GEOTECHNICAL EVALUATION AND DEVELOPER'S ASSESSMENT REPORT SECTIONS FOR PROPOSED PRAIRIE CREEK ALL-SEASON ROAD NEAR NAHANNI BUTTE, NORTHWEST TERRITORIES

PRESENTED TO

Canadian Zinc Corporation

MARCH 2015
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EXECUTIVE SUMMARY

The Prairie Creek Mine is located in the southwest corner of the Northwest Territories, surrounded by the Nahanni National Park Reserve of Canada, which is a UNESCO World Heritage site, known for karst terrain of global significance, as well as the South Nahanni River, a Canadian Heritage River. The Mine and access routes have been a part of the landscape and history of the Northwest Territories since 1966, and the mine area is part of the traditional territory claimed by the Nahanni Butte Dene Band. The original winter road before mine construction was 288 km long, accessing the site along the Ram and North Nahanni Rivers from the Mackenzie River to the northeast. In 1980, the construction of Liard Highway No. 7 allowed access from the southeast from Lindberg Landing near Blackstone, and a new winter route, shortened by over 100 km, was used for mine construction. The project owner, Canadian Zinc Corporation (CZN), acquired new mine operating permits in 2013, including new permits for the same winter route, but with some re-alignments.

In 2015, thirty-five years after construction of the existing winter road, climate change, as well as environmental and operational factors, have made a strong case for CZN to consider an all-season road to access the Mine, essentially following the winter road alignment. The all-season road will cross terrain that includes discontinuous permafrost and karst, with the potential occurrence of thermokarst, sinkholes, debris flows and thaw slumps, as well as rock fall, rock slides, and snow avalanches in mountain terrain. Some 85 km of the road passes through the Nahanni National Park Reserve (NNPR).

Tetra Tech EBA was requested by CZN to evaluate the terrain along the proposed all-season route, including analysis of historical stereo aerial photos, review of geology and surficial geology mapping, review of recent high-resolution orthophotography and contour data derived from LiDAR, previous geotechnical and terrain analysis reports for the route and its predecessors, and other terrain and geotechnical reports from the region. Key aspects of the study included the evaluation of likely contributing factors of existing natural and/or anthropogenic slope instabilities in rock and soils as related to the surrounding terrain and/or permafrost, consideration of ground instabilities in karst terrain including sinkholes; and ground-truthing in the form of geotechnical field investigation and laboratory testing for selected portions of the route. Goals of the Tetra Tech EBA's work included providing baseline information on terrain, geology, soils, and permafrost to land managers, stakeholders, and environmental reviewers, including First Nations organizations and communities represented by Dehcho First Nations, Liidlii Kue First Nation, and Naha Dehe Dene Band, as well as providing a basis for the suitable design and construction of an all-season road.

Though most of the route has the potential for permafrost, not all of it is thaw-sensitive. Tetra Tech EBA estimated that about 73 km likely has at least some thaw-sensitive permafrost, and another 24 km may also have thaw-sensitive permafrost, but slope aspect or elevation makes it slightly less likely. Based on a qualitative risk assessment, Tetra Tech EBA estimated that about 7.2 km of the terrain along the proposed all-season route represents a high risk to the road route with respect to slope instabilities or other ground movements (by thawing, sliding, flowing, falling, settling or collapsing), and 54.9 km represents a moderate risk, out of a total of 174.1 km evaluated. The Liard River crossing has a high risk with respect to flooding, and 20.65 km of the route has a moderate risk. Other moderate risks include 4.3 km of the route for overland flow, 29.6 km for seismic activity, and 17.8 km for avalanche activity. Since there is considerable overlap in the moderate risk designations, a total of 76.7 km was estimated to represent a moderate risk to the road, and 7.4 km was estimated to represent a high risk to the road. Where road design and construction mitigations are insufficient to adequately reduce the risk, there are management methods to help further reduce the risk and, in high risk zones, there are also specific contingencies to help manage the risk. Many of the same areas of risk introduced by terrain are also potentially more affected by road development than the lower-risk sections of the road, and so it is anticipated that the proposed mitigations will help protect both the terrain and the road. Road sections KP048.8 to KP050.8, KP053.7 to KP054.6, KP055.8 to KP059.9, and KP115.7 to KP115.9 will need particular attention during detailed design.

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

LIST OF FIGURES IN TEXT

APPENDICES

DEFINITIONS

Active layer	The upper layer of soil that thaws and freezes every year. Does not always extend to the permafrost table in discontinuous permafrost. Active layer thickness depends on average air temperature, type of soil (coarse- or fine-grained), thickness of peat at ground surface, slope aspect, vegetation, etc.
Detachment slide	A type of slope failure that happens when the active layer detaches from the permafrost and slides downslope. Such slides can result from high air temperatures, rainfall events, rapid snowmelt, or surface disturbances.
Discontinuous permafrost	Permafrost that has unfrozen zones around or in it.
Frost-stable	Soils that do not settle or heave when subjected to thawing or freezing. Granular soils like sand or gravel are frost-stable if they have less than 10% silt and clay.
Frost-susceptible	Soils that will settle or heave when subjected to thawing or freezing. Silts are highly frost-susceptible, clays are also frost-susceptible but less so than silts. Sands and gravels can be frost-susceptible if they have more than 10% silt and clay.
Headscarp	The exposed soil face at the upper edge of a slope failure, often near-vertical.
Ice-rich	Permafrost that is more than 100% saturated and/or has visible ice will lose its strength and settle or flow if it thaws. Fine-grained soils are usually more likely to be ice-rich. Ice-rich soils, even if they stay frozen, can creep and deform under very small loads. See also thaw-sensitive.
Karst	Karst topography is landscape formed from the dissolution of soluble rocks, primarily limestone and dolomite in this region. Features include sinkholes, caves, towers, arches, canyons, pavements, corridors, springs and sinking streams.
Patterned ground	Geometric patterns at ground surface, including circles, polygons, and stripes that show the sorting of fine-grained or coarse-grained soils and/or the presence of ice wedges in the soil.
Permafrost	Ground (soil or rock and including ice or organic material) that remains at or below 0°C for at least two consecutive years.
Permafrost table	Top of the permafrost.
Polje	A karst terrain feature with a flat bottom and steep walls, and no obvious outflowing surface stream, sometimes water-filled forming a lake, and sometimes drained. Polje is another name for a major sinkhole. Poljes can have smaller sinkholes on the bottom that are visible when the water is low.
Retrogressive thaw slump/flow	A type of slope instability triggered by permafrost thaw. Compared to slides, slumps and especially flows tend to happen when the moisture contents are higher in the failed soil. If the headscarp keeps failing and advancing upslope, making the failure larger, then it is a retrogressive failure.
Sinkhole (also known as Doline)	Sinkholes are common in karst terrain. They can result from suffosion (see below), collapsed caves (collapse sinkholes), or when the underlying carbonate bedrock dissolves unevenly and creates dish-shaped depressions (solution sinkholes). Sinkholes can be shaped like bowls, funnels, or cylinders; or they can be irregularly-shaped, depending on the cause. Sinkholes can range in size from 1 m to over 1000 m in diameter or length. Sinkholes often occur in lines or groups, and can be water-filled.
Suffosion	The process by which most sinkholes form. In suffosion, water seepage or flow causes underground leaching, piping, and erosion of soils or rocks, where the eroded material is washed into fissures and joints in the limestone or dolomite bedrock into caves below. The resulting material loss material can cause settlement at ground surface and create conical depressions and sinkholes in the landscape. Suffosion sinkholes can be only 1-5 m across, but suffosion can also enlarge other sinkhole types.
Talik	Layer of unfrozen soil, sometimes between the active layer and the permafrost, and sometimes under or beside a water body (river or lake). Taliks can include other unfrozen zones between patches or zones of permafrost in discontinuous permafrost.
Thaw-sensitive	Soil, often fine-grained, permafrost that has an ice content high enough that it will lose its strength and settle significantly or even flow if it thaws. Seasonally-frozen materials can also be thaw-sensitive if they have a high enough moisture content. See also ice-rich.

LIMITATIONS OF REPORT

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1.0 INTRODUCTION

1.1 General

Canadian Zinc Corporation (CZN) owns the Prairie Creek Mine which is located northwest of Nahanni Butte and is surrounded by the Nahanni National Park Reserve (NNPR) in the Northwest Territories. Access to the Mine property is currently authorized via a winter road route, which CZN is proposing to upgrade to an all-season access road. CZN is working through the regulatory process for the proposed all-season access road.

Tetra Tech EBA Inc. (Tetra Tech EBA) was retained by CZN to investigate, characterize and document the anticipated subsurface conditions along the proposed Prairie Creek all-season route in order to support the regulatory submissions for the all-season access road. The focus of Tetra Tech EBA's work was to address geotechnical engineering-related questions in the final Terms of Reference (TOR) prepared for CZN by the Mackenzie Valley Environmental Impact Review Board (MVEIRB). Questions relating to permafrost were of particular interest, although slope stability and karst terrain were also identified by CZN and/or Allnorth Consultants Ltd. (Allnorth) as items for assessment. Existing environment and baseline conditions, effects of the environment on the route, immediate and cumulative effects of the road on the environment were considered. Climate change was also considered. This assessment of potential impacts is to be incorporated by CZN into its Developer's Assessment Report (DAR) for the proposed all-season road.

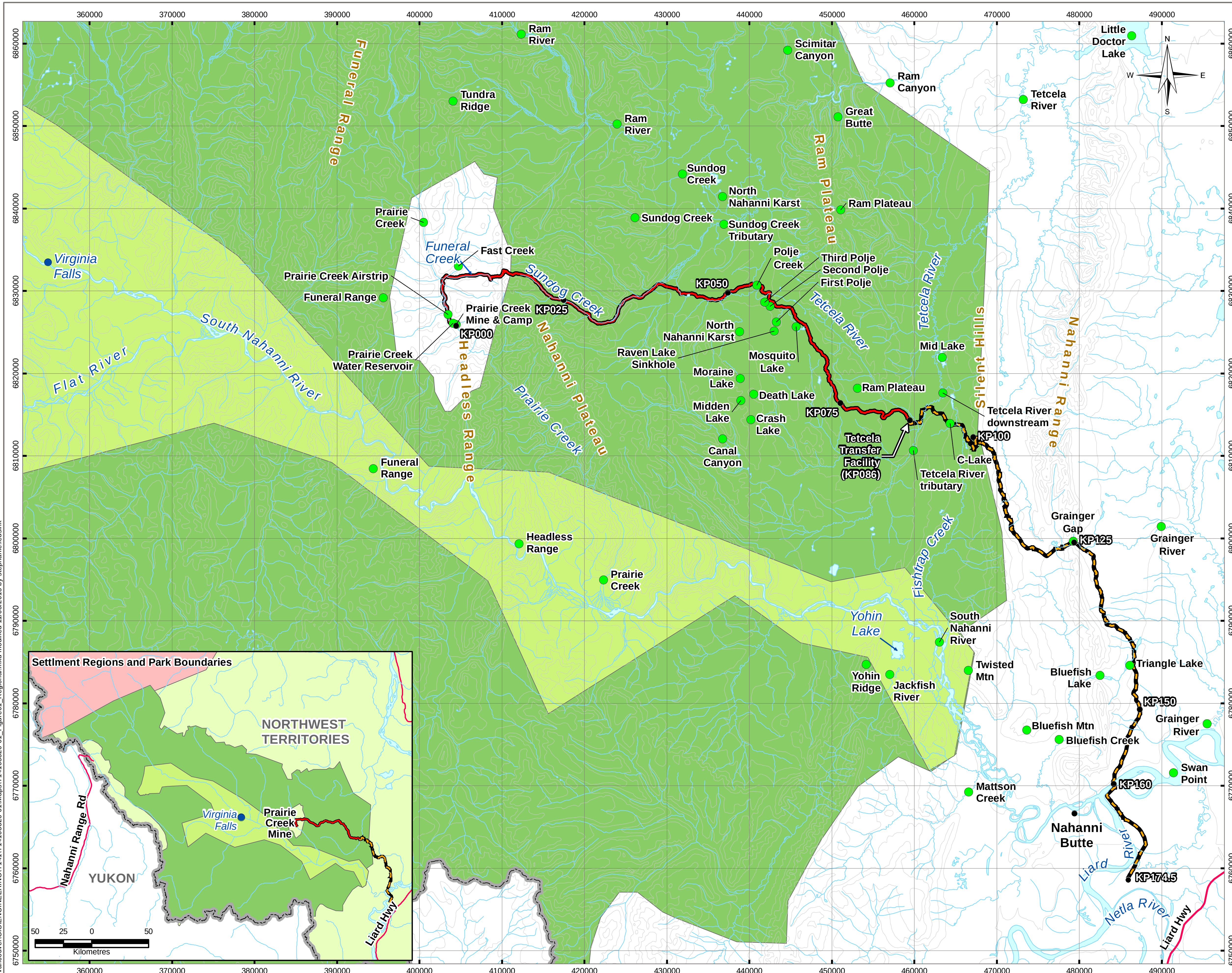
The work was authorized by Mr. Alan Taylor, VP Exploration, Chief Operating Officer, of Canadian Zinc Corporation (CZN), by email on September 15, 2014, with a Change Order transmitted via email on December 1, 2014. The workscope and project requirements were coordinated by Mr. David Harpley, VP Environment & Permitting Affairs, of CZN.

1.2 Background and Regulatory History

The Project consists of the proposed all-season road to the Prairie Creek Mine. The Prairie Creek Mine is located at approximately 61° 33' N and 124° 48' W, adjacent to Prairie Creek, which flows into the South Nahanni River approximately 43 km downstream of the Prairie Creek Mine, and upstream of Nahanni Butte, NT, the nearest community to the Project (Figure 1). The following paragraphs provide some background and regulatory history about the road.

The Mine received Land Use Permits (LUP's) in 1980 and a Water Licence in 1982 for mine and winter road construction and operations. The existing winter access road from the Liard Highway to the Prairie Creek Mine was constructed in 1980 and operated for two winter seasons carrying over 800 loads into the Mine site. The Mine was nearly complete, including an operational winter road to the Liard Highway, when it was placed on 'care and maintenance' due to unfavourable market conditions. Canadian Zinc Corporation (CZN) acquired the Prairie Creek Mine property in 1991 and acquired commercial operating permits in 2013.

Since 1991, CZN has further developed the mineral resource, and completed various studies to support applications to the Mackenzie Valley Land and Water Board (MVLWB) for a Type "A" Water Licence and LUP's to reactivate the Mine and to build two transfer facilities. CZN already held LUP MV2003F0028 to operate the winter access road. MVLWB referred the Mine project, including construction and operation of the winter access road, to the MVEIRB for environmental assessment (EA0809-002). On December 8, 2011, the MVEIRB issued their Report of Environmental Assessment (REA). The MVEIRB concluded that the proposed development, as described in the REA and including CZN's commitments, is not likely to have any significant adverse impacts on the environment or to be a cause for significant public concern.



LEGEND

- Landmark

Proposed All-Season Road

- Phase 1
- Phase 2
- Existing Road
- Contour (200 m)
- Watercourse
- Waterbody
- Previous Nahanni National Park Reserve Boundary
- Current Nahanni National Park Reserve Boundary
- Deh Cho Settlement Region
- Sahtu Settlment Region
- Yukon / NWT Border

NOTES
Base data source:
NTS 1:250,000
Canadian Zinc

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Project Location

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:450,000
Kilometres

TETRA TECH EBA

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PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 1

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The file was returned to the Mackenzie Valley Land and Water Board (MVLWB) and mine operations permits were subsequently issued, including Water Licence MV2008L2-0002 issued on September 24, 2013. Since changes were made to the winter access road alignment during the EA, CZN applied for and received new access road Land Use Permits (LUP's) and Water Licences from both the MVLWB (MV2012F0007, MV2012L1-0005) and Parks Canada (Parks2012-L001, Parks2012-W001).

In the previous environmental assessment (EA0809-002), CZN received approval for winter road access to the Mine. CZN is now proposing to upgrade the winter road to an all-season road. The length of the access road from the Mine to the existing Nahanni Butte Access Road, located on the south side of the Liard River, is 174.5 km. Approximately 85 km of the proposed all-season road crosses the Nahanni National Park Reserve (NNPR). The proposed all-season road follows the overall winter road alignment assessed and approved during the EA0809-02 review process. Some realignments are proposed, designed to mitigate geotechnical and logistical issues for all-season use. CZN has proposed to complete the access road upgrade in two phases. A summary of these two phases, as they have been described to date, is presented in Section 2.0 of this report.

1.3 Report Organization

This report has been organized in separate sections reflecting the organization of the DAR. Tetra Tech EBA has provided content herein for specific sections of the DAR to be prepared by CZN as part of their submission requirements to MVEIRB, specifically: terrain, geology, soils, and permafrost, identifying relevant features along the proposed route, based on the review of available aerial photography, oblique photographs taken from the helicopter, and ground-truthing data, for the following DAR sections:

- Existing environment and baseline conditions: Conditions as noted on the aerial coverage and/or from the field and laboratory work (Section 4.1.2 of proposed Table of Contents (TOC), corresponding to Section 5.1.1 of the TOR);
- Effects assessment – accidents and malfunctions (TOC Sections 9.4 and 9.5, TOR Section 7.2.2 Items 7-9): contributions to this section to include commentary on how the environment may contribute to potential accidents, malfunctions and spills with respect to terrain-related aspects; risk assessment including hazards, consequences and risks, and site-specific contingencies for high-risk zones.
- Effects assessment – other (TOC Section 11.1, TOR Section 7.3.1): consideration of the affects that the proposed road might be expected to have on the terrain, geology, soils and permafrost along the route, including karst and slope stability. Possible mitigations that could be implemented; and
- Cumulative assessment (TOC 14.4, TOR Section 7.3.1 - as for effects assessment, in relation to other existing or proposed projects in the vicinity of the proposed all-season road.

The various report sections present the assessment of the potential effects of the Project on the terrain, geology, soils and permafrost and, conversely, of the effects of the terrain, geology, soils and permafrost on the Project.

2.0 PROJECT DESCRIPTION

2.1 Project Roles

CZN is the project owner and provided direction as to the primary areas of interest to be investigated by Tetra Tech EBA. Allnorth is CZN's road consultant for the Project. Based on the findings of the various field programs carried out in 2014, Allnorth developed some further realignments of the proposed route, with the current alignment intended to be within about +/- 50 m of the finished route. As well, Allnorth investigated stream crossings and structures, investigated borrow sources, prepared a general road construction approach and methodology, prepared general design concepts, and estimated construction earthworks requirements and volumes. Tetra Tech EBA provided geotechnical consulting engineering services to the Project. Tetra Tech EBA accompanied Allnorth in the field to investigate several areas of interest to the Project, and provided further route evaluation and commentary to Allnorth as the route alignment evolved after completion of the field work.

2.2 Summary of Development Phases

The all-season access road project is divided into two development phases (Table 2.2-1). The phased approach to construction includes clearing of the right-of-way (ROW), including some existing sections of winter road that were developed in 1980, as well as some approved, but not yet developed, sections of the winter road route. Based on the findings of the various field programs carried out in 2014, Allnorth has developed some further realignments of the route. It is Tetra Tech EBA's understanding that the current alignment is intended to be within about +/- 50 m of the finished route. We anticipate that some further refining and optimization of the route may be done during detailed design and when the road is actually laid out on the ground. Locations for the observations documented in this report have been recorded corresponding to kilometre post stations, to the approximate nearest 100 m. For example, an observation may be reported at KP122.5, or between KP24.3 and KP28.3. It is noted that because the road alignment is a living document, some of these stations have changed somewhat since the observations were made. For example, one recent change on the Silent Hills switchbacks alignment has resulted in a road length difference of about 300 m from the previous version. However, sufficient description is provided for each observation so that the location can be retrieved using visual landmarks even if the stations are no longer exact.

It is understood from CZN that the route will initially be developed as a winter road to support mine construction and initial operations. The winter road cleared ROW is understood to be up to 20 m wide. The all-season road cleared ROW will be about 30 m wide. Further information about proposed R-O-W clearing and variations in clearing widths are provided in Section 2.4 below. The running surface width of the proposed single-lane road is understood to be generally 5 m wide, with up to three turnouts proposed per kilometre to allow opposing traffic to pass. Actual road embankment footprint width will depend on fill thickness and side-slope gradients. The following proposed Project development phases are proposed by CZN and Allnorth.

Table 2.2-1: Summary of Project Development Phases

Project Scope	Geographic Scope	Temporal Scope	Included as Part of All-Season Access Road Assessment
PHASE 1			
Clearing the road alignment (average 20 m wide ROW) from the Mine to KP086, currently approved under existing Land Use and Water Licences	KP000-KP086	September to January, Year 1 of mine construction	*No. Currently approved.*
Clearing a 4 km long, average 20 m wide ROW along road alignment different from existing winter route	KP024.5-KP028.5	Summer/fall construction, Year 2 or 3 of mine operation	Yes
Construction of an 86 km long all-season road with 5 m wide running surface from the Prairie Creek Mine to the Tetcela Transfer Facility.	KP000-KP086	Summer/fall/winter construction, Year 2 or 3 of mine construction	Yes

Table 2.2-1: Summary of Project Development Phases

Project Scope	Geographic Scope	Temporal Scope	Included as Part of All-Season Access Road Assessment
Clearing and excavation of 31 borrow pits (up to 13.31 ha) and access roads (up to 0.80 ha)	As shown in DAR	Clearing September to January, summer/fall or winter construction, Year 2 or 3, up to Year 5.	Yes
Construction of an expanded Tetcela Transfer Facility (2.0 ha additional compared to approval with winter road)	KP085.8-KP086	Summer/fall or winter construction, Year 2 or 3 of mine construction	Yes
Construction/operation of temporary construction support infrastructure (camps, laydowns, staging, fuel storage; 3.69 ha)	As shown in DAR	Summer/fall or winter construction, Year 2 or 3, up to Year 5 for temporary, life of mine for permanent.	*No. Currently approved.*
Operation and maintenance of the road and facilities	KP000-KP086	~14-year mine life, plus 6-year closure	Yes
PHASE 2			
Clearing the winter road alignment (average 20 m wide ROW) from KP086 to the Nahanni Butte Access Road, currently approved as a winter road under existing Land Use and Water Licenses	KP086-KP174.5	September to January, Year 1 of mine construction	*No. Currently approved.*
Clearing the road alignment (20 m wide ROW) for a 4 km long, 5 m wide running surface different from the existing winter road route.	KP090.5-KP094.5	Winter clearing, tentatively Year 5 of mine operation	Yes
Clearing a 1 km long, 20 m wide ROW along all-season road alignment different from the approved existing winter road route	KP 122.5-KP123.5	Winter clearing, tentatively Year 5 of mine operation	Yes
Construction of an 88.5 km long all-season road with 5 m wide running surface from the Tetcela Transfer Facility to Nahanni Butte Access Road.	KP 86 - KP174.5	Combination of summer/fall and winter construction, tentatively Year 5 of mine operation	Yes
Clearing and excavation of approximately 18 borrow sources (26.15 ha) and access to the borrow sources (3.86 ha)	Locations as identified in the DAR	Clearing September to January. Combination of summer/fall and winter construction, commencing in Year 2 or 3 and tentatively extending to Year 5 of mine operation	Yes
Construction/operation of temporary construction support infrastructure (camps, laydowns, staging, fuel storage; 3.69 ha)	As shown in DAR	Summer/fall or winter construction, Year 2 or 3, up to Year 5 for temporary, life of mine for permanent.	*No. Currently approved.*
Construction of landing areas and operation of a barge crossing of the Liard River	KP160	~14 year mine life, plus 6 year closure	Yes

Table 2.2-1: Summary of Project Development Phases

Project Scope	Geographic Scope	Temporal Scope	Included as Part of All-Season Access Road Assessment
Operation and maintenance of the road and facilities	KP086-KP184.5	~14 year mine life, plus 6 year closure	Yes
Construction and operation of the Liard River winter crossing	KP160	~14 year mine life, plus 6 year closure	*No.* *Currently approved.*
AIRSTRIP*			
Clearing to accommodate a 1 km long x 50 m wide airstrip	KP055	Winter clearing, ~14 year mine life, plus 6 year closure	Yes
Construction, operation, and maintenance of the airstrip	KP055	~14 year mine life, plus 6 year closure	Yes
COMBINED DEVELOPMENTS			
Closure and reclamation	KP000-174.5 and airstrip	~ 6 years after mine closure (2029-2036)	Yes

Tetra Tech EBA understands that construction will be timed to take place during the most appropriate season(s) for each road section.

2.3 Road Alignment

During EA0809-002, the route was optimized to reduce environmental and logistical risks. Four reroutes were included in the revised route:

- Polje By-Pass, within the expanded Nahanni National Park Reserve (NNPR);
- Silent Hills reroute, within the expanded NNPR;
- Wolverine-Grainger Gap reroute; and,
- Nahanni Front Range reroute.

These rerouted sections were addressed by the positive MVEIRB EA decision in 2012 of the overall route as a winter road, acknowledging that minor changes in the route could be anticipated (MV2012F0007). An updated version of the route for the purpose of an all-season road was presented to MVEIRB in April 2014 (CZN, 2014). Current route designations begin with KP000 at the mine site and about KP160 at the Liard River. From the river, the all-season road follows the old Nahanni Logging Road, meeting the Nahanni Butte Access Road at KP174.5 (Figure 1). Kilometre posts used in the field have been updated to the post-fieldwork stations, as shown on each of the figures and presented on Allnorth's website. We note that there may be minor differences in the stations noted by each party, as each minor change in the route affects the stations further along the route in an iterative design process. However, these stations are generally within 100 m of each other, close enough to reasonably conclusively determine the location under discussion. As mentioned above, kilometre posts are also generally associated with landmarks.

In addition to applying for all-season road use from the Mine to the TTF (Phase 1), CZN also applied for all-season road use from the TTF to the Liard Highway (Phase 2), which when combined represents the entire road. This will enable the year-round transport of concentrates and consumables.

The first 40 km of road between the Mine (KP000) to just beyond Cat Camp (KP039) is located at the northwestern end of the road, traversing a series of steep mountain valleys and a high mountain pass (1525 m elevation). Cadillac Explorations Ltd.'s road LUP (1980) provided for all-season use of this section. The road follows mainly the existing winter road alignment between KP000 and KP033.1. A few sections were flagged for further investigation by either Tetra Tech EBA or Allnorth, and a 5 km section was considered for realignment (current realignment from about KP024.3 to KP028.3). Of the remaining 151 km to the Liard Highway, several sections have been rerouted for winter use compared to the 1980 winter route, and will be retained for all-season use. Some of the rerouted sections are intended to avoid challenging terrain, including ice-rich permafrost or intense karst terrain associated with sinkholes and slope stability issues, and one long section at the southeast (Nahanni Butte) end avoids wetland terrain along the Grainger River. Although initial road use for early mine operations would be winter-only, using existing permits, CZN wishes to obtain new permits to allow phased construction, and use of, an all-season road.

Phase 1 includes upgrading of the western portion of the road for all-season use to allow the mineral concentrates to be transported to the TTF year-round. Phase 2 would include upgrading of the eastern portion of the road for all-season use from the TTF to the Liard Transfer Facility.

It is understood that the Nahanni Butte Access Road (KP174.5 to KP184.5) portion may require improvements, including additional gravel, to be carried out by the appropriate organization.

The following sections summarize information provided by CZN and Allnorth regarding proposed road design and construction methods (Allnorth 2015).

2.4 Right-of-Way Clearing

It is understood that CZN intends to complete construction of the Mine using the winter road, and use that road for the first few years of operation. The majority of the winter road ROW (up to 20 m wide) is proposed to be cleared during winter road construction in the first years of mine construction and operations, as shown in Table 2.2-1 above.

For the all-season road, additional clearing would be carried out at a later date. A total typical clearing width of up to about 30 m is proposed depending on vegetation cover, road geometry, side slopes (cut/fill), and environmental restrictions. In relatively flat floodplains, Allnorth anticipates that a smaller clearing width may be needed, but in areas with steep side slopes, a ROW width of up to 40 m may be needed. If viable, mature merchantable timber will be removed and hauled to the nearest market destination(s). However, as this location is remote with very limited market demand, Allnorth references British Columbia Ministry of Forests, Lands and Natural Resource Operations (BCMF 2013) for typical methods to dispose of materials that will not be used in the road embankment. Tetra Tech EBA notes that these methods will need to be chosen or modified according to local conditions along the route.

Allnorth indicates that for embankment fill-only construction (in areas with thaw-sensitive permafrost), a slightly narrower ROW clearing width may be possible, depending on side-slope and fillslope gradients. The organic surface layer, generally peat, would not be disturbed (no stripping), and appropriately-sized ROW timber may be reserved for use in the road prism, as further discussed below in Section 2.5.

Allnorth notes that, when required, burning is to be conducted in accordance with local and NWT regulations. Slash and non-merchantable timber is proposed to be piled within the ROW or other designated disturbed area (such as a borrow area) during the construction phase. Burn piles will be located in areas not at risk for permafrost degradation. If burning is conducted, it will be done in a manner that mitigates potential fire risk.

2.5 Road Design and Construction

This summary of road embankment design and construction is as provided in Allnorth's report (Allnorth 2015), except as otherwise noted. The proposed width of the all-season road surface is understood to be generally 5 m for a single lane and 8 m wide at turnouts for passing. Allnorth proposes two short sections between about KP025.2 and KP025.6, and KP028.0 and KP028.4 at 4 m width to reduce cost and environmental footprint. Turnouts would be spaced at up to three turnouts per kilometre. Each turnout is proposed to be about 30 m long.

Allnorth has proposed two main construction techniques: conventional road construction in locations where there is little likelihood of the presence of thaw-sensitive permafrost, and embankment fill-only (overlanding) techniques for crossing thaw-sensitive permafrost terrain, with or without existing thermokarst. Allnorth references British Columbia Ministry of Forests, Lands and Natural Resource Operations (BCMF 2013) for typical methods of road construction.

For conventional road sections in areas not located within thaw-sensitive permafrost, Allnorth proposes that soils, organics and woody debris such as limbs and stumps that are not suitable in the road subgrade be stripped and stockpiled outside of the road prism as described above in Section 2.4 for clearing of vegetation (BCMF 2013). Tetra Tech EBA understands that such materials may be reused during reclamation, and that stockpiles will be designed with erosion and sedimentation controls.

In conventional road sections, Allnorth proposes that the subgrade would be constructed using primarily local material, major stream crossing structures would be installed, and ditching and cross drainages installed as required to maintain natural drainage patterns. The placement of suitable granular material [for sub-base and/or base course] would follow. For crossing soft ground, Allnorth indicates that the embankment thickness may need to be increased, and/or a geotextile would be laid first. Some typical cross-sections for conventional construction techniques are provided by Allnorth (BCMF 2013). Tetra Tech EBA notes that these typical cross-sections are generic and the actual cut slope and fill slope gradients will need to be site-specific according to the types of site soils encountered and borrow materials available. Borrow materials and likely corresponding fill slope gradients are further discussed below.

Allnorth proposes embankment fill-only (overland) construction for two construction scenarios: to cross the above-mentioned thaw-sensitive terrain; and, along Sundog Creek (KP033-KP039) where large coarse rock material is to be end-hauled and placed to build up the road grade. Road sections over thaw-sensitive permafrost may be designed with additional subgrade support. Such designs may include geotextiles and/or timber from the ROW placed horizontally in a corduroy style in the road prism. Tetra Tech EBA notes that such methods designed appropriately may help to reduce excessive deformations in the peat and/or creep in the underlying permafrost soils. Corduroy-type designs have received renewed interest in regions with challenging subgrade conditions (de Guzman and Alfaro 2014). For Sundog Creek, primarily between KP033 and KP039, the intent is to build up a platform at the edge of the floodplain and/or channel to form the road subgrade. This platform is to be composed of angular talus. Boulders and blocks would also provide a well-armoured face along the channel where needed for erosion protection.

Allnorth has indicated that there may be a few sections where cuts may be unavoidable in thaw-sensitive permafrost terrain, due to side-slope gradients. If this occurs, the cut slope configuration and mitigations implemented will be tailored to the specific site conditions. Tetra Tech EBA has emphasized that cut slopes in thaw-sensitive permafrost can be expected to result in a long-term requirement for vigilance and higher maintenance to avoid problems, even when mitigations are implemented, so it is best to avoid cuts if at all possible (personal communication: E.Kragt, R.Kors-Olthof; March 5, 2015).

Tetra Tech EBA understands that the road subgrade is intended to be built with locally-available borrow materials whenever possible to reduce hauling requirements. Allnorth notes that granular material for road construction will be sought from a number of local sources to minimize hauling distances. Investigations will be undertaken to confirm and further define suitable sources. A portable crusher may also be utilized to produce gravel-sized material for use in the road. Allnorth further notes that coarse granular materials are not available in all sections of the road, and it is anticipated that some sections of the road will require the use of suitable local materials (including sand or sand/silt mixtures) to build the subgrade, then topped with imported coarser materials from elsewhere along the road. Tetra Tech EBA notes that some road sections, particularly those in thaw-sensitive permafrost terrain, may also require importing fill from elsewhere on the route even for the subgrade, and this will need to be determined on a site-by-site basis.

In general, Tetra Tech EBA anticipates that embankment side-slopes are likely to be sloped at about two horizontal to one vertical units (2H:1V) for coarse well-graded granular fill. Steeper fills may be possible with suitable material such as coarse angular rock carefully placed to interlock, and crushed rock. Fill slopes in blast rock could be as steep as 1.5H:1V to 1H:1V, depending on the angularity of the rock and whether the rock particles tend to be flat and elongated, or equidimensional. Equidimensional particles interlock better and therefore can stand reliably at steeper angles than flat/elongated particles. These anticipated fill slope angles are based on the assumption that the natural subgrade does not require flatter fill slopes for slope stability reasons, and so should be considered on a site-specific basis. Flatter fill slope gradients may also be required for finer-grained borrow materials such as sands, or sand-silt mixtures. Allnorth proposes a cover layer of coarser-grained material to protect large fills composed of the finer-grained materials against erosion.

Allnorth notes that larger watercourses will be crossed by span-crossing structures (bridges). Some of these have already been proposed for the winter road. Smaller watercourses, and areas where runoff would pond upslope of the road, would be addressed by closed or open-bottom culverts on a case-by-case basis, as required.

2.6 Borrow Sources

Tetra Tech EBA understands that borrow materials for road construction will be obtained from multiple local sources located within or in close proximity to the all-season road right-of way. Approximately 49 preferred borrow sources have been identified by Allnorth for use during the construction phase, and some 25 additional borrow sources have been identified as possible backup sources, targeting granular borrow sources where available. Allnorth has categorized each borrow site by the type of material available and its construction application. The borrow sites will be utilized for three construction applications; Subgrade Borrow Supply, Surfacing Aggregate Supply, and Rock Quarry Supply (includes riprap). Possible sources for winter sand are also noted (Allnorth 2015). Allnorth notes that borrow source development needed for construction of the all-season road will conform with Aboriginal Affairs and Northern Development Canada (AANDC)'s Northern Land Use Guidelines – Pits and Quarries (INAC 2010a).

3.0 SCOPE OF WORK

Tetra Tech EBA has carried out the following tasks:

- Conducted a review of relevant available information to characterize anticipated subsurface conditions along the proposed route;
- Prepared preliminary field maps for areas with insufficient terrain information to be verified by ground-proofing, and to optimize reconnaissance priorities in the field. Allnorth provided base field maps for this task;

- Observed targeted road sections and obtained geo-referenced photos of site features;
- Excavated test holes using hand tools at selected locations to verify shallow soil and permafrost characteristics in mapped terrain areas;
- Installed a temporary ground temperature cable in one test hole;
- Performed laboratory testing of samples collected during the site investigation for purposes of soil classification and determination of relevant engineering properties;
- Verified terrain mapping with field observations and laboratory results;
- Prepared a stand-alone geotechnical evaluation report to be included as an appendix to the DAR to describe the findings of the site investigation as it relates to the road and to permafrost- or stability-related aspects of specific borrow sources, and to address MVEIRB's TOR (currently in the form of this Issued-for-Review report);
- Prepared the applicable sections of the DAR within the standalone report such that they can excerpted and included in the DAR to be submitted by CZN to MVEIRB; and
- Worked with Allnorth's road design team to review and discuss various road sections in an iterative process to optimize proposed route realignments, develop design and construction parameters, and reduce geotechnical engineering-related risks.

4.0 METHODOLOGY

4.1 Review

Prior to mobilizing to the subject site, Tetra Tech EBA conducted a review of available information for the proposed road alignment. Since virtually all previous work was geared towards a winter road alignment, the review included additional review of existing aerial photos, orthoimagery, and Light Detection and Ranging (LiDAR) data, along with the preparation of preliminary field maps (map-books) to guide the onsite evaluation of the all-season road alignment. Allnorth assisted us with the preparation of map-books for use in the field. In addition to checking specific road sections to be rerouted, the primary objective of the review was to identify areas which might require specific focus during the field investigation and to locate suitable locations for potential test holes to be advanced.

Additional information obtained from CZN and Allnorth in advance of the field work included the 1994 aerial photos of the existing winter route, terrain mapping, site reconnaissance reports, previous geotechnical evaluation reports, as well as the proposed road route with route alternatives in some sections. A complete list of information sources is listed in the References at the end of this report.

Further review was carried out after the field work, to correlate the field observations with the anticipated conditions. Tetra Tech EBA contacted Mr. Lynden Penner, P.Eng., of J.D. Mollard & Associates (2010) Ltd. (JDMA) to attempt to locate their mapping and mosaics from 1995. No mosaics or mapping were found, although we had previously noted occasional markings on the aerial photos provided by CZN related to JDMA's 1995 winter route review. Mr. Penner did locate some notations on 1:250,000 scale maps, originally from Dr. Wayne Savigny, of BGC Engineering, and received by Tetra Tech EBA on October 1, 2014. Areas with gaps in aerial coverage along the all-season alignment could not be mapped directly, so, where necessary, Google Earth (2014) or Bing (2014) imagery was used for reference. Existing surficial geology mapping was also referenced where available along the route (Hawes, 1975). A complete list of information sources is listed in the references at the end of this report.

4.2 Site Evaluation

4.2.1 Ground-Truthing

Tetra Tech EBA carried out a ground-truthing program from September 21 through 26, 2014. Tetra Tech EBA's onsite representative was Rita I. Kors-Olthof, P.Eng., P.E. The ground-truthing program was helicopter-assisted.

Tetra Tech EBA was accompanied on site by a representative of Allnorth, Mr. Ernest Kragt or Mr. Brian Mitchell. Onsite coordination with Allnorth enabled the project team to identify potential problem areas while still on site, as well as to improve the efficiency of data acquisition and recording. Tetra Tech EBA geo-referenced points of interest using GPS coordinates. It is noted that GPS accuracy can be limited by vegetation and terrain obstructions. Where possible, Tetra Tech EBA also tied in points of interest to local landmarks or features.

Priority for site evaluation was given to road segments with one or more of the following conditions:

- Anticipated permafrost areas, particularly those considered likely to be ice-rich;
- Slopes in suspected ice-rich permafrost areas;
- Slopes that currently exhibit signs of instability or that are affected by debris flow activity;
- Areas requiring large cuts or fills; and
- Realignment areas lacking ground-truthing data.

Tetra Tech EBA's focus was to identify and target potential trouble spots, and otherwise to obtain a general overview of geotechnical conditions along the proposed road alignment. While the above-mentioned review identified in advance most of the areas that should be visited, Tetra Tech EBA was also able to identify and evaluate some additional challenging terrain features or issues along the proposed road route(s) during the course of the field work. When potential trouble spots were identified, the project team worked on route changes to avoid those areas whenever possible and, where such areas were unavoidable, to find design and construction solutions that would mitigate the possible issues.

In the targeted areas of interest that were visited, Tetra Tech EBA noted relevant terrain features, the presence of patterned ground, surface water drainage features, vegetation, as well as exposed soils, tension cracks and other signs of slope instability. Where no local topographic information was available, Tetra Tech EBA also measured sideslope gradients.

Tetra Tech EBA obtained near-surface soil samples with hand tools in order to verify the available terrain mapping as well as other terrain features that were identified in the field. Tools used include a pick and shovel, as well as an Edelman-type hand auger. In addition to excavating test pits and drilling boreholes, exposed soil at natural slopes and slope instabilities were sampled where encountered, and where they could be safely accessed. Slope failure headscarps of up to 2.25 m in height were sampled, with an additional 0.25 to 0.30 m obtained by drilling until refusal on frozen soils. In ground undisturbed by either slope instability or human influences, sampling to depths of up to 1.25 m could be achieved using the hand auger, sometimes meeting refusal before that depth on frozen soils or granular material. During the course of the site work in September 2014, Tetra Tech EBA logged 40 test pits, test holes and/or slope failure headscarps along the route, and we understand that Allnorth has also excavated numerous shallow test holes along the route and in proposed borrow areas. The 40 test holes logged by Tetra Tech EBA, and four test holes sampled by Allnorth on behalf of Tetra Tech EBA, are located as shown in the figures presented in Section 5 for each ground-truthing location. Borehole and test hole logs are presented in Appendix B, organized by road sections. Relevant borehole logs from SNC-Lavalin Inc. (SLI 2012a) are also included for specific road sections.

Tetra Tech EBA installed one temporary ground temperature cable at TP-14, recovering the cable after completion of measurements.

4.2.2 Road Sections Visited

Tetra Tech EBA visited representative locations along the following proposed road sections in order to characterize the terrain along and adjacent to the proposed road route, as follows:

- **KP024.3 to KP028.3:** The all-season route is proposed to run along the south side of the valley, whereas the winter route is on the north side. Tetra Tech logged five test holes in this section.
- **KP048.8 to KP058.6:** The road is to be re-routed to the north of the winter route. Four shallow boreholes were advanced by SLI at a set of switchbacks between about KP057 and KP057.5 (old KP 57 and 58) in 2012, then designated as the “M switchbacks” (SLI 2012a). EBA logged 10 test holes in the western two-thirds of this section, including two that incorporated observations on exposed soils at the headscarps within the thaw slump/flow at KP054.
- **KP080.3 to KP086:** The north Tetcela re-route leaves the existing winter route at about KP080.3, staying north of the winter route and on higher ground. The Tetcela Transfer Facility is located between KP085.8 and KP086. SLI logged two test holes in this section for the proposed Tetcela Transfer Facility on the winter road (SLI 2012a). Tetra Tech EBA logged three test holes along the proposed reroute.
- **KP086 to KP095:** The south Tetcela re-route, south of existing winter route. The route rejoins the winter road at about KP086.6. Subsequent to the September 2014 field work, this section was subsequently divided into two sections by Allnorth: KP 86.2 to 90.6 (staying on the winter route from Tetcela River up to KP 90.6) and about KP 90.6 to 95 (reroute south to toe of uplands area, skirting around west and south sides of C-Lake and then east to the existing winter alignment). Tetra Tech EBA logged six test holes in this section, including one on the currently proposed route. Allnorth obtained an additional sample after Tetra Tech EBA’s departure from site.
- **KP095.7 to KP101.7:** The road is to be re-routed on the west flank of the Silent Hills, west of Wolverine Pass, for the most part located north of the existing winter route. In 2012, SLI advanced 10 shallow boreholes in this section, designated “Silent Hills Switchbacks” (SLI 2012a). Tetra Tech EBA logged two confirmatory test holes in this section.
- **KP101.7 to KP118.0:** The all-season road is to be located west of the existing winter road and along the east flank of the Silent Hills. Tetra Tech EBA was able to traverse this part of the route in the helicopter. Allnorth obtained three soil samples in this section on behalf of Tetra Tech EBA after our departure from site.
- **KP124.7 to KP159.8:** The road is to be realigned to the west of the existing winter road, and along the toe of the Front Range. Tetra Tech EBA logged 14 test holes along this section.

The remainder of the route between the Liard River crossing and Liard Highway 7 follows the approximate alignment of the Nahanni Logging Road and the Nahanni Butte Access Road. The Nahanni Logging Road portion is from KP160 to KP174.15 and the Nahanni Butte Access Road portion is from KP174.15 to KP184.17. The boreholes advanced by SLI as noted above are the only recent test holes known to Tetra Tech EBA, other than six test holes at Polje Crossing, also by SLI (SLI 2012a). Golder did not advance any testholes along the route during their terrain assessment in September of 2009, and J.D. Mollard and Associates Limited (Mollard)’s work in 1995 was strictly a desktop study of the winter route. It is not known whether there may be borehole information available from earlier in the history of the road. Tetra Tech EBA's test holes were intended to confirm and augment the information available along the route from previous studies.

4.3 Laboratory Testing

Laboratory testing was carried out in Tetra Tech EBA's Yellowknife and Edmonton geotechnical laboratories to characterize the soils along the route, including soil moisture content, grain size analysis (sieves and hydrometers), and Atterberg limits. Laboratory test results are presented in Appendix B on and following the test hole logs.

4.4 Effects Assessment

The assessment methodology employed to assess potential impacts on the valued components – that is, impacts on existing ground conditions including permafrost, slopes, and karst terrain conform to the impact assessment steps summarized in Section 4.1 of the MVEIRB TOR for the Prairie Creek All-Season road. Consistent with the MVEIRB TOR, the assessment methodology employed includes:

- identify valued components used and how they were determined;
- identify the natural range of background conditions (where historic data are available), and current baseline conditions, and analyze for discernible trends over time in each valued component, where appropriate, in light of the natural or existing variability for each;
- identify potential direct and indirect impacts (consequences) on the valued components that may occur as a result of the proposed development, identifying analytical assumptions;
- identify and evaluate proposed mitigation measures as to their technical and economic feasibility to reduce the predicted impacts and discuss constraints, uncertainties and implementation challenges to the effective use of the proposed measures and clearly identify mitigation commitments;
- predict the likelihood of each impact occurring after the committed-to mitigation measures are implemented, providing a rationale for the confidence held in the prediction. The developer will also present the predictions in a manner that facilitates the formulation of testable questions for future follow-up programs, as well as textually and schematically indicate the pathways of predicted impacts;
- compare the predicted impacts to pre-development conditions or to conditions without the Project as appropriate. Include a description of any plans, strategies or commitments to avoid, reduce or otherwise manage and mitigate the identified potential adverse impacts, with consideration of best management practices in relation to the valued component or development component in question;
- describe techniques such as models utilized in impact prediction including techniques used where uncertainty in impact prediction was identified;
- identify, and provide an opinion on the significance of any residual adverse impacts predicted to remain after any mitigation measures and indicate the methodologies for reaching such conclusions; and
- identify any monitoring, evaluation, and adaptive management plans required to:
    i. detect potential unexpected changes;
    ii. confirm that predictions are accurate; and

iii. proactively manage against developing adverse impacts when they (or unexpected changes) are encountered.

The developer will describe how the predicted impacts are expected to arise from the proposed development, as well as its views on impact significance. This will include describing the mechanisms for cause and effect and providing supporting references (including where Traditional Knowledge was used). Where professional judgment has been used in determining impacts, this must be made clear. The developer will also provide a discussion on the uncertainty involved with each prediction. For each predicted impact, the developer will describe:

- the nature or type of the impact;
- the geographical range of the impact;
- the timing of the impact (including duration, frequency and extent);
- the magnitude of the impact (what degree of change is expected);
- the reversibility of the impact; and
- the likelihood and certainty of the impact.

The criteria described above will be used by the developer as a basis for its opinions on the significance of impacts on the biophysical and human environment.

This assessment of potential effects related to the all-season road addresses the terrain, surficial geology, permafrost and karst issues discussed in this supporting report to the DAR for the Prairie Creek all-season road. The assessment of effects considers magnitude, geographic extent, estimated duration, qualitative frequency of occurrence, reversibility and likelihood of predicted effects.

The following criteria have been used for the significance determination with respect to terrain conditions, as summarized in Table 4.4-1:

- Direction and Magnitude – The degree, extensiveness, or scale to which an activity may affect a valued component. Effects can be negative (adverse) or positive (beneficial) while magnitude may be defined as low, moderate or high, depending on how the particular valued component or group of components are affected;
- Geographic Extent – The geographic location or area where the effect is predicted to occur. The geographic extent may be identified as local (confined to the area of the access road), regional (with respect to Dehcho), or territorial in scale;
- Duration – The length of time that an effect is expected to occur as a result of an activity. Short-term duration is defined as the construction phase (in this case one year for each phase), medium-term duration (up to the end of service life of the road, estimated at 20 years), or long-term duration (extending beyond end of road life);
- Frequency – The predicted rate of occurrence over which an effect may take place. Frequency is defined as low if it occurs once, medium if it occurs intermittently or periodically, or high if it occurs often or continuously;
- Reversibility – Whether the predicted effect(s) can be reversed, or the capacity of the valued component to be restored to pre-development conditions with mine and road closure and reclamation; and
- Likelihood - the likelihood and certainty of an effect.

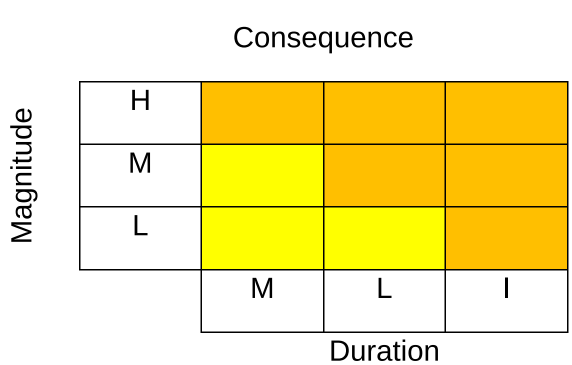
Table 4.4-1: Effects Assessment and Consequence Criteria Associated with the Project

Criterion (of effect)	Low	Moderate	High
Magnitude	Change is slightly above baseline conditions but within likely range of natural variability	Change is measurably above baseline conditions within likely range of natural variability	Change exceeds baseline conditions and causes changes beyond the range of natural variability
Geographic extent	Area of effect does not extend past the footprint of the project	Area of effect extends beyond the project footprint but is not of regional or territorial consequence	Area of effect is likely to extend into the region or be of territorial consequence
Duration	Effect is only evident during the construction or startup phase	Effect occurs or lasts for the service life / operational phase of the road	Effect extends beyond the operational life of the road
Frequency	Factors causing the effect occur infrequently (i.e. may or may not occur during the Project life)	Factors causing the effect occur at irregular intervals and infrequently (i.e. could occur two or more times during the Project life)	Factors causing the effects may occur regularly and/or frequently (i.e. could occur annually or as a result of high precipitation)
Reversibility	Effect can be reversed during the Project life	Effect can be reversed within 100 years	Effect is not reversible even after road closure, reclamation and regrowth
Likelihood	Unlikely, but could occur	Could reasonably be expected to occur	Will occur, or is likely to occur
Consequence	Slight decline in condition of the VC* during Project life, likely not noticeable thereafter	Changes in the condition of the VC over baseline that exceed guidelines and/or persist past Project life	Significant long-term or irreversible changes to the condition of the VC

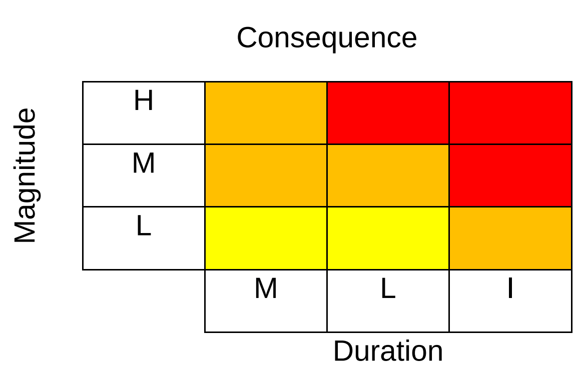
To determine the level of consequence from a residual effect as it is defined in Table 4.4-1 above, the primary factors considered are the magnitude, duration, and location of the effect. In the local area or footprint, the highest consequence rating is moderate, whereas in the regional area, the highest consequence rating is high.

The following schematics summarize the concept of consequence, where magnitude is low (L), moderate (M), or high (H), and durations are short- to medium-term (M), long-term (L), and irreversible (I). Colour-coding is as follows: red indicates "high" consequence, orange is "moderate" and yellow is "low" consequence.

Local Level of Consequence



Regional Level of Consequence



An explanation of the significance of environmental effects based on the criteria outlined in Table 4.4-1 is provided in Table 4.4-2.

Table 4.4-2: Significance Criteria for Environmental Effects Assessment

Overall Significance	**Low**	The effect is expected to be of low significance and further assessment and/or specific management are likely not required.
	Moderate	The effect is expected to be of moderate significance and specific management measures or plans are necessary.
	High	The effect is expected to be of high significance and further study or monitoring is necessary to supplement the baseline data, and to be used for refining a management strategy and plan.

Further discussion specific to the determination of hazards, consequences and risks directly applicable to slope stability and permafrost vulnerability is presented in Section 6 of this report.

4.5 Assessment of Permafrost Impact

The assessment of permafrost is an important part of this study. As noted in the definitions at the beginning of this report, permafrost is defined as ground (soil or rock, and including ice or organic material) that remains at or below 0°C for at least two consecutive years. The differences in permafrost in coarse-grained soils compared to fine-grained soils typically include the thickness of the active layer, soil moisture contents (frozen and unfrozen), sensitivity to thaw, and the likelihood or rate of soil creep.

Not all permafrost is a concern to the successful construction and operation of an all-season road. The type of permafrost that is of most concern is permafrost that is thaw-sensitive and/or ice-rich. For example, fine-grained soils that contain visible ice or are more than 100% saturated are considered thaw-sensitive. Such soils could lose most or all of their strength if thawed, and this could lead to potential instability and/or intolerable settlement. Ice-rich soils, even if they do not thaw, can also be prone to creep deformation under very small loads. This can potentially lead to the movement of road embankments on even very flat cross-slopes, due only to the weight of the fill as the ice-rich soil beneath creeps and spreads outward away from under the embankment.

As noted, bedrock can also be classified as permafrost. Usually, bedrock is not ice-rich, so if it thaws, it would remain stable, and so would not be cause for concern. Similarly, dense granular soils that do not contain excess ice would not be considered thaw-sensitive.

4.6 Reporting

Tetra Tech EBA's geotechnical evaluation report summarizes the findings of the information review, the field work, and the laboratory testing, and addresses the applicable sections of the MVEIRB TOR. The report includes sections on climate, permafrost, and climate change considerations as they relate to permafrost at the site, and each road section has a short discussion about the permafrost characteristics in that section of the road. This current version of the report is issued for review, pending receipt of commentary from CZN. The "Issued-for-Use" report will be included as an appendix to the DAR, and specific sections of the report will be incorporated in the main text of the DAR. Tetra Tech EBA requests the opportunity to review the portions of the DAR incorporating any part of our work product.

5.0 EXISTING ENVIRONMENT AND BASELINE CONDITIONS

5.1 Terrain, Geology, Soils and Permafrost

5.1.1 General

Terrain, geology, soils and permafrost are diverse over the length of the proposed all-season road, with numerous and varied terrain units encountered along the route. These features are summarized in the following report sections on the basis of existing information, supplemented with the ground-truthing work carried out in 2014. The description of features encountered is organized by road section evaluated. Figures are included to show where the 2014 field work was done, as well as related previous field work done by others in road sections where permafrost and/or slope stability is important.

Items relating to permafrost or borrow that are consistent to all of the road sections are described in separate subsections, after the station-by-station discussions. Borrow is discussed further in Section 5.2. Permafrost is discussed further in Section 5.4. Test hole logs are presented by road section in Appendix B, along with the related laboratory test results. A summary of site-specific features along the proposed all-season route is also included in the station-by-station summary of mapping and field observations in Appendix C.

Further discussion of hazards, consequences and risks related to the various features encountered along the road section is presented in Section 7.0.

5.1.2 KP000 to KP024.3

5.1.2.1 General

This section at the western end of the road leads from the Mine along the valley bottoms or low on the steep slopes of the Prairie Creek, Fast Creek, and Funeral Creek drainages, and the upper end of the Sundog Creek drainage. Much of the existing road bed in this section appears to be located on relatively coarse-grained materials. Allnorth reports that, within the road section that could be reached by ATV from the Mine (KP000 to about KP025), about 80% of the road bed was about 3 to 3.5 m wide, with occasional sections up to about 4 m wide or less than about 3 m wide. A few locations were affected by sloughing and will need repairs to restore access.

5.1.2.2 Geology

The route crosses several bedrock units in this section of the route, including cherty shales near the Mine, then heading north along Prairie Creek, dolostones and dolomites of the Cadillac and Arnica Formations, up to Casket Creek at about KP006.2. These formations appear to be dipping out of the slope, creating some increased likelihood of debris on the road should rock slides or falls occur. North of this point, and then heading east along Fast Creek and Funeral Creek to about KP009, there are thinly-bedded argillaceous limestones of the Funeral formation, which appear to be subject to periodic ravelling and failure as indicated by two large scalloped headscarps in sloughing talus above the route between about KP008 and KP008.7. Further east, bedrock mapping on the south slope above the road alternates between exposures of Arnica dolomites (about KP009 to KP011.3, KP012.5 to KP012.8), Funeral limestones (KP009 to KP012.5), Cadillac dolostones (KP012.8 to KP015.3), and Root River dolomites (KP015.3 to KP017.8). The Funeral formation, which is the most prevalent rock type north of Funeral Creek seems also to have an effect on the slope south of the creek, with possible run-up noted between KP010.2 and KP010.6. This possibility is not entirely clear, however, from the available air photos and imagery. Talus between KP011 and KP012 also seems more recent than adjacent areas, suggesting that the Funeral formation is more active in the generation of talus. Beyond KP017.8, limestones and dolostones of the Sunblood formation are mapped. Along the route are also dolomites from the Camsell formation (about KP016.5 to KP024).

5.1.2.3 Surficial Materials and Soils

The primary surficial materials on the slopes in this road section are talus and scree, essentially broken rock from progressive and ongoing failures in the bedrock exposed further upslope. The age of the talus mounds varies in accordance with the frequency of failure, which seems to be correlated with the types of rock as noted above. For instance, sections of the route through the Funeral formation seem to have more recent deposits.

Surficial materials anticipated at the valley bottoms in this section of the route are likely to consist of alluvial deposits, typically cobbly, along the streams, with materials between gravel and boulder size possible along the floodplains which could include glaciofluvial terraces in the areas influenced by the last glaciation. According to Duk-Rodkin et al (2007), the Prairie Creek drainage was not glaciated during the last glaciation. A Cordilleran ice cap was present at the height of land between the Funeral Creek and Sundog Creek drainages, mapped between roughly KP014 and KP020, a glaciation that began about the time that the Laurentide continental ice sheet reached its maximum, about 30,000 years ago. Glaciation is relevant to this section of route in the types of materials that will be encountered beneath the road, terraces available that allow for easy placement of the route, and in opportunities for borrow. Glaciofluvial deposits encountered downstream of about KP014 in the Funeral Creek drainage, or downstream of about KP020 in the Sundog Creek drainage may relate to this glaciation.

In some of the wider valley bottom areas, particularly in the Sundog drainage which has more of this type of terrain, there may be additional development of soils in the terraces and lower-lying areas, and even the development of organic soils in some places, similar to that seen in the field on the glaciofluvial terraces near KP025.4. Similar gradations of soils are anticipated anywhere there are terraces in this section, including gravel and sand with cobbles and boulders, and varying proportions of silt.

Generally, the route seems to be optimized with respect to location, although there are some terrain sections to be crossed that are quite steep with sidehill cuts, e.g. KP013.85 climbing to a hairpin corner at KP016.1 and then east. Due to the amount of elevation to be gained in the Funeral Creek section, it cannot all be done at valley bottom, since the valley is generally narrow and tight, and not conducive to route refinements. In the route section mapped within the Funeral formation type rocks, it is probably also an advantage to be up on the slope somewhat, since at least one section of the route appears as though slope failure events on the north side of the creek could potentially affect the south side, as mentioned above.

5.1.3 KP024.3 to KP028.3

5.1.3.1 General

The all-season route is proposed to run along the south side of the valley, whereas the winter route is on the north side (Figures 2 and 3). The all-season route is intended to take advantage of level to moderately-sloped terrain along what appears to be a series of treed bedrock-controlled ledges covered with rubble and/or debris deposits from upslope in this section. Tetra Tech logged five test holes in this section: TP-08, TP-08a, TP-09, TP-10, and TP-11.

5.1.3.2 Geology

Bedrock was not encountered in any of the shallow test holes, but is visible along the KP025.4 tributary and along Sundog Creek (the main stream along this road section).

Bedrock has therefore not been ground-truthed in this area but is anticipated to be similar to the bedrock units mapped in the surrounding area: primarily dolomites of the Arnica and Sombre formations are expected, with silty argillaceous dolomite of the Camsell formation also mapped near the west end of this section.

LEGEND

- Sinkhole
- Testpit

Proposed All-Season Road

- Phase 1

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Sundog Creek Crossing at KP025.4 and Realignment

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:3,000

50 25 0 50

Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_Figure02.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 2

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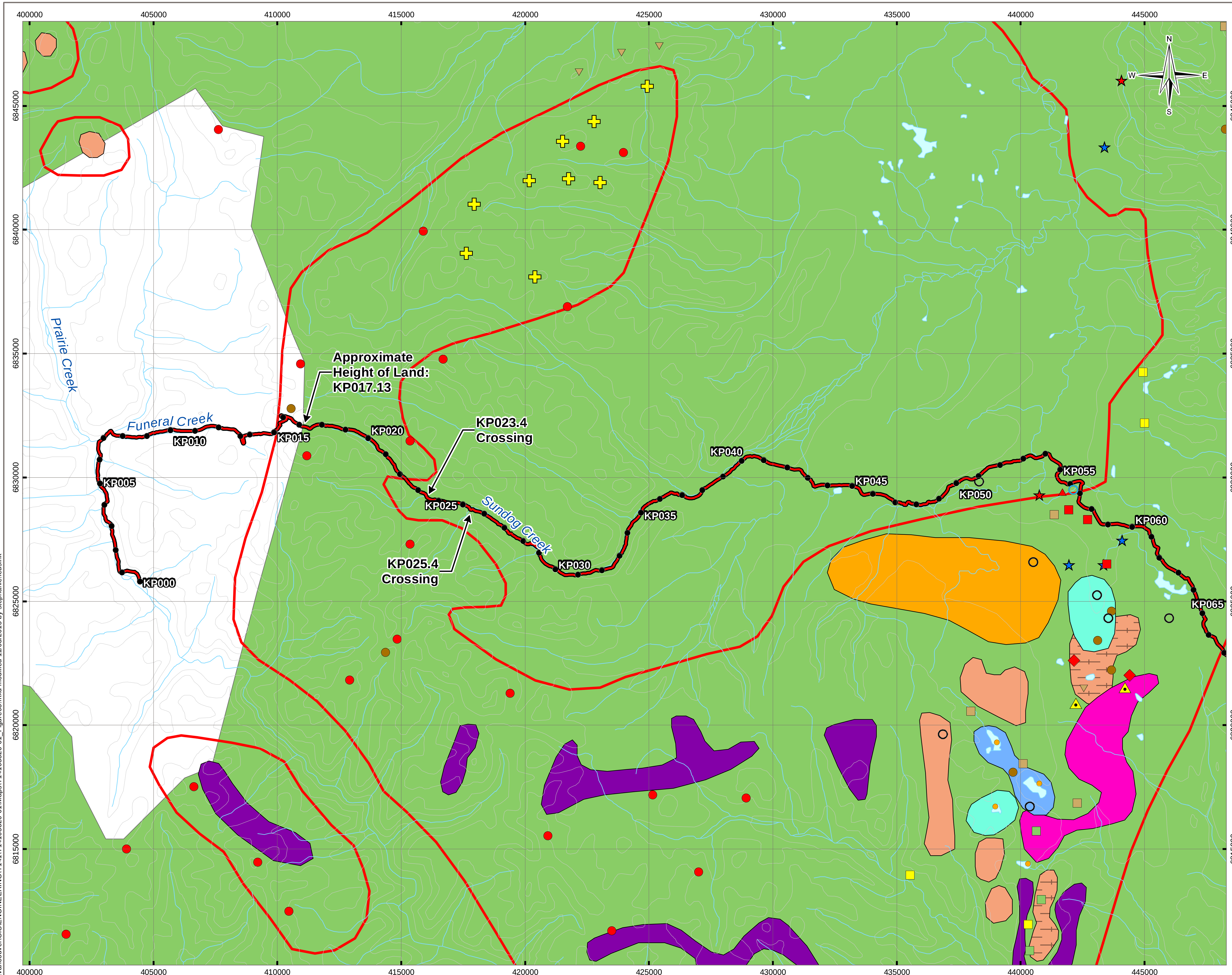

LEGEND

- Sinkhole (EBA)

Karst Features (Parks Canada)
- Arch
- Canyon
- Caves
- Corridor Karst
- Karst Lake
- Karst Pavement
- Karst Tower
- Polje (Karst Corrosion Plain)
- Remnant Karst Plateau
- Sinkhole, Cenote, Collapse Sinkhole
- Spring

Karst Features (ENR)
- Karst Cave penetrable >= 10 m
- Large Tor on Karst Rocks
- Sinkhole Exceptional
- Spring
- Closed depression draining underground
- Closed depression sinking stream
- Suffosion sinkholes
- Sinkholes clustered
- Sinkholes scattered
- Intersecting solutional corridors
- Solutional pavement

Significance Ranking of Karst Terrains (ENR)
- Established global - very significant

Proposed All-Season Road
- Phase 1
- Contour (200 m)
- Watercourse
- Waterbody
- Current Nahanni National Park Reserve Boundary

NOTES
Parks Canada data is approximated from Parks Canada (2006).
ENR data is approximated from Ford (2009), PAS-ENR (2012).
Base data source: NTS 1:250,000; Canadian Zinc.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Karst Topography KP015 to KP065

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:150,000
2 1 0 2
Kilometres

FILE NO.
Y14103320-01_Figure03.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

TETRA TECH EBA

Figure 3

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Exposed bedrock in the vicinity of the KP025.4 tributary stream crossing thus appears to be dolomite. West and north of this road section, the road passes through an area mapped as established karst terrain, and karst terrain is also mapped within 1 km south of this road section, with remnant karst plateaus and sinkholes also mapped in the area, so it is reasonable to anticipate that some similar features might also be encountered along the route (Figures 3a and 3b; Ford 2009, 2012; Parks 2006). This section of the route is therefore considered to potentially host karst features, and it is anticipated that similar features may be encountered elsewhere in this mountainous section, whether or not they are currently obvious at ground surface.

Figure 3 presents some excerpts from the mapping by Ford (2009) and Parks Canada (2006) which show the proximity of important features in the general area of the road. Some suspected suffosion-related micro-landforms were observed in the field in this section at and near TP-11, at about KP025.6 along the route. On the 2012 aerial coverage, two larger suspected sinkhole features (5 m estimated diameter) were identified between the route and the creek, at about KP026 and about 60 m or more downslope of the route (Figure 2). These features could be related either to water carrying sediments through dissolved passages in the underlying carbonate bedrock, or fines being washed through coarse-grained debris ranging from coarse gravel to talus blocks. The limited depth achievable with hand-held investigation equipment means that the reason(s) for the piping could not be determined conclusively; however, the nearby bedrock mapping and the apparent presence of limestone in the vicinity is suggestive of potential suffosion in rock. It is anticipated that these micro-landforms can be avoided or managed with detailed design and layout. The available information suggests that the hazards presented by these features are likely to be of a lower level than the upslope hazards along the existing route on the north side of Sundog Creek. Therefore, the reroute on the south side of Sundog Creek is preferred.

5.1.3.3 Surficial Materials and Soils

Terrain and soil types vary in this road section, with relatively coarse-grained soils encountered on the open slopes near the KP025.4 tributary stream crossing (TP-08, TP-08a, TP-09), and finer-grained silt/sand mixtures found on the bedrock-controlled ledge to the south. The exact thickness of landforms could not be determined with the equipment on hand, but a range of thicknesses may be roughly estimated based on contour information, landform type and visual observations. Development of the landforms in this area have resulted in densely-vegetated elongated depressions along the bedrock-controlled ledges, interspersed with older talus (light areas with trees) and more recent alluvial mounds, between which the proposed all-season road is routed. The deposits near the road appear older than the more-active talus further upslope, which is also further from the reroute than active talus on the existing route. There is likely to be some creep on steeper sections of the mounds and talus deposits. Terraces were also noted west and east of the KP025.4 tributary crossing. The upper terraces are probably glaciofluvial, while lower terraces may be fluvial. This terrain unit becomes glaciofluvial veneer and colluvial veneer where bedrock is near-surface. Where the glaciofluvial terraces are present, talus forming aprons, cones, blankets and veneers can be expected on top of the terraces. Soil thicknesses could range from less than 1 to 2 m, to more than 10 m, depending on proximity to the bedrock-controlled ledges and/or the eroded stream gully below as well as the lower reaches of tributary gullies, where bedrock is exposed.

Where talus is close to the road, the possibility exists that periodic or ongoing ravelling could impact the road. As well, rock slides or rock falls from bluffs or cliffs upslope are also potential hazards along this road section. Such hazards appear to be somewhat mitigated along route sections located along well-vegetated bench areas, whose dense vegetation suggests longer periods between impacts are likely.

Two important soil types were encountered along this road section, gravel and silt. These are described below, according to results of index testing, and classified in accordance with anticipated engineering behaviour.

On the northwest and southeast sides of the KP025.4 tributary crossing, the soils appear stable enough to have developed a significant organic layer, ranging from 50 mm thick in TP-08a, to 150 mm thick in TP-08, to 250 mm thick in TP-09. This organic layer is generally coarse-grained with most of the constituents also found in the soils beneath. Generally, the underlying mineral soil consists of GRAVEL, trace to some sand, trace to some cobbles, trace of boulders, trace of silt and clay, trace of organics. As would be expected in a glaciofluvial deposit, there are some large variations in gradation, with some areas closer to SAND and GRAVEL, or GRAVEL and COBBLES. Some boulders were also encountered, both at ground surface and below. Appendix B presents test hole logs and laboratory test results for this area.

Further east, there appears to be a gradual transition from glaciofluvial terraces to bedrock-controlled ledges with glaciofluvial and/or colluvial veneers where the soil is thinner. According to Duk-Rodkin et al (2007), the western extent of the Laurentide ice sheet is mapped at roughly KP026. At about KP025.6 and nearby to the east, the surficial soils are finer-grained than the soils near the tributary crossing, consisting of SILT, with a trace of sand or SAND and SILT, with a trace of clay, moist, light brown, with organic pockets, and increasing sand and gravel with depth. Because the material is fine-grained, ice-rich permafrost may be more likely here. However, no frozen soil was encountered in the test holes, and no obvious indicators were noted at ground surface (TP-10 and TP-11). If present, the thickness of frozen soils may be limited by relatively shallow bedrock.

5.1.3.4 Permafrost

Permafrost in this area is mapped as extensive discontinuous, which means it may be present under 50 to 90% of the terrain. Elevations are high enough in this area (in the range of about 1100 m amsl) that it may well be present. Where present, the active layer (zone of seasonal freezing and thawing) will vary in thickness according to the type of ground cover and soil type. In this area, the active layer in the coarser-grained soils could be 2 to 3 m deep, tending to be deeper in areas with little peat at ground surface. The active layer is likely to be somewhat thinner in the silty soils, possibly less than 2 m. If there is a significant layer of peat on top of the mineral soils, conceivably the active layer could be less than 1 m. Permafrost, where present, is considered likely to be “warm” permafrost, probably warmer than -2°C, and potentially just below freezing. Continued climate warming is likely to result in eventual thaw of permafrost soils. As there are no obvious indicators of ice-rich zones along this section, the effects of thaw are anticipated to be relatively minor.

Most of the streams on open slopes in this section are likely to be ephemeral and/or freeze to the bottom every winter. It is possible that the main stream could have water year-round in pools, particularly in bedrock substrates. In this road section, no obvious permafrost-related issues were noted along streams. It is noted, however, that there are numerous debris flow channels along the route, including a series of channels from about KP027.2 to KP027.7. As debris flow deposits can be very wet, it is possible that they could freeze while still wet if they occur late in the season. If the deposits thaw again in spring, it is possible that they could remobilize, or if the deeper portions do not thaw in spring, they could be subject to creep. Since the local climate is assumed still to be subject to warming, however, the aggradation of permafrost is considered to be unlikely in this area.

At the proposed borrow site, ice content for the total thickness of the deposit is not known, but no ice was encountered in the shallow test holes. While permafrost may be present here, it is unlikely that there will be significant ice-rich zones if the bulk of the deposit is as coarse as the material encountered.

While fires are possible along this road section, none are recorded here, and no obvious evidence of past fires was observed in the field. It is anticipated that fires in this road section are likely to be self-limiting due to the large proportion of ground that is un-treed. Fires potentially could affect ground temperature regimes and permafrost, but such effects are anticipated to be relatively minor in this road section.

5.1.3.5 Borrow

Because a full-bench cut is proposed on the southeast approach to the crossing, Allnorth has proposed a borrow site here. Fines content for this material varied from 4.6 to 6.5 to 11.8% from the various test holes. Results with fines content of less than 10% indicate a generally frost-stable material, whereas fines content of more than 10% indicates a frost-susceptible material. Materials proposed for borrow should be further tested to confirm their suitability for a specified use, for example, use in subgrade as compared to use as base course or structural fill.

5.1.4 KP028.3 to KP040.1

5.1.4.1 General

This road section is the remainder of the route following the Sundog Creek drainage, which is a wide braided stream in this section. The route generally stays on the south and southeast side of the stream, except for a short distance at the west end between KP028.3 and KP028.8 where it crosses to the north and again back to the south side.

5.1.4.2 Geology

The route is located within dolomite of the Arnica formation, then transitions at the Sundog fault between about KP032 and KP036.5 to a northeast-running section of limestones of Nahanni formation, calcareous shales and argillaceous limestones of the Headless formation, and dolomites of the Sombre and Camsell formations. These layers seem to be relatively level both in the mapping and in the formations consisting of large bedrock bluffs observed in the slope above the route in this area (Appendix C), which likely improves the stability of the slopes along this section compared to those with out-dipping bedrock layers noted elsewhere on the route. The route then stays within the Nahanni formation for the remainder of the route to Cat Camp.

5.1.4.3 Surficial Materials and Soils

As for the sections further west, most of this section is located in a valley in which the road skirts along the toes of talus/scree and around the outer edges of alluvial debris fans. Talus/scree predominates until about KP033.6, after which the talus/scree slopes are interspersed with prominent bedrock bluffs. The debris fans can be expected to continue to accumulate, and some events may be large enough to cross the road or plug culverts, particularly in sections that cross over the fan, such as KP031.3. Some road sections are also subject to rock fall from above, although the bedding layers being relatively horizontal means that rock slides along bedding planes are probably uncommon in this part of the road. Areas of wider floodplains are present, but in most of this section, there is not a consistent terrace for the road to follow, due to the meandering and braiding of the stream within it. The primary purpose of the all-season road in this section as compared to the winter road is to avoid crossing and recrossing Sundog Creek, except at the west end where it is easier to avoid the climb over a large rock knoll on the south side.

5.1.4.4 Permafrost

Permafrost in this area is mapped as extensive discontinuous, which means it may be present under 50 to 90% of the terrain. Elevations are high enough in this area (in the range of about 1100 m amsl at the west end down to about 800 m amsl at the northeast end) that it may well be present. Where present, the active layer (zone of seasonal freezing and thawing) will vary in thickness according to the type of ground cover and soil type. In this area, the active layer in the coarser-grained soils could be 2 to 3 m deep, tending to be deeper in areas with little peat at ground surface. The active layer is likely to be somewhat thinner in silty soils if present on the alluvial fans, possibly less than 2 m. If there is a significant layer of peat on top of the mineral soils, conceivably the active layer could be less than 1 m. Permafrost, where present, is considered likely to be “warm” permafrost, probably warmer than -2°C, and potentially just below freezing. Continued climate warming is likely to result in eventual thaw of permafrost soils. As there are no obvious indicators of ice-rich zones along this section from the imagery, the effects of thaw are anticipated to be relatively minor.

Most of the streams on open slopes in this section are likely to be ephemeral and/or freeze to the bottom every winter. It is possible that the main stream could have water year-round in pools, as described in the previous section.

5.1.5 KP040.1 to KP048.8

5.1.5.1 General

This section of the proposed route follows the existing winter road. It climbs out of the Sundog Creek drainage, and from KP041.5 to KP045.5 is located on a series of granular terraces. Further east, the route continues along the north side of a stream (Polje tributary) until it reaches the Polje reroute point at about KP048.8.

5.1.5.2 Geology

Bedrock is not evident along the proposed all-season road section between KP040.1 to KP048.8. However, this section of the road appears to be underlain by the Horn River formation, which includes black pyritic shale that is fissile and brittle, and may be associated with slope failures especially in locations where bedrock is shallow.

5.1.5.3 Surficial Materials and Soils

No estimate of bedrock depth or surficial material unit thickness is possible in this section. However, some estimates may be made of the possible thicknesses of the granular terraces at the west end of this section, based on the heights of slopes ascended or descended to get on and off the terraces. The flat terrace located from KP041.5 to KP043.3 and the duned terraces from KP043.5 to KP045.5 could be up to 15 m or so thick. The duned terraces appear to be somewhat thinner and also more irregular, however. These terraces are reported by Allnorth to consist of fine sand, which may be glaciofluvial in origin, and have been modified into dunes at the east end.

At the west end of this portion of the route, the existing winter road climbs from the Sundog Creek drainage at KP040.1 up to the edge of the granular terrace at KP041.5, crossing a series of swales and gullies along the climb east. Mollard (1995) suggested the possibility of an area of old mass-wasted till here. There is no obvious distress, but patchy trees on this irregular north-facing slope suggest possibly wet seeping areas in mid-slope and slopewash colluvium.

At KP045.5, the terrain returns to slopewash colluvium, possibly over old till, with the route mostly in the valley bottom. From KP046.3, the terrain eastbound becomes steeper, with the road winding its way around steep toes of knolls, especially between about KP047 and KP048, where there are some areas of exposed soils on the air photos at each cut location on knolls, and on a steep slope section above an outside bend of the creek between about KP047.4 and KP047.6. From KP047.6 to KP047.65, a very tight outside bend of the creek has resulted in erosion at the slope toe and a slope failure below the road. The sloughing has not retrogressed to the road yet, even in the 2012 imagery, but some consideration should be made to protecting this slope from further erosion. A similar situation is present near KP048.45, at HP49b, where another outside bend of the creek comes very close to the road. There is little vertical difference between road and creek here though, so it may be easier to protect.

5.1.5.4 Permafrost

Because the area is mapped as extensive discontinuous permafrost (Heginbottom et al 1995), 50 to 90% of the terrain may have permafrost. There is only a net change of about 20 m elevation along this route section, so the prevalence of permafrost is probably about the same throughout. The main differences along the route will be in the depth to permafrost, that is, in the thickness of the active layer. On the granular terraces at the west end of this section, the active layer could be 2 m or more deep, especially in areas that have little overlying organics. In the slopewash colluvium/till terrain in the far west end and eastern sections of this part of the route, active layer thickness is probably a little thinner due to the likely finer-grained nature of the till/colluvial soils, especially where a thick layer of organics is present. In shady gullies that are well-treed, it is possible that permafrost could be shallower than 1 m. But in areas where the soils have been exposed by slope disturbances, or along the winter road itself, the active layer may be 1.5 to 2 m thick, or more if those soils have been exposed for some time. Where present, permafrost will be “warm” as discussed for the previous road sections.

No recent forest fires appear to have occurred in this section, as the area appears fully vegetated on the imagery, so related effects from fires in permafrost terrain would not be expected in this area.

There are no obvious indicators of thaw-sensitive permafrost in this area. However, because the soils are generally finer-grained than the soils along the westernmost 40 km of the route, it is anticipated that the soils will be more thaw-sensitive and frost-susceptible in this section if the soil moisture contents are high enough.

5.1.6 KP048.8 to KP058.6

5.1.6.1 General

The current winter road route has been re-routed to the north of the previous winter road in order to avoid intense karst terrain upslope to the south (Figures 4, 5 and 6), where small- to moderate-sized soil slope failures were noted by Golder Associates (Golder 2010). For the all-season road, some additional modifications are proposed. Four shallow boreholes were advanced by SNC-Lavalin Inc. (SLI) at a set of switchbacks between about KP057 and KP057.5 (old KP 57 and 58) in 2012, designated “M switchbacks” (SLI 2012a). This switchback has been widened and kept further north and upslope out of a drainage area. KP054 was of particular importance due to a large retrogressive thaw slump/flow located immediately south of the proposed route. EBA logged 10 test holes in this road section, including two that incorporated observations of exposed soils at the headscarps within the thaw slump/flow (BH-01 through BH-05, TP-01 through TP-03, TP-06, and TP-07).

5.1.6.2 Geology

Bedrock is not evident along the proposed all-season road section between KP048.8 and about KP054; however, limestone, dolomites, and shale may be present, as encountered elsewhere on the route. Bedrock outcrops are noted between KP054 and KP058.6, where both carbonates (KP054.6) and shale rock (KP055.3 and KP055.9) types are noted and proposed as potential borrow sources (Allnorth 2014). The Horn River formation is suggested by Golder (2010) along the south side of the valley, on the steeper slopes near the existing winter route. This formation consists of shale, and on the Ram Plateau it is underlain by limestone and dolomite of the Nahanni formation, which in turn overlie the shale and argillaceous limestone of the Headless and/or Funeral formations. This mapping appears to be consistent with the observations made of the relative elevations of rock types seen along the route in this section. The Poljes are evidence of the karst terrain in the region, which is to be protected by the reroute as it is presently proposed for the revised winter road and all-season road. The locations of the Poