recommended to be installed between the road embankment and the subgrade in these areas.

5.4 Embankment Design Summary

Embankment design parameters were developed for each PCAR section for consideration during the ongoing design and engineering of the MVH. Table 5-1 summarizes the recommended embankment design parameters for each section of the PCAR.

Table 5-1: PCAR Minimum Embankment Design Parameters

PCAR Section	MVWR Milepost (km)		Embankment Thickness (m)	Sideslope Gradient	Cuts Allowed?	Geotextile Over Subgrade?
	From	To				
South (Prohibition Creek to MVWR km 999)	995.3	999.2	-	2H:1V	Yes	No
Middle (MVWR km 999 to Christina Creek)	999.2	1001.7	1.6	3H:1V	No	Woven (km 999.5 to 1000.5)
North (Christina Creek to Canyon Creek)	1001.7	1009.3	1.4	2.5H:1V	Yes	No

The above design parameters are the minimum recommended design parameters based on the PCAR's thermal conditions. The final design of embankment thicknesses and sideslope gradients along the PCAR may be governed by conventional pavement structure design or road safety requirements, which have not been considered in the recommendations provided.

Woven geotextile is recommended to be installed between the road embankment and the subgrade for a 1 km portion of the Middle Section, between MVWR km 999.5 to km 1000.5, where frequent ground ice was observed within fine-grained soils and there is a potential for increased thaw settlement. Widespread use of geotextile is generally not warranted; however, installing a woven geotextile along the PCAR subgrade would provide improved confinement, separation, and reinforcement for the road embankment.

5.5 Embankment Settlement

Settlement along the PCAR alignment was estimated based on two mechanisms:

1. Self-weight and thaw settlement of placed embankment fills due to frozen fill placement during winter construction; and

2. Thaw settlement and consolidation of permafrost in the subgrade.

Estimated settlements for each PCAR section are summarized in Table 5-2.

Table 5-2: Estimated PCAR Embankment Settlement

PCAR Section	Estimated Range of Settlement (m)		
	Embankment Fill Settlement [1]	Thaw Settlement of Frozen Subgrade [2]	Total Settlement
South (Prohibition Creek to MVWR km 999)	0.1 – 0.3	0.1 – 0.4	0.2 – 0.7
Middle (MVWR km 999 to Christina Creek)	0.1 – 0.3	0.1 – 0.9	0.2 – 1.2
North (Christina Creek to Canyon Creek)	0.1 – 0.3	0.1 – 0.3	0.2 – 0.6

[1] Embankment Fill Settlement includes self-weight and thaw settlement of placed embankment fills due to frozen fill placement during winter construction. It was estimated to equal 5% of the road embankment height, assuming that embankment fill will consist of frozen, coarse-grained granular material placed in the winter.

[2] Thaw Settlement of Frozen Subgrade Soils estimated using the dry density method from Andersland and Ladanyi (2003).

The embankment settlements noted above represent the total estimated settlement for the range of road embankment heights in each PCAR section. Significant thaw settlement is expected, over the service life of the PCAR, in the Middle Section where ice-rich permafrost has been identified in the subgrade.

Embankment fill settlement is expected to occur primarily during the first two years of construction when winter placed frozen fill materials thaw and settle during the summer seasons. Initial fill settlement will likely be limited to the top 3 m of the embankment (due to the depth of thaw) and the core of the road structures will continue to thaw beyond the construction period (i.e., fill settlement for embankments with heights larger than 3 m is anticipated to take longer than two years). Based on this, embankment fill settlement is expected to be between 0.1 m and 0.3 m along the PCAR. Consideration should be given to overbuilding the embankment fills by approximately 0.3 m to allow for this.

Thaw settlement and consolidation of the frozen subgrade could be up to 0.9 m over the service life of the road. Long-term embankment settlements are expected to occur while a new thermal equilibrium is established and in response to climate warming projections. Based on historical observations from other highway structures in the Northwest Territories, the majority of long-term settlement of the road embankment and native subgrade appears to occur within 10 years of construction.

Tetra Tech does not recommend undertaking quantitative geothermal modelling in an attempt to estimate the time for post-construction thaw settlement to occur in the road embankment and native subgrade as the results are unlikely to change the design basis, construction approach, or performance of the PCAR.

6.0 CLIMATE CHANGE

The anticipated rise in ground temperatures over time, due to climate change, will change the behaviour of permafrost soils and could lead to weather changes such as increased precipitation and runoff events that could impact infrastructure. The potential impacts due to climate change should be considered in the design of the PCAR. CSA (2019) provides technical guidance for screening the vulnerability of northern infrastructure due to climate change.

The CSA guideline describes a risk-based approach to evaluate the sensitivity of the permafrost and the consequence of degradation due to climate change which is used to determine a level of risk. The level of risk

guides the detail of the assessment and analysis that is warranted due to climate change impacts. Climate change must be considered in all phases of permitting, design, operation, and closure planning of the PCAR as the project advances.

The sensitivity of a site to climate change is governed by the characteristics of the permafrost at the site. The PCAR site is in an area of extensive, discontinuous permafrost and permafrost soils were encountered in 23 of the 25 overland boreholes. The permafrost is *warm* with a mean annual ground temperature above -2°C and subsurface materials were predominantly fine-grained soils (silts and clays). Accordingly, Tetra Tech characterizes the permafrost sensitivity of the PCAR site as *High* (Table 5.3, CSA 2019).

CSA provides guidance on the potential implications of climate change on ground temperature. Under a “high” (RCP8.5) greenhouse gas emission scenario, the mean annual air temperature for the PCAR site (located in Arctic Sector W2) is expected to warm 1.6°C by 2040, 4.1°C by 2070, and 7.1°C by 2100 (Table 4.3, CSA 2019). In the absence of modelling to indicate otherwise, the CSA recommends assuming that ground temperatures increase in step with air temperatures.

Considering the measured ground temperatures along the PCAR alignment and the noted climate warming projections, it is expected that the permafrost will warm over time and could begin to thaw during the design life of the road. The practical implications of this are that ground settlement and loss of soil strength are likely to occur; however, since this is a low volume gravel road, the consequences of climate change impacts on the performance of the PCAR are considered to be relatively *Minor*.

According to CSA, the level of risk related to climate change effects can be estimated by considering the sensitivity of the permafrost (i.e., likelihood of permafrost degradation) along with the associated consequences (i.e., effect to the structure if permafrost degradation occurs). Considering the permafrost sensitivity and the associated consequences together results in a climate change risk level of *B: Moderate Risk* (Table 5.1, CSA 2019). This risk level warrants a semi-quantitative analysis together with the application of expert judgement which should be employed during the design and engineering of the PCAR, provided that the embankment structures and foundation systems have been successfully used on similar sites. This is the level of effort that has been employed for estimating the amount of thaw settlement and consolidation expected along the PCAR (see Section 5.5).

7.0 MONITORING

Ground temperature readings from each GTC were collected in October 2020 and March 2021; however, additional data collection and ongoing monitoring is recommended to understand the annual temperature fluctuations and permafrost conditions along the PCAR alignment. Additional site visits by a trained environmental monitor from the nearby town of Norman Wells are recommended so that ground temperature data can continue to be collected for the PCAR.

It is recommended that all GTCs be read a minimum of two times each year. Readings should be collected in spring (early April) when ground temperatures are the coldest for the year and in the fall (late September) when ground temperatures are warmest for the year. Readings in spring and fall provide ground temperature profiles that reasonably bound the range in ground temperatures produced by annual surface temperature variations. Ground temperature readings collected at other times of year provide intermediate temperature profiles.

Tetra Tech will continue to update and track ground temperatures as data is collected from the PCAR. The GNWT will be provided with the ground temperature data as it is collected and will be informed of any design and engineering considerations that arise in light of the ongoing monitoring.

8.0 CLOSURE

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

Respectfully submitted,
Tetra Tech Canada Inc.

REGISTERED PROFESSIONAL ENGINEER
LICENSEE
NT/NU
June 10, 2021

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PERMIT NUMBER: P 018
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/jf

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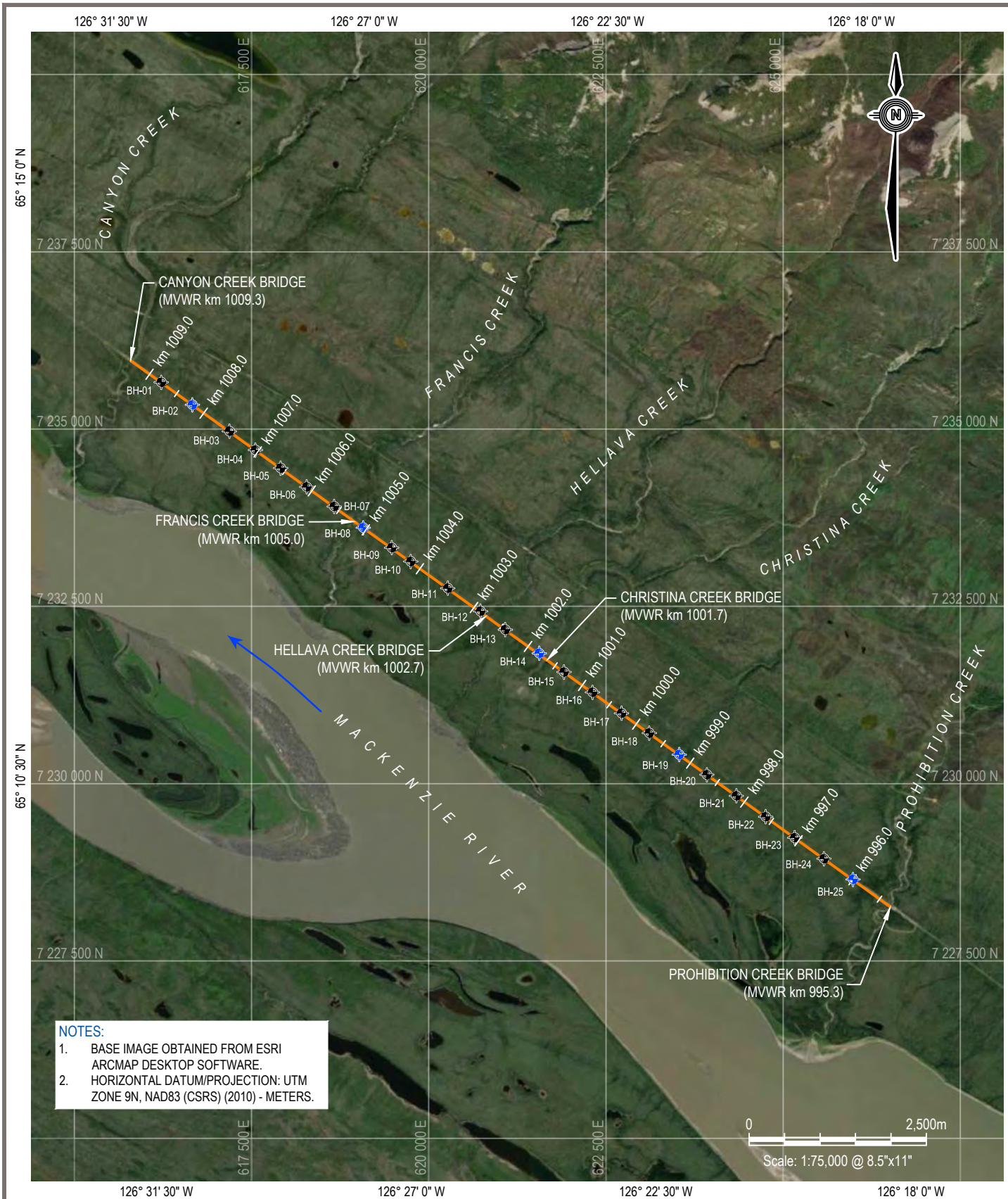
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FIGURES

Figure 1 Site Plan
Figure 2 MVWR km 995.3 to km 999.5
Figure 3 MVWR km 999.5 to km 1004.0
Figure 4 MVWR km 1004.0 to km 1009.3



NOTES:
1. BASE IMAGE OBTAINED FROM ESRI ARCMAP DESKTOP SOFTWARE.
2. HORIZONTAL DATUM/PROJECTION: UTM ZONE 9N, NAD83 (CSRS) (2010) - METERS.

LEGEND:

- PROHIBITION CREEK ACCESS ROAD (PROPOSED)
- 2020 BOREHOLE WITH GROUND TEMPERATURE CABLE (TETRA TECH)
- 2020 BOREHOLE (TETRA TECH)

CLIENT

Kãlo Stantec

TETRA TECH

PROHIBITION CREEK ACCESS ROAD THERMAL ASSESSMENT

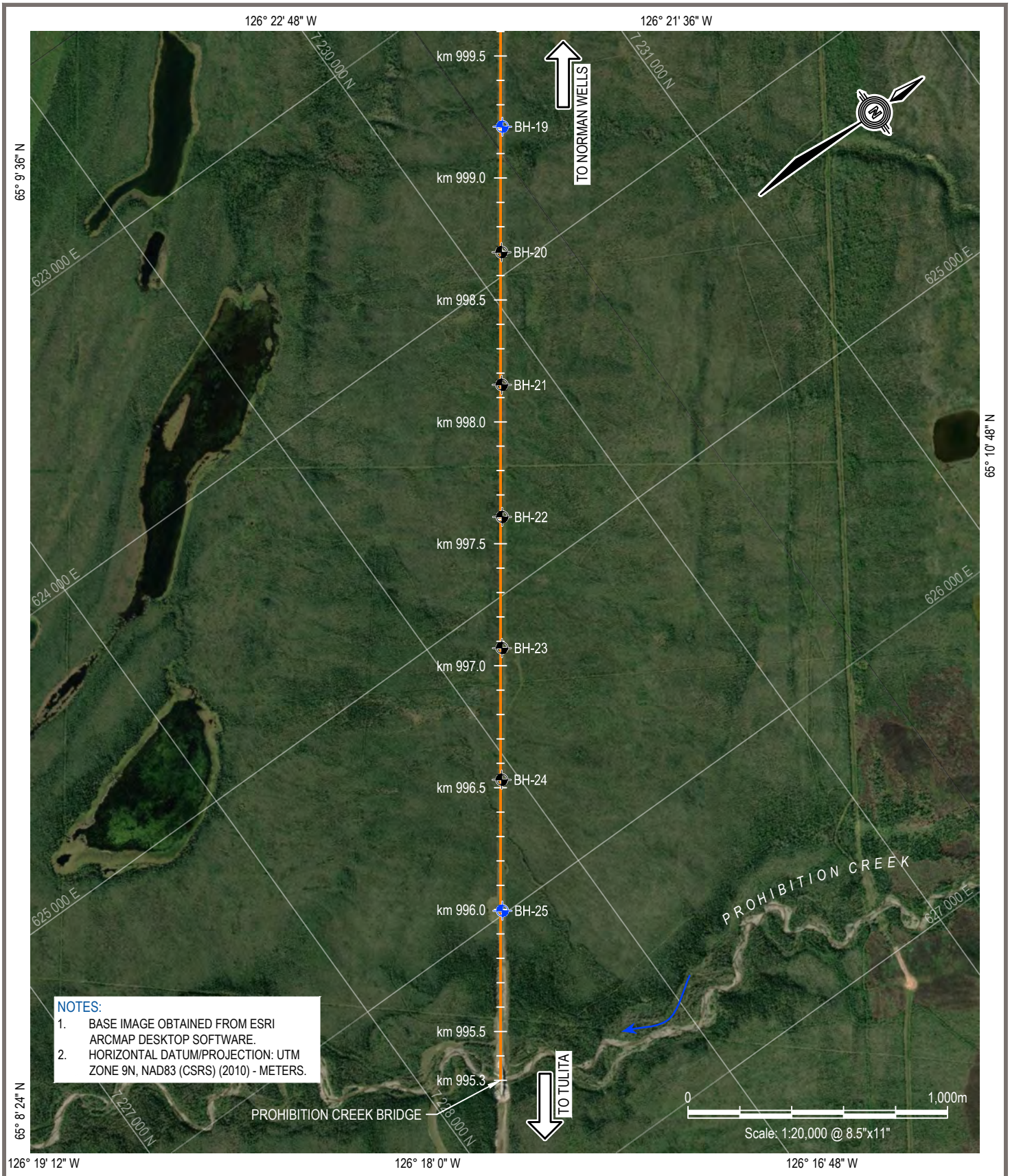
SITE PLAN

PROJECT NO.	DWN	CKD	REV
ENG.YARC03354-02	EL	TB	IFU

OFFICE	DATE
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FIGURE 1

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PROHIBITION CREEK ACCESS ROAD THERMAL ASSESSMENT

MVWR km 995.3 to km 999.5

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FIGURE 2

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PROHIBITION CREEK ACCESS ROAD THERMAL ASSESSMENT

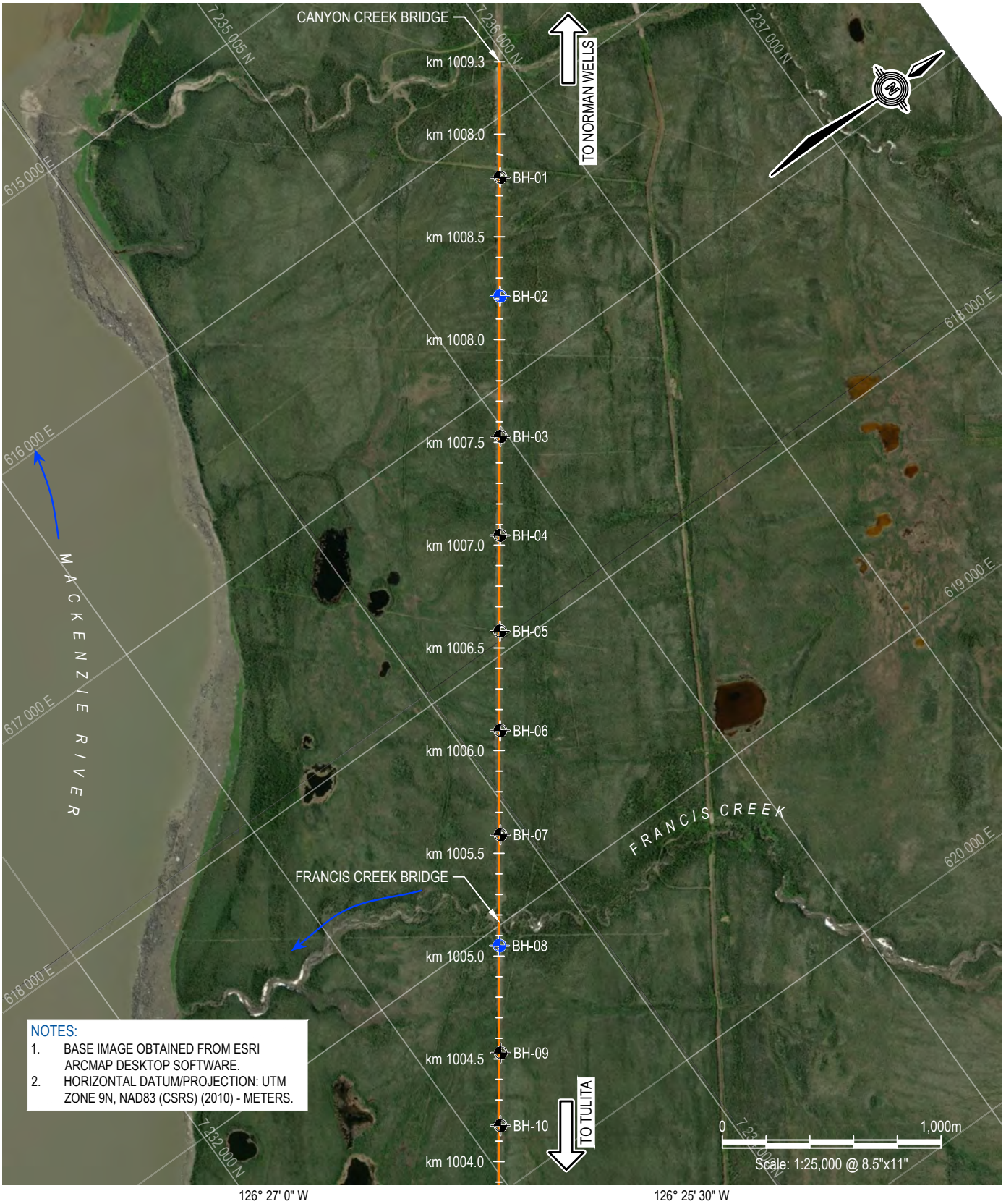
MVWR km 999.5 to km 1004.0

PROJECT NO.	DWN	CKD	REV
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FIGURE 3

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PROHIBITION CREEK ACCESS ROAD THERMAL ASSESSMENT

MVWR km 1004.0 to km 1009.3

PROJECT NO.	DWN	CKD	REV
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FIGURE 4

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APPENDIX A

TETRA TECH'S LIMITATIONS ON USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

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The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

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This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

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

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards 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. TETRA TECH 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.

1.9 LOGS OF TESTHOLES

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.

1.10 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 historical environment. TETRA TECH 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 exploration and review may be necessary.

1.11 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.

1.12 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.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact 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, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and 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.

1.15 DRAINAGE SYSTEMS

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. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters 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 used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH 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.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

APPENDIX B

2020 BOREHOLE LOGS

Borehole No: **BH01**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 84.5 m
Norman Wells, Northwest Territories	UTM: 616225 E; 7235660 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	ODEX	TOPSOIL - organics, grass, rootlets, (150 mm thick)	Frozen, no visible ice					84
		CLAY - silty, trace sand, trace gravel, olive brown						
1		SAND AND SILT - trace clay to clayey, trace gravel, brown, medium to coarse gravel						
		- (Gravel - 0%; Sand - 45%; Silt & Clay - 55%)	Vx, 10-15% ice by volume		SPT-1	17		83
2								
								82
3		- trace gravel - (Gravel - 6%; Sand - 35%; Silt - 53%; Clay - 6%)	Nbn		SPT-2	18		
4								81
		SILT - trace sand, no visible gravel, light greyish brown - (Gravel - 0%; Sand - 2%; Silt & Clay - 98%)			SPT-3	22		80
5								
								79
6		- (Gravel - 0%; Sand - 5%; Silt - 87%; Clay - 8%)			SPT-4	20		
		END OF BOREHOLE (6.45 metres)						78
7								
								77
8								
								76
9								
								75
10								

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 11
Logged By: AR	Completion Date: 2020 March 11
Reviewed By: EG	Page 1 of 1

Borehole No: **BH02**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 79.5 m
Norman Wells, Northwest Territories	UTM: 616665 E; 7235343 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	PVC	Elevation (m)
0	ODEX	TOPSOIL - organics, grass, rootlets, (100 mm thick)	Frozen, Vx, Vc, 15% ice by volume						79
		SILT - some gravel, some sand, some clay, olive brown, medium to coarse gravel							
1									
		- trace peat, orange brown - (Gravel - 19%; Sand - 17%; Silt & Clay - 64%)	Vx, 5% ice by volume		SPT-1	16	●		78
2									
									77
3		SAND - silty, some gravel, trace clay, brown - (Gravel - 13%; Sand - 51%; Silt - 28%; Clay - 8%)	5% ice by volume		SPT-2	13	●		
									76
4		SILT - sandy, some clay, trace gravel, low plastic, light brown							
					SPT-3	13	●		75
5		- (Gravel - 8%; Sand - 35%; Silt - 44%; Clay - 13%)				11	●		74
6		- grey			SPT-4				
									73
		END OF BOREHOLE (6.45 metres) 25 mm diameter PVC pipe installed to 8.0 metres							
7									72
8									
									71
9									
									70
10									

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 12
Logged By: AR	Completion Date: 2020 March 12
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH03**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 77.8 m
Norman Wells, Northwest Territories	UTM: 617187 E; 7234970 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (100 mm thick)	Frozen, Vx, Vc, 30% ice by volume					
		SAND - silty, some gravel, light brown						
1		- (Gravel - 15%; Sand - 45%; Silt & Clay - 40%)						77
			Vx, Vc, 5% ice by volume					
2					SPT-1	15		76
								75
3	ODEX	SILT - sandy, some clay, trace gravel, low plastic, light brown	15% ice by volume					
		- (Gravel - 5%; Sand - 33%; Silt - 51%; Clay - 11%)			SPT-2	22		
4								74
		- sandier						
		- (Gravel - 9%; Sand - 46%; Silt & Clay - 45%)			SPT-3	13		73
5								
								72
6		- trace clay, non plastic, grey						
		- (Gravel - 4%; Sand - 24%; Silt - 64%; Clay - 6%)	Vx, 5% ice by volume		SPT-4	13		
		END OF BOREHOLE (6.45 metres)						
7								71
								70
8								
								69
9								
								68
10								

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 12
Logged By: AR	Completion Date: 2020 March 12
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH04**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 76.6 m
Norman Wells, Northwest Territories	UTM: 617554 E; 7234705 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		TOPSOIL - clay, silty, organics, grass, rootlets	Frozen, Vx, Vc, 30% ice by volume					76
		SILT - trace clay, trace sand, brown						
1								
		- (Gravel - 0%; Sand - 9%; Silt & Clay - 91%)	20-30% ice by volume		SPT-1	34		75
2								74
3	ODEX	- sandy, some gravel - (Gravel - 14%; Sand - 35%; Silt - 44%; Clay - 7%)	10% ice by volume		SPT-2	17		73
4								
			10% ice by volume		SPT-3	14		72
5								71
6		- low plastic - (Gravel - 8%; Sand - 30%; Silt - 49%; Clay - 13%)			SPT-4	9		
		END OF BOREHOLE (6.45 metres)						70
7								69
8								68
9								67
10								

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 12
Logged By: AR	Completion Date: 2020 March 12
Reviewed By: EG	Page 1 of 1

Borehole No: **BH05**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 75.2 m
Norman Wells, Northwest Territories	UTM: 617909 E; 7234450 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (150 mm thick)	Frozen, Vx, 10-15% ice by volume					75
		CLAY - silty, sandy, some gravel, low to medium plastic, dark brown						
1								74
		- (Gravel - 16%; Sand - 27%; Silt - 42%; Clay - 15%)			SPT-1	23	●	
2								73
3	ODEX	- trace gravel, brown - (Gravel - 2%; Sand - 24%; Silt & Clay - 74%)	5% ice by volume		SPT-2	25	●	72
4								71
		- some gravel, low plastic - (Gravel - 13%; Sand - 32%; Silt - 44%; Clay - 11%)			SPT-3	11	●	
5								70
6		- trace gravel, grey - (Gravel - 10%; Sand - 35%; Silt & Clay - 55%)			SPT-4	9	●	69
		END OF BOREHOLE (6.45 metres)						
7								68
8								67
9								66
10								

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 12
Logged By: AR	Completion Date: 2020 March 12
Reviewed By: EG	Page 1 of 1

Borehole No: **BH06**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 75.8 m
Norman Wells, Northwest Territories	UTM: 618279 E; 7234185 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (200 mm thick)	Frozen, ice crystals, Vx, 50% ice by volume					75
		CLAY - silty, trace sand, trace gravel, low plastic, olive brown						
1								
		- no visible gravel, brown - (Gravel - 0%; Sand - 7%; Silt & Clay - 93%)	Vx, 10-30% ice by volume		SPT-1	35	●	74
2								
								73
3	ODEX	- sandy, trace gravel - (Gravel - 1%; Sand - 24%; Silt & Clay - 75%)	10% ice by volume		SPT-2	23	●	
4								72
		- some gravel, low plastic - (Gravel - 17%; Sand - 32%; Silt - 43%; Clay - 8%)			SPT-3	12	●H	
5		- trace gravel						71
6		- (Gravel - 4%; Sand - 32%; Silt - 48%; Clay - 16%)			SPT-4	12	●H	70
		END OF BOREHOLE (6.45 metres)						
7								69
8								68
9								67
10								66

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 13
Logged By: AR	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH07**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 81.3 m
Norman Wells, Northwest Territories	UTM: 618666 E; 7233908 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (50 mm thick)	Frozen, Vx, 30% ice by volume					81
		SILT - trace sand, low plastic, brown						
1								80
		- becomes more clayey	Vx, 15% ice by volume					
		- (Gravel - 0%; Sand - 4%; Silt - 76%; Clay - 20%)			SPT-1		28	
2								79
		- sandy						
3	ODEX	- (Gravel - 0%; Sand - 23%; Silt - 62%; Clay - 15%)	5% ice by volume					
		- gravelly			SPT-2		23	78
4								
		- (Gravel - 22%; Sand -38%; Silt & Clay - 40%)	Nbn					77
		- SPT refusal on gravel			SPT-3		12	
5		- (Gravel - 16%; Sand - 37%; Silt & Clay - 47%)						
						50/ 25mm	14	76
6		- some gravel			SPT-4			
								75
		END OF BOREHOLE (6.45 metres)						
7								74
8								73
9								72
10								

SPT (N) 20 40 60 80

Plastic Limit | Moisture Content | Liquid Limit

20 40 60 80

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 13
Logged By: AR	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH08**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 81.8 m
Norman Wells, Northwest Territories	UTM: 619075 E; 7233609 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	PVC	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (200 mm thick)	Frozen, Vx, 30% ice by volume						81
		SAND AND SILT - gravelly, some clay to clayey, low plastic, olive brown, medium to coarse gravel							
1									
		- (Gravel - 29%; Sand - 29%; Silt - 31%; Clay - 11%)	Vx, 10% ice by volume		SPT-1	14			80
2									
									79
3	ODEX	- (Gravel - 23%; Sand - 55%; Silt & Clay - 22%)	10-15% ice by volume		SPT-2	17			
		SAND - gravelly, some silt, trace clay, brown							78
4									
		- dark brown and black	5% ice by volume						
		- (Gravel - 34%; Sand - 53%; Silt & Clay - 13%)			SPT-3	13			77
5									
									76
6		- clayey, silty, trace gravel	2% ice by volume						
		- (Gravel - 9%; Sand - 66%; Silt - 25%; Clay - 33%)			SPT-4	25			
		END OF BOREHOLE (6.45 metres)							75
7		25 mm diameter PVC pipe installed to 8.6 metres							
									74
8									
									73
9									
									72
10									

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 13
Logged By: AR	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH09**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 78.2 m
Norman Wells, Northwest Territories	UTM: 619477 E; 7233327 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (150 mm thick)	Frozen, Vx, 20% ice by volume					78
		SILT - gravelly, sandy, trace clay, rootlets, organics, olive brown						
1								77
		- no visible organics, no visible rootlets, light brown - (Gravel - 28%; Sand - 26%; Silt & Clay - 46%)	Nbn		SPT-1		16	
2								76
		GRAVEL AND SAND - some silt, trace clay, wet, brown - moist	Unfrozen					
3	ODEX	- (Gravel - 46%; Sand - 39%; Silt - 12%; Clay - 3%)			SPT-2	14	35	75
		SILT - sandy, gravelly, trace clay, brown						
4								74
							16	
5		- grey - (Gravel - 25%; Sand - 30%; Silt & Clay - 45%)						73
							21	
6		- grey						72
		END OF BOREHOLE (6.45 metres) water - 2.5 metres						
7								71
8								70
9								69
10								

SPT (N) 20 40 60 80

Plastic Limit — Moisture Content — Liquid Limit

20 40 60 80

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 13
Logged By: AR	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH10**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 80.6 m
Norman Wells, Northwest Territories	UTM: 619746 E; 7233133 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		TOPSOIL - organics, grass, rootlets, (100 mm thick) CLAY - silty, sandy, some gravel, organics, rootlets, grass, low plastic, light brown	Frozen, ice crystals, Vx, 40-50% ice by volume					80
1								
2		- (Gravel - 15%; Sand - 27%; Silt - 46%; Clay - 12%)	Nbn, Vx, 5% ice by volume		SPT-1	21		79
3	ODEX	- trace gravel, grey and brown - (Gravel - 8%; Sand - 35%; Silt & Clay - 57%)	Nbn, no visible ice		SPT-2	10		78
4								77
5		- grey - (Gravel - 2%; Sand - 27%; Silt - 50%; Clay - 21%)			SPT-3	11		76
6		- some gravel, dark grey - (Gravel - 12%; Sand - 30%; Silt & Clay - 58%)			SPT-4	9		75
7		END OF BOREHOLE (6.45 metres)						74
8								73
9								72
10								71

Contractor: Geotech Drilling	Completion Depth: 6.45 m
Drilling Rig Type: Truck mounted B80	Start Date: 2020 March 13
Logged By: AR	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH11**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 80.1 m
Norman Wells, Northwest Territories	UTM: 620268 E; 7232756 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice					80
		SAND - gravelly, silty, trace clay, olive brown, rounded to subrounded gravel to 40 mm diameter						
1								79
		- gravelly - (Gravel - 27%; Sand - 39%; Silt - 26%; Clay - 8%) - orange oxidation for 100 mm		☒	SPT-1	10	●	
2		CLAY - silty, sandy, gravelly, low to medium plastic, brown						78
3		- (Gravel - 20%; Sand - 30%; Silt - 33%; Clay - 17%)	Vx, <1% ice by volume	☒	SPT-2	10	●⊢	77
4		- some gravel, greyish brown						76
		- (Gravel - 17%; Sand - 29%; Silt & Clay - 54%)		☒	SPT-3	9	●	
5								75
6		- (Gravel - 14%; Sand - 32%; Silt & Clay - 54%)	2 mm thick vertical ice lens, Vr, 5% ice by volume	☒	SPT-4	9	●	74
		END OF BOREHOLE (6.3 metres)						
7								73
8								72
9								71
10								

TETRA TECH

Contractor: Geotech Drilling	Completion Depth: 6.3 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 17
Logged By: DY	Completion Date: 2020 March 17
Reviewed By: EG	Page 1 of 1

Borehole No: **BH12**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 80.3 m
Norman Wells, Northwest Territories	UTM: 620731 E; 7232433 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice					80
		GRAVEL - sandy, silty, trace clay, brown, rounded to subrounded gravel to 75 mm diameter						
1								79
		- gravel to 40 mm diameter - (Gravel - 33%; Sand - 31%; Silt & Clay - 36%)			SPT-1	15		
2								78
		GRAVEL AND SAND - trace silt, trace clay, brown						
3		- (Gravel - 49%; Sand - 37%; Silt & Clay - 14%)			SPT-2	6		77
4								76
		CLAY - silty, trace sand, low to medium plastic, olive brown	Vx, 5% ice by volume		SPT-3	12		
5		- (Gravel - 0%; Sand - 6%; Silt - 74%; Clay - 20%)			SPT-4	24		75
		SAND AND GRAVEL - some silt, trace clay, mottled brown and black						
6		- (Gravel - 41%; Sand - 43%; Silt - 12%; Clay - 4%)			SPT-5	14		
		END OF BOREHOLE (6.2 metres)	Ice crystals, Vx, 10% ice by volume					74
7								73
8								72
9								71
10								

Contractor: Geotech Drilling	Completion Depth: 6.2 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 12
Logged By: DY	Completion Date: 2020 March 12
Reviewed By: EG	Page 1 of 1

NORTHERN ZONE9.GPJ EBA.GDT 20-10-20

Borehole No: **BH13**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 81.3 m
Norman Wells, Northwest Territories	UTM: 621079 E; 7232172 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice					81
		CLAY - silty, trace sand, low plastic						
1		- (Gravel - 0%; Sand - 10%; Sand - 79%; Clay - 11%)			SPT-1	18		80
2		- some gravel, rounded to subrounded gravel to 25 m diameter						79
3		- becomes sandy, trace gravel - (Gravel - 10%; Sand - 37%; Silt & Clay - 53%)	Ice crystals, Vx, 10% ice by volume Nbn, no visible ice		SPT-2	12		78
4								77
		SILT - trace gravel, low plastic, grey - (Gravel - 8%; Sand - 42%; Silt - 35%; Clay - 15%)			SPT-3	9		
5								76
6		- (Gravel - 8%; Sand - 40%; Silt & Clay - 52%)			SPT-4	10		75
		END OF BOREHOLE (6.3 metres)						
7								74
8								73
9								72
10								

Contractor: Geotech Drilling	Completion Depth: 6.3 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 16
Logged By: DY	Completion Date: 2020 March 17
Reviewed By: EG	Page 1 of 1

Borehole No: **BH14**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 80.1 m
Norman Wells, Northwest Territories	UTM: 621558 E; 7231839 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	PVC	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, random ice, Vr, 30% ice by volume						80
		PEAT - dark brown							
		CLAY - silty, trace sand, medium plastic, brown	Vx, 1% ice by volume						
1									79
		- (Gravel - 0%; Sand - 10%; Silt - 68%; Clay - 22%)	10% ice by volume						
					SPT-1	36			
2		- some gravel, rounded to subrounded gravel to 25 mm diameter	1% ice by volume						78
			Marginally frozen, Nbn						
3		- becomes sandy, gravelly							77
		- (Gravel - 25%; Sand - 43%; Silt & Clay - 32%)			SPT-2	11			
	Solid stem auger								
4		- trace gravel, damp, firm, multicoloured, rounded to subrounded gravel to 20 mm diameter							76
					SPT-3	13			
5									75
6		- dark greyish brown							74
		- (Gravel - 4%; Sand - 30%; Silt & Clay - 66%)			SPT-4	11			
7									73
		- some sand							
		- (Gravel - 6%; Sand - 20%; Silt - 38%; Clay - 36%)			SPT-5	13			
8									72
		END OF BOREHOLE (8.1 metres)							
		25 mm diameter PVC pipe installed to 8.0 metres							
9									71
10									

Contractor: Geotech Drilling	Completion Depth: 8.1 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 12
Logged By: DY	Completion Date: 2020 March 12
Reviewed By: EG	Page 1 of 1

Borehole No: **BH15**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 82.3 m
Norman Wells, Northwest Territories	UTM: 621909 E; 7231574 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick) PEAT - dark brown CLAY - silty, trace sand, medium plastic, brown	Frozen, visible ice, 30% ice by volume Nbn					82
1		- (Gravel - 0%; Sand - 9%; Silt & Clay - 91%)	Ice crystals, Vx, 10% ice by volume 20 mm thick ice lens, Vr		SPT-1	51		81
2		- trace gravel, rounded to subrounded gravel to 20 mm diameter						80
3		- (Gravel - 4%; Sand - 14%; Silt - 40%; Clay - 42%)	Ice crystals, Vx, 1% ice by volume		SPT-2	23		79
4		- grey						78
5		- (Gravel - 1%; Sand - 13%; Silt - 44%; Clay - 42%)	1 mm thick ice lenses, Vr		SPT-3	18		77
6		- (Gravel - 4%; Sand - 29%; Silt & Clay - 67%)	1 mm thick ice lenses, Vr		SPT-4	14		76
7		END OF BOREHOLE (6.5 metres)						75
8								74
9								73
10								

Contractor: Geotech Drilling	Completion Depth: 6.5 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 15
Logged By: DY	Completion Date: 2020 March 15
Reviewed By: EG	Page 1 of 1

NORTHERN ZONE9.GPJ EBA.GDT 20-10-20

Borehole No: **BH16**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 82.5 m
Norman Wells, Northwest Territories	UTM: 622310 E; 7231288 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice					
		PEAT - dark brown, slight organic odour						
		SAND AND SILT - some clay, trace gravel, brown, rounded to subrounded gravel to 25 mm diameter	Vx, 2% ice by volume					82
1	Solid stem auger	- (Gravel - 6%; Sand - 43%; Silt - 38%; Clay - 13%)	Nbn		SPT-1	20		81
2		CLAY - silty, some sand, trace gravel, medium plastic, grey, rounded to subrounded gravel to 25 mm diameter						80
3		- (Gravel - 3%; Sand - 18%; Silt & Clay - 79%)			SPT-2	19		79
4								
		- sandy - (Gravel - 6%; Sand - 31%; Silt - 34%; Clay - 29%)	Vx and Vr 1mm thick Vr, 2% ice by volume		SPT-3	12		78
5		- gravel to 40 mm diameter						77
6		- (Gravel - 3%; Sand - 23%; Silt & Clay - 74%)			SPT-4	15		76
		END OF BOREHOLE (6.5 metres)						
7								75
8								74
9								73
10								

Contractor: Geotech Drilling	Completion Depth: 6.5 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 15
Logged By: DY	Completion Date: 2020 March 15
Reviewed By: EG	Page 1 of 1

Borehole No: **BH17**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 84.3 m
Norman Wells, Northwest Territories	UTM: 622719 E; 7230994 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, visible ice, 30% ice by volume					84
		PEAT - roots, rootlets, dark brown						
		CLAY - silty, some sand, trace gravel, medium plastic, grey, rounded to subrounded gravel to 20 mm diameter - trace cobbles for 300 mm	Vx, <1% ice by volume					
1								83
		- (Gravel - 3%; Sand - 11%; Silt & Clay - 86%)	Vx, 25% ice by volume		SPT-1	31		
2			Vx, <1% ice by volume					82
3		- dark grey - (Gravel - 6%; Sand - 19%; Silt - 40%; Clay - 35%)	2 mm thick vertical ice lenses, Vs, 5% ice by volume		SPT-2	20		81
			Vx, 1% ice by volume					
4								80
		- some gravel - (Gravel - 13%; Sand - 19%; Silt & Clay - 68%)	10 mm thick ice lenses, Vs, 20% ice by volume		SPT-3	19		
5			Vx, 2% ice by volume					79
6		- trace gravel - (Gravel - 1%; Sand - 21%; Silt - 42%; Clay - 36%)	10-20 mm thick vertical and diagonal ice lenses, Vs, 30% ice by volume		SPT-4	19		78
		END OF BOREHOLE (6.5 metres)						
7								77
8								76
9								75
10								

Contractor: Geotech Drilling	Completion Depth: 6.5 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 13
Logged By: DY	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

TETRA TECH

NORTHERN ZONE9.GPJ EBA.GDT 20-10-20

Borehole No: **BH18**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 84.4 m
Norman Wells, Northwest Territories	UTM: 623111 E; 7230713 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, random ice, Vr, 30% ice by volume						84
		PEAT - dark brown							
1	Solid stem auger	CLAY - silty, trace sand, low plastic, greyish brown	Ice crystals, Vx, 2% ice by volume						
		- (Gravel - 0%; Sand - 3%; Silt - 77%; Clay - 20%)	Ice crystals (Vx) and ice lenses (Vs), 20% ice by volume		SPT-1		32		83
2		- sandy, trace gravel, rounded to subrounded gravel to 40 mm diameter							82
3		- (Gravel - 4%; Sand - 25%; Silt & Clay - 71%)	Ice crystals, Vx, 2% ice by volume		SPT-2		24		81
4									
		- some sand, medium plastic - (Gravel - 2%; Sand - 20%; Silt - 45%; Clay - 33%)	Ice crystals, Vx, 5% ice by volume		SPT-3		17		80
5									
		- grey				46			79
6		- (Gravel - 6%; Sand - 19%; Silt & Clay - 75%)	Ice crystals (Vx) and ice lenses (Vs), 2% ice by volume		SPT-4		15		78
		END OF BOREHOLE (6.5 metres)							
7									77
8									76
9									75
10									

Contractor: Geotech Drilling	Completion Depth: 6.5 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 16
Logged By: DY	Completion Date: 2020 March 16
Reviewed By: EG	Page 1 of 1

Borehole No: **BH19**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 85.6 m
Norman Wells, Northwest Territories	UTM: 623533 E; 7230411 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	PVC	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, visible ice, 30% ice by volume						85
		PEAT - roots, dark brown							
1		CLAY - silty, some sand, medium plastic, black and grey	Vx, 20% ice by volume						
		- (Gravel - 0%; Sand - 20%; Silt & Clay - 80%)	2% ice by volume		SPT-1	65			84
2			10% ice by volume						
									83
3	Solid stem auger	- some gravel, dark grey, rounded to subrounded gravel to 25 mm diameter - (Gravel - 15%; Sand - 26%; Silt - 29%; Clay - 30%)	(Vx) and ice lenses (Vs), 5% ice by volume Vx, 2% ice by volume		SPT-2	32			
4									82
		- (Gravel - 11%; Sand - 30%; Silt & Clay - 59%)	Vx and 2 mm thick ice lenses (Vs), 2% ice by volume		SPT-3	13			81
5			Vx, 1% ice by volume						
									80
6		- some sand			SPT-4	18			
									79
7			Nbn						
		- no visible gravel, greyish brown - (Gravel - 0%; Sand - 11%; Silt - 61%; Clay - 28%)			SPT-5	15			78
8		END OF BOREHOLE (7.8 metres) 25 mm diameter PVC pipe installed to 7.8 metres							
									77
9									
									76
10									

Contractor: Geotech Drilling	Completion Depth: 7.8 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 14
Logged By: DY	Completion Date: 2020 March 15
Reviewed By: EG	Page 1 of 1

Borehole No: **BH20**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 86.2 m
Norman Wells, Northwest Territories	UTM: 623924 E; 7230126 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, visible ice, Vr, 30% ice by volume					86
		PEAT - dark brown						
		SAND - silty, some gravel, some clay, brown, gravel to 10 mm diameter	Nbn					
1								85
		- (Gravel - 11%; Sand - 44%; Silt & Clay - 45%)	Vx, 40% ice by volume Nbn		SPT-1	12	●	
2								84
		CLAY - silty, trace sand, low to medium plastic, olive brown						
3		- (Gravel - 0%; Sand - 10%; Silt - 70%; Clay - 20%)			SPT-2	14	●⊢	83
		SHALE - crumbly, powdery, dry, grey						
4								82
					SPT-3	11	●	
5								81
						9	●	
		END OF BOREHOLE (5.5 metres)						
6								80
7								79
8								78
9								77
10								

Contractor: Geotech Drilling	Completion Depth: 5.5 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 16
Logged By: DY	Completion Date: 2020 March 16
Reviewed By: EG	Page 1 of 1

TETRA TECH

Borehole No: **BH21**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 87.8 m
Norman Wells, Northwest Territories	UTM: 624340 E; 7229829 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	SPT (N) 20 40 60 80 / Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice						87
1	Solid stem auger	CLAY - silty, some sand, trace gravel, firm, low plastic, light grey, rounded to subrounded gravel to 50 mm diameter							
		- (Gravel - 3%; Sand - 19%; Silt & Clay - 78%)	Vx, 5% ice by volume		SPT-1		21		86
2		SILT - sandy, some clay, trace gravel, low plastic, brown	Unfrozen						
3		- (Gravel - 7%; Sand - 32%; Silt - 46%; Clay - 15%)					6		85
4		- some sand, olive brown							84
		SHALE - crumbly, powdery, dry, grey			SPT-2	50/ 150mm	10		83
5									
6					SPT-3	58/ 150mm	9		82
		END OF BOREHOLE (6.2 metres)							
7									81
8									80
9									79
10									78

Contractor: Geotech Drilling	Completion Depth: 6.2 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 13
Logged By: DY	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH22**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 89.9 m
Norman Wells, Northwest Territories	UTM: 624754 E; 7229533 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick) PEAT - dark brown SILT - some clay, trace sand, low plastic, brown	Frozen, visible ice, Vr, 30% ice by volume Nbn					89
1			Unfrozen Nbn					
		- (Gravel - 0%; Sand - 8%; Silt - 77%; Clay - 15%)			SPT-1	26		
2			Vx, 2% ice by volume					88
3		SAND - trace gravel - (Gravel - 9%; Sand - 41%; Silt & Clay - 50%)	10% ice by volume		SPT-2	17		87
4		SHALE - crumbly, powdery, friable, grey	Nbn					86
5					SPT-3	11		85
6					SPT-4	10		84
		END OF BOREHOLE (6.2 metres)						
7								83
8								82
9								81
10								80

TETRA TECH

Contractor: Geotech Drilling	Completion Depth: 6.2 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 16
Logged By: DY	Completion Date: 2020 March 16
Reviewed By: EG	Page 1 of 1

Borehole No: **BH23**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 90.4 m
Norman Wells, Northwest Territories	UTM: 625163 E; 7229238 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice					90
		SILT - some sand, some clay, non plastic, brown						
1		- (Gravel - 0%; Sand - 11%; Silt - 71%; Clay - 18%)	Vx, 5% ice by volume 10 mm thick ice lens, Vs		SPT-1	38	●	89
2		CLAY - sandy, silty, trace gravel, firm, low to medium plastic, brown, multicoloured gravel, rounded to subrounded gravel to 25 mm diameter	Nbn					88
3		- (Gravel - 6%; Sand - 45%; Silt & Clay - 49%)			SPT-2	11	●	87
4		SHALE - crumbly, powdery, grey						86
5					SPT-3	11	●	85
6					SPT-4	11	●	84
7		END OF BOREHOLE (6.3 metres)						83
8								82
9								81
10								

Contractor: Geotech Drilling	Completion Depth: 6.3 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 13
Logged By: DY	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

Borehole No: **BH24**

Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 90.9 m
Norman Wells, Northwest Territories	UTM: 625575 E; 7228941 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Elevation (m)
0	Solid stem auger	ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice					90
		SILT - some sand, trace clay, non plastic, brown	Nbn					
1								
		- (Gravel - 0%; Sand - 19%; Silt - 73%; Clay - 8%)			SPT-1	27		89
2		SAND - silty, some clay, some gravel, brown, rounded to subrounded gravel to 20 mm diameter						
		- (Gravel - 13%; Sand - 42%; Silt & Clay - 45%)			SPT-2	11		88
3		SHALE - crumbly, powdery, dry, grey						
								87
4								
					SPT-3	9		86
5								
								85
6					SPT-4	8		
		END OF BOREHOLE (6.2 metres)						
7								84
8								83
9								82
10								81

Contractor: Geotech Drilling	Completion Depth: 6.2 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 15
Logged By: DY	Completion Date: 2020 March 16
Reviewed By: EG	Page 1 of 1

TETRA TECH

NORTHERN ZONE9.GPJ EBA.GDT 20-10-20

Borehole No: **BH25**

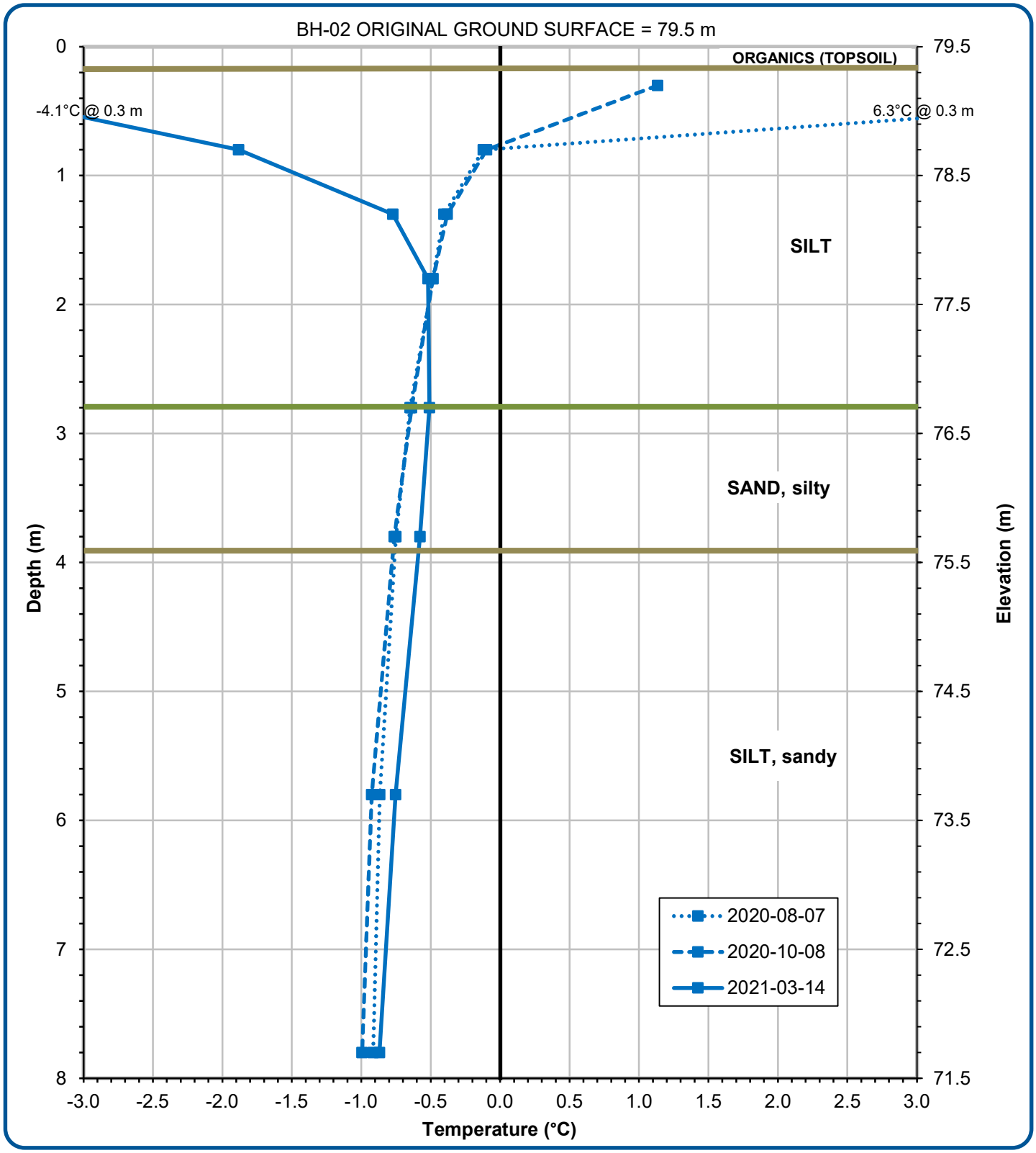
Project: Geotechnical Evaluation for PCAR	Project No: ENG.YARC03329-01
Location: Prohibition Creek Access Road	Ground Elev: 95 m
Norman Wells, Northwest Territories	UTM: 625986 E; 7228649 N; Z 9

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	PVC	Elevation (m)
0		ORGANICS - grass, rootlets, topsoil, (20 mm thick)	Frozen, no visible ice						95
		CLAY - silty, sandy, medium plastic, brown							
1									94
		- (Gravel - 0%; Sand - 25%; Silt & Clay - 75%)	Vr, <1% ice by volume		SPT-1	23			
2									93
		- no visible sand							
3		- (Gravel - 0%; Sand - 0%; Silt - 64%; Clay - 36%)			SPT-2	32			92
	Solid stem auger		Vx, 5% ice by volume						
4		- trace sand, medium to high plastic, dark greyish brown							91
		- (Gravel - 0%; Sand - 5%; Silt - 41%; Clay - 54%)	Vx, 1% ice by volume		SPT-3	30			
5		SHALE - crumbly, powdery, dry, grey	Nbn						90
6					SPT-4	10			89
7									88
					SPT-5	10			
8		END OF BOREHOLE (7.8 metres) 25 mm diameter PVC pipe installed to 7.7 metres							87
9									86
10									85

Contractor: Geotech Drilling	Completion Depth: 7.8 m
Drilling Rig Type: Truck mounted M5T	Start Date: 2020 March 13
Logged By: DY	Completion Date: 2020 March 13
Reviewed By: EG	Page 1 of 1

APPENDIX C

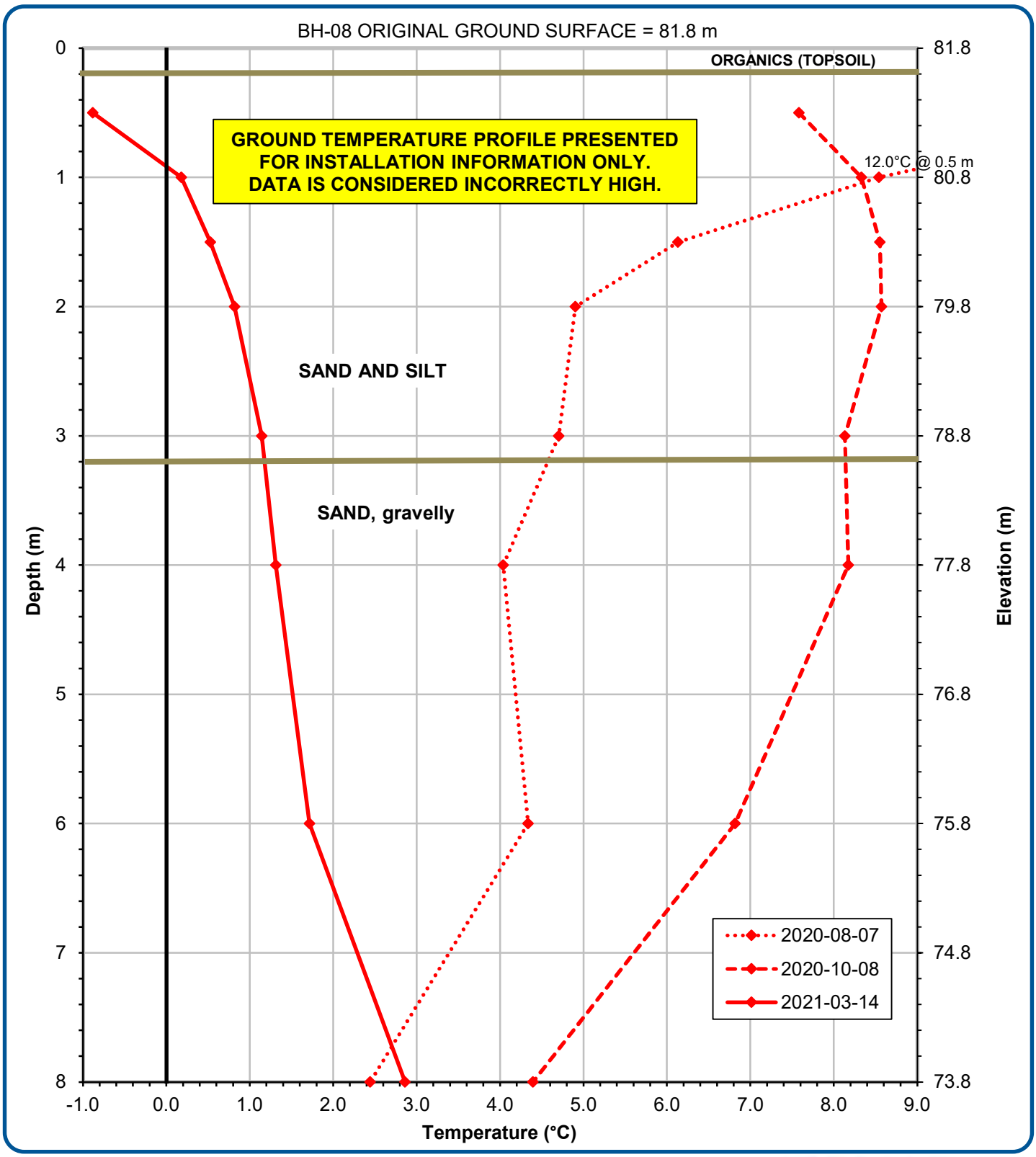
GROUND TEMPERATURE PROFILES



GTC Serial No. 2739
Date Drilled: March 12, 2020
Date Installed: August 5, 2020

Borehole BH-02 (MVWR km 1008.2)
Ground Temperature Profile

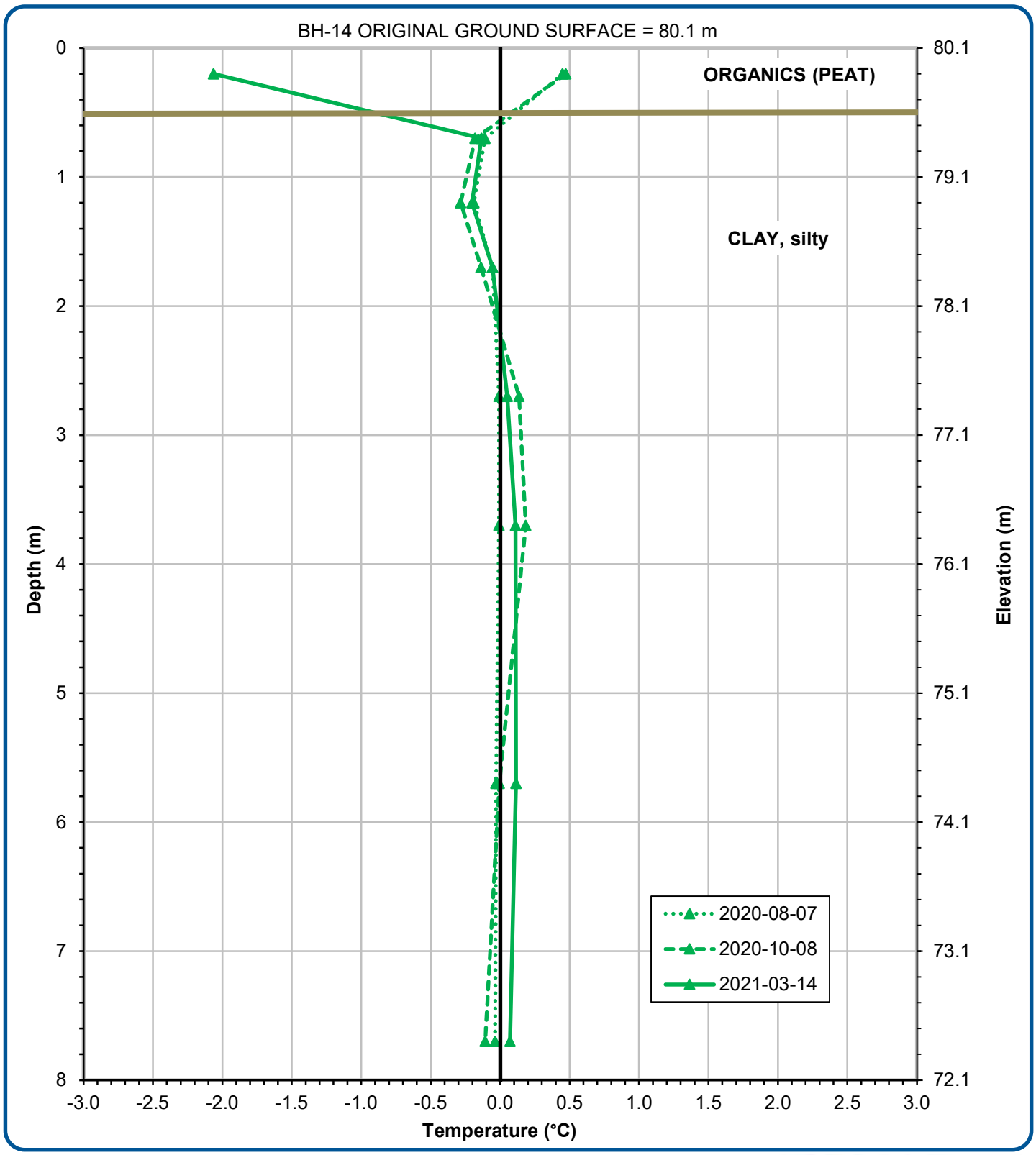
TETRA TECH



GTC Serial No. 2738
Date Drilled: March 13, 2020
Date Installed: August 5, 2020

Borehole BH-08 (MVWR km 1005.0)
Ground Temperature Profile

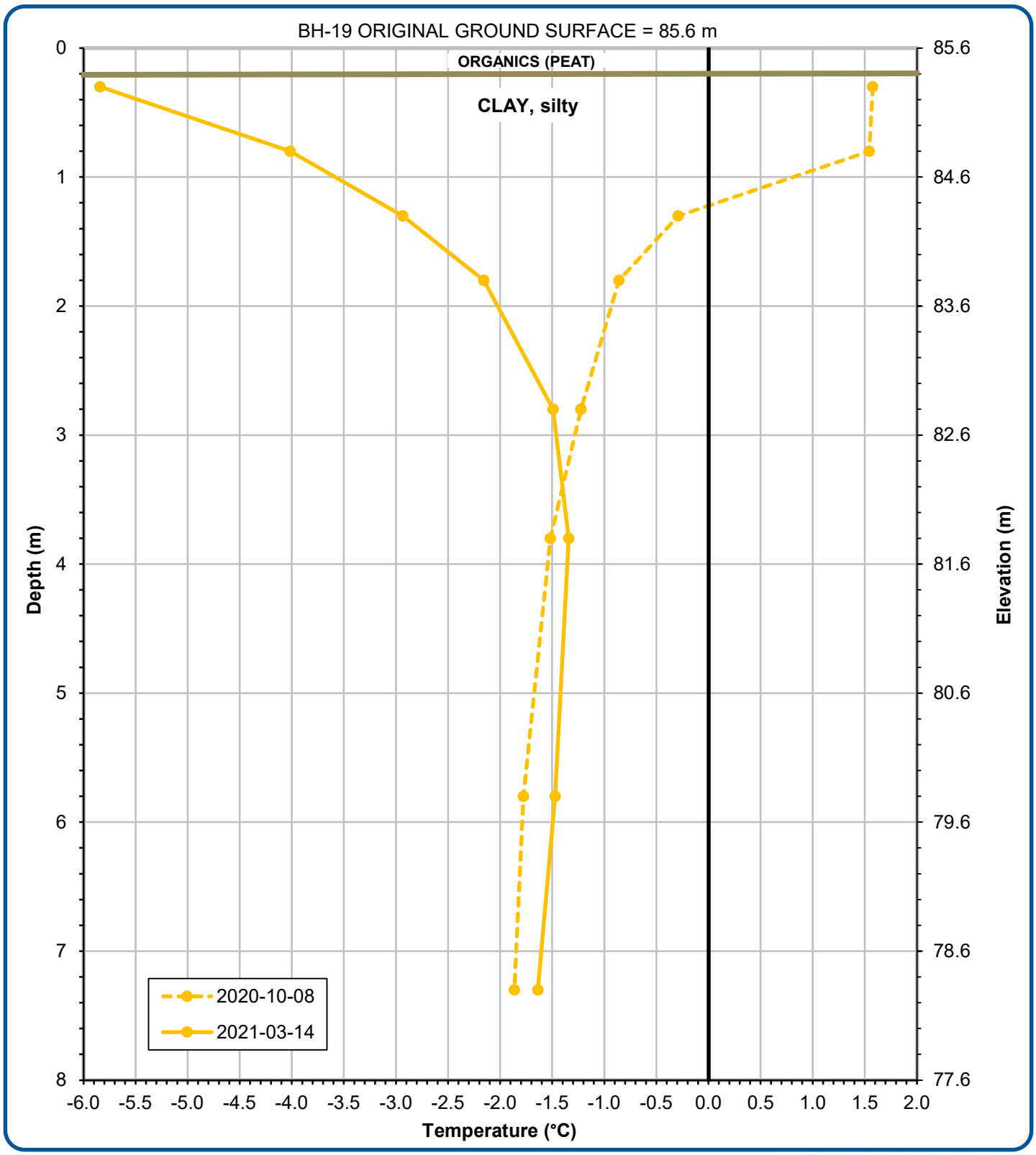
TETRA TECH



GTC Serial No. 2737
Date Drilled: March 12, 2020
Date Installed: August 5, 2020

Borehole BH-14 (MVWR km 1001.8)
Ground Temperature Profile

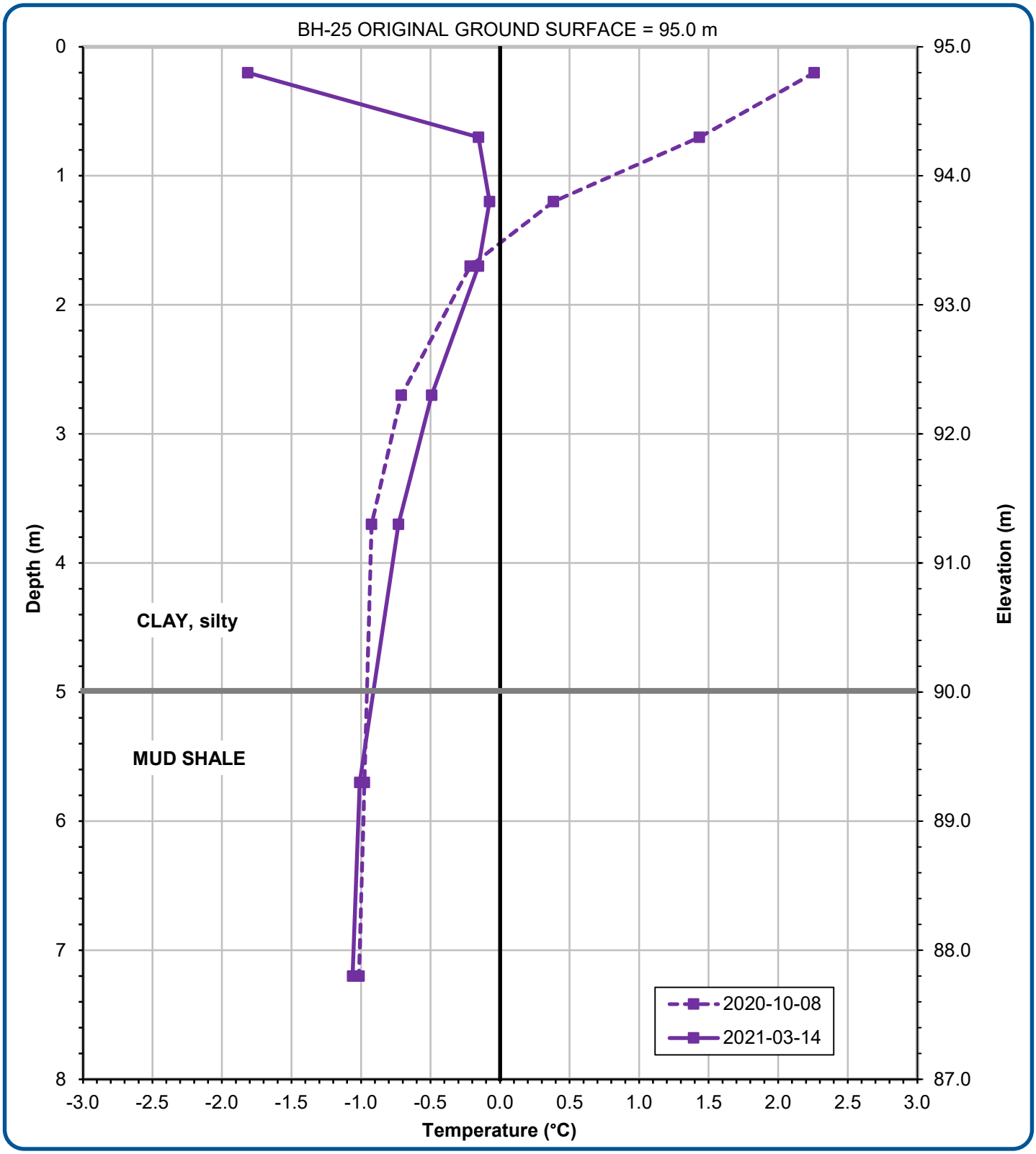
TETRA TECH



GTC Serial No. 2741
Date Drilled: March 6, 2020
Date Installed: August 7, 2020

Borehole BH-19 (MVWR km 999.2)
Ground Temperature Profile

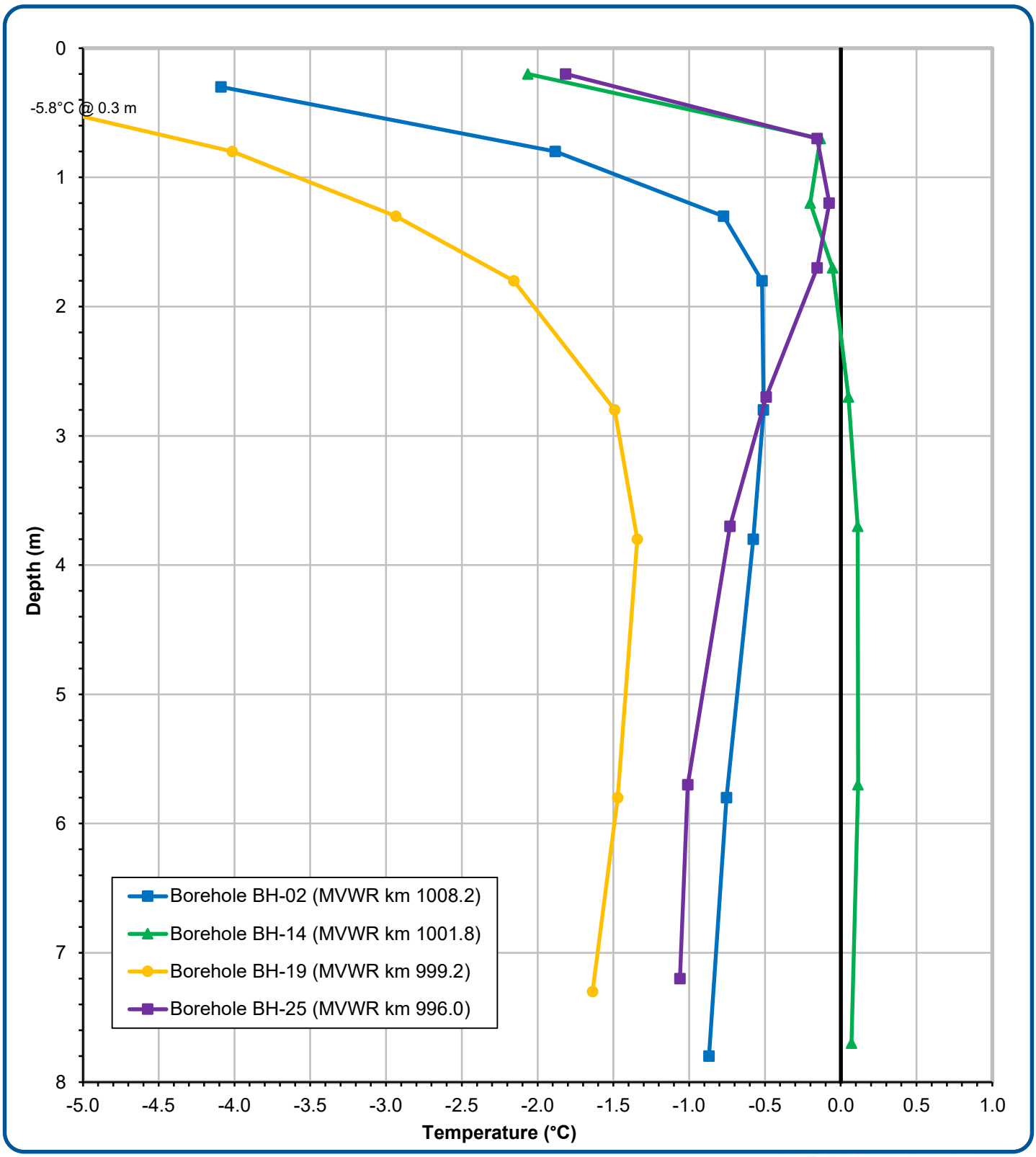
TETRA TECH



GTC Serial No. 2740
Date Drilled: March 13, 2020
Date Installed: August 7, 2020

Borehole BH-25 (MVWR km 996.0)
Ground Temperature Profile

TETRA TECH



Dates Drilled: March 6 - 13, 2020
Dates Installed: August 5 - 7, 2020
Date Read: March 14, 2021

Boreholes BH-02, BH-14, BH-19, BH-25
Combined Ground Temperature Profile

TETRA TECH

Topic: NRCan-01: Hazards Associated with Icing (aufeis)

Reviewer Preamble:

Accumulations of ice related to aufeis or icing can cause hazards to road travel, block culverts and also lead to accumulation of water on the surface in the spring with impacts to the ground thermal regime. Information on icing occurrence is required to adequately assess potential impacts of the environment on the Project and impacts of the Project on the environment. Icings have been observed to occur in the Mackenzie Valley including those near Norman Wells on the winter road resulting from water flowing from Kee scarp through a talik (e.g. Taylor et al. 1998). The Proponent indicates that there is no spatial data on icing occurrence along the highway route. A study published by Crites et al. (2020) mapped icing occurrence in the Mackenzie Valley and provides a digital database.

Reference: Taylor AE, Nixon M, Eley J, Burgess M, Egginton P (1998) Effects of atmospheric inversions on ground surface temperatures and discontinuous permafrost, Norman Wells, Mackenzie valley, Canada. In: Lewkowicz AG, Allard M (eds) Proceedings of the 7th International Conference on Permafrost. Collection Nordicana, Yellowknife, 1043-1047.

Crites H, Kokelj SV, Lacelle D (2020) Icings and groundwater conditions in permafrost catchments of northwestern Canada. Scientific Reports 10:3283

Reviewer Request:

NRCan requests from the Proponent:

Please clarify whether existing mapping of icing occurrence has been incorporated into project design and environmental assessment

Please provide information on any plans to map icing occurrence as project design advances.

Response from the Government of the Northwest Territories:

The Government of Northwest Territories (GNWT) appreciates the reference information provided by Canadian Northern Economic Development Agency, and will add it to the Project-specific knowledge base.

Local knowledge of overflow/icing locations along the Mackenzie Valley Winter Road has been collected through Project-specific engagement since 2010. These are communicated as descriptive locations (e.g., "north of Steep Creek"), and as georeferenced locations provided in private comments on the GNWT's interactive map tool included on the "Have Your Say" page (Mackenzie Valley Highway Project | Have Your Say - Government of Northwest Territories (nwt-tno.ca). Additionally, cross-highway surface and groundwater flow is anticipated along much of the route due to its setting along the general regional drainage between the Norman Wells and Franklin Ranges, and the Mackenzie River (see the Conceptual Groundwater Model in the Hydrogeology Technical Data Report [Developer's Assessment Report Volume 3, Appendix 15B, Section 5]). Icing of culverts is also expected. Knowing the locations of existing icings and overflow through engagement will help to focus future field studies and detailed design.

Both cross-slope flow and icing will be factored into the detailed Project design, as discussed in the GNWT's response to MVEIRB IR#71.

Topic: HC-04:Air Quality Monitoring for Implementation of mitigation Measures

Reviewer Preamble:

The response to HC-7 states that "mitigation and monitoring measures associated with air quality have been identified, based on visual monitoring for dust plumes." PM10 and PM2.5, the latter being of particular concern for human health, are invisible and only tools such as atmospheric dispersion modelling and/or monitoring stations can provide the information required to assess potential risks to human health.

HC's Guidance for Evaluating Human Health Effects in Impact Assessment- Air Quality (p.29) states, "The need for corrective actions for on-site emission management or implementation of additional control measures can be determined by comparing monitoring results to trigger levels." Project-specific trigger levels should be informed by reference guideline values (e.g. CAAQS), pre-project baseline concentrations, atmospheric dispersion modeling results, and the analysis of local air quality in relation to the air zone management levels for each pollutant. As mentioned in the Proponent's response to HC-6, and supported by the Project falling in the yellow CAAQS management level, the Project is located in a relatively pristine environment. Other considerations such as public complaints, wind speed, visual observations can also trigger the implementation of mitigation measures.

Reviewer Request:

HC recommends that air quality monitoring for COPCs, specifically PM2.5, and the development of Project-specific trigger levels, be used to inform the implementation of appropriate mitigation measures. Monitoring should be performed where the closest receptors to the Project are located and could be informed by the results of atmospheric dispersion modelling.

Response from the Government of the Northwest Territories:

Please refer to the Government of Northwest Territories' response to CanNor IR #02, which responds to this request.

Topic: HC-03: Sources of Air Contaminant Emissions

Reviewer Preamble:

The response to HC-5 states that $PM_{2.5}$ and PM_{10} are only considered in the context of vehicle usage (e.g., diesel particulate matter). The exclusion of fugitive dust may underestimate the potential health impacts associated with Project-related activities and should be included in the determination of Project effects. In order to fully assess the potential health risks from the Project's expected changes to air quality, it is best practice that all sources of emissions be considered.

Reviewer Request:

HC recommends:

Considering all sources of emissions, for each COPC, including Project-related processes, on-site vehicle usage, and fugitive emissions, or

Providing additional evidence-based rationale to justify excluding any emissions, or specific COPCs, from further assessment.

Response from the Government of the Northwest Territories:

Additional assessment of fugitive dust has been provided by including the larger total suspended particles (TSP). The assessment of TSP emissions is presented below. Generally, larger, heavier particles disperse closer to the source than smaller, lighter particles. This additional assessment is not expected to change the mitigation measures described in Developer's Assessment Report (DAR), Chapter 12.

The other relevant contaminants are assessed in Chapter 12 and the Government of the Northwest Territories (GNWT)'s response to ORS CanNor-21 (HC-5).

The calculation of TSP emissions from the Project activities and TSP emission thresholds are as follows:

- The TSP emissions are calculated based on the known annual emissions of $PM_{2.5}$ and PM_{10}, and the ratio of $PM_{2.5}$:PM_{10}:TSP estimated for the Project activities.
    - The $PM_{2.5}$ and PM_{10} annual emissions for the mobilization and demobilization activities and the operations and maintenance activities come from the DAR Chapter 12 Table 12.8. The $PM_{2.5}$ and PM_{10} emissions for the road construction activities have been revised and reported in the GNWT's response to ORS CanNor-21 (HC-5) Table HC5c.
    - The ratio of $PM_{2.5}$:PM_{10}:TSP estimated for industrial road activities comes from the United States Environmental Protection Agency (US EPA) AP-42 Table 13.2.2-2 (US EPA 2024), and is summarized in Table HC03-1. The category of industrial roads activities is deemed more representative of the Project activities than the alternative category of public roads activities because the Project activities include heavy duty vehicles (Table HC03-1).
    - The TSP emissions are calculated from the $PM_{2.5}$:TSP ratio (e.g., 0.15:4.9, Table HC03-1) and from the PM_{10}:TSP ratio (e.g., 1.5:4.9, Table HC03-1). The final TSP emissions are obtained from the average of the two ratios. The TSP annual emissions are presented in Table HC03-2.
- The determination of the criteria air contaminant (CAC) thresholds for TSP is as described in the DAR Chapter 12 section 12.1.1.1. There are two thresholds, based on the National Pollutant Release Inventory (NPRI) reporting thresholds and the Average Northwest Territories (NWT) facility emissions. These thresholds are presented in Table 2 below. Under NPRI, TSP is called total particulate matter.
    - NPRI reporting thresholds: The level at which the substances begin to pose a risk to the environment or to health. These reporting thresholds are obtained from the ECCC NPRI website (ECCC, 2022a).
    - Average NWT facility emissions: The average facility CAC emissions are the average of each individual facility CAC emissions reported for the NWT for 3 years, from 2018 to 2020 (ECCC, 2022b). This gives an indication of where the Project's CAC emission levels stand in comparison to the existing CAC-emitting facilities in the NWT and is a better indicator of the potential effects from the CAC emissions.

Table HC03-1 Ratio of Particles for Industrial Roads

Ratio for Industrial Roads		
$PM_{2.5}$	**PM_{10}**	**PM_{30} [1]**
0.15	1.5	4.9

Source:
US EPA AP-42 Table 13.2.2-2 (US EPA 2024)

Note:
[1] As described in US EPA AP-42 Table 13.2.2-2, PM_{30} is assumed to be equivalent to TSP.

Table HC03-2 Estimated Total Suspended Particles Annual Emissions from the Project

Project Phase or Activity	CAC Emissions (t/year)		
	$PM_{2.5}$ [3]	**PM_{10} [3]**	**TSP**
Construction Phase			
Mobilization and Demobilization Activities	**0.35**	0.37	6.27
Road Construction Activities	**1.84**	**4.98**	**38.26**
Operations and Maintenance Phase			
Operations and Maintenance Activities	**1.15**	**1.51**	**21.29**
CAC Thresholds from NPRI			
NPRI Reporting Thresholds [1]	0.30	0.50	20
2018 to 2020 Average NWT Facility Emissions [2]	8.75	24.26	254.62

Notes:

Bold values indicate that the emissions level exceeds the reporting threshold.

1 The level at which the substances begin to pose a risk to the environment or to health.

2 The average of each individual facility CAC emissions reported for the NWT for the past 3 years.

3 The $PM_{2.5}$ and PM_{10} emissions for the mobilization and demobilization activities and the operations and maintenance activities comes from the DAR Chapter 12 Table 12.8. The $PM_{2.5}$ and PM_{10} emissions for the road construction activities come from CANNOR-57 - HC-05 Table 3.

The predicted Project TSP emissions exceed the NPRI reporting threshold for the road construction activities and the operations and maintenance activities. None of the Project phase or activities exceed the 2018 to 2020 average NWT facility emissions.

The criteria that determine the effect significance are described in the DAR Chapter 12 Section 12.1.6. Since the predicted annual TSP emissions are below the 2018 to 2020 average NWT facility emissions for all phases of the Project, the residual effects of the Project on air quality from changes to CAC emissions, which include contribution from TSP, are not significant.

References

United States Environmental Protection Agency (US EPA). 2024. AP 42: Compilation of Air Emissions Factors from Stationary Sources. Fifth Edition, Volume I Chapter 13: Miscellaneous Sources. Section 13.2.2 Unpaved Roads. Last updated on January 3, 2024. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/13.2.2_unpaved_roads.pdf

ECCC. 2022a. NPRI. Substance list by threshold. Available at: https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/substances-list/threshold.html. Accessed March 2022.

ECCC. 2022b. NPRI. Five-year data tables by province – releases. Available at: https://open.canada.ca/data/en/dataset/ea0dc8ae-d93c-4e24-9f61-946f1736a26f. Accessed August 2023.

Topic: HC-02: Methodology for Assessing Project Effects on Air Quality

Reviewer Preamble:

HC does not support the methodology used to assess the Project's effects on air quality, as described in the DAR (Volume 3, Section 12.0) and the Proponent's responses to HC-5 and HC-6. HC does not agree with the statement that the National Pollution Release Inventory (NPRI) reporting thresholds are set at "the level(s) at which the substance begin to pose a risk to the environment or to health" (Volume 3, Section 12.1.1.1). Instead, the NPRI thresholds are for reporting requirements and they should not be considered as emission thresholds below which no health effects exist. As indicated on the NPRI website (https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/using-interpreting-data.html), "NPRI data is not enough to assess the risks and impacts posed by pollution to the environment and human health." Additional information, such as inherent toxicity, physical and chemical properties, amount, timing, nature and level of exposure are required to assess potential health risks. As described in HC-6, the rationale for this methodology includes the assumption that emissions of contaminants of potential concern (COPCs) are expected to disperse or settle within the local assessment area (1 km). Dust particles may settle within a 1-km buffer but fine particulate matter (PM2.5) and precursor pollutants can travel large distances in the atmosphere and affect receptors within and beyond this 1 km buffer distance. Additionally, the distance traveled by dust depends on various factors (e.g., turbulence, wind, dust properties). Given the transient nature (e.g., mobile sources over temporary periods of time) of this Project and the varying spatial and temporal land use by humans (e.g., intermittent harvesting activities), HC recommends use of dispersion modelling to assess potential health effects with a receptor-based approach at key locations along the route where receptors are the closest. HC relies on the expertise of ECCC in the areas of emissions, dispersion, and atmospheric modelling.

Reviewer Request:

HC recommends:

Using a receptor-based assessment that follows HC's Guidance for Evaluating Human Health Effects in Impact Assessment: Air Quality.

Comparing against conservative health-based air quality criteria, including the Canadian Ambient Air Quality Standards (CAAQS), when evaluating the predicted COPC concentrations.

Response from the Government of the Northwest Territories:

In general, it is difficult to make meaningful comparisons between air dispersion modelling results (i.e., computer simulations based on past meteorological conditions) and actual dustfall monitoring results. Air dispersion models are based on a number of assumptions and are typically expected to agree with actual ambient air quality measurements within a factor of two (US EPA 1992). Air dispersion modeling is generally better suited for continuously operating stationary sources with stacks. The Project activities consist of construction and transportation sources that are mostly mobile, intermittent, and the emissions intensity is relatively low compared to large stationary sources such as municipal or industrial diesel power plants. As such, the Government of Northwest Territories (GNWT) does not intend to conduct air dispersion modeling for this project.

Instead, the GNWT plans to develop an Adaptive Air Quality Management Plan consisting of monitoring for contaminants at the closest receptors.

- This may require installing temporary aerosol monitors, such as DustTrak, at one or two residences in Wrigley to monitor for the concentration of dust particles in the ambient air while Project activities are occurring close to (within 1 km of) Wrigley.
- Since no Project activities are expected to occur within 1 km of residences in Tulita and Norman Wells, monitoring for dust at these residences is not necessary.
- Note that there are air quality sensors, PurpleAir, installed in Wrigley, Tulita and Norman Wells which monitor for $PM_{2.5}$ particles. In addition, there is an existing GNWT air quality monitoring station in Norman Wells that monitors for $PM_{2.5}$, PM_{10}, NO_2 and O_3.
- Forest fire smoke has a major influence on regional ambient air quality, and project specific contribution may be difficult to determine during the forest fire season.

The Adaptive Air Quality Management Plan will also include mitigation measures to reduce changes to air quality from criteria air contaminants (CAC) emissions, as reported in Chapter 12 Table 12.7. These measures are listed again below.

- A dust control program will be implemented during construction, operations and maintenance. Dust suppression will follow the GNWT Guideline for Dust Suppression (GNWT, 2013).
- Dust suppression will be conducted as necessary to reduce dust and sediment from entering watercourses or waterbodies.
- Details of management and operation of incinerators will be included in the Waste Management Plan (WMP), Appendix A, Incinerator Management Plan.
- Incinerators, if intended to be used by the contractor, will be operated in accordance with manufacturer's specifications and emissions will meet Canadian Council of Ministers of the Environment Canada Wide Standards for Dioxins & Furans and Mercury.
- Vehicles and equipment will be maintained regularly.
- Equipment idling will be discouraged or limited.

- Vehicle speeds will be limited to 50 kilometres per hour (km/h) on unfinished project road surfaces.
- Cold starts of equipment will be limited to the extent possible.
- Efficient project planning will be used to reduce haul distances and the number of trips required to move road construction materials.
- Road surfaces will be repaired and maintained to reduce rolling resistance of vehicles.
- The contractor will be encouraged to use passenger vehicles (e.g., passenger van or bus) to move crews.

References

GNWT (The Government of the Northwest Territories). June 2013. Environment and Natural Resources (ENR). Guideline for Dust Suppression. Available at: https://www.enr.gov.nt.ca/sites/enr/files/guidelines/dustsupression.pdf.

United States Environmental Protection Agency (US EPA). 1992. Protocol for Determining the Best Performing Model. United States Environmental Protection Agency (US EPA). Office of Air Quality, Planning and Standards. Research Triangle Park, NC 27711. EPA-454/R-92-025. December 1992. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/model_eval_protocol.pdf

Response from the Government of the Northwest Territories:

Long-Term Community Annoyance assessment does not apply to the Project construction activities because the construction site and the staging/mobilization sites are mobile (i.e., not fixed for the duration of construction) and are not expected to remain near receptors (within 5 km) for more than several weeks.

Nighttime sleep disturbance assessment does not apply for the construction activities as the work is planned to be conducted during daytime periods only.

The Government of the Northwest Territories (GNWT) has committed to developing a noise complaint resolution plan, as previously indicated in the GNWT's response to ORS CanNor-64 (HC-4). The plan will include the elements listed in the CanNor-64 response, and will consider the information listed above.

Additionally, the mitigation measures described in Chapter 13 (Table 13.5 and Section 13.4.2.2) will be considered as part of the noise complaint resolution plan, specifically those that pertain to community involvement as listed below.

- The GNWT will develop a system to track complaints and responses to manage and mitigate feedback from the public regarding noise concerns.
- Communities will be informed of time periods and characteristics of noise that may exceed the recommended noise threshold.
- The GNWT will engage with communities to inform them of the activities and the noise sources that will occur prior to construction.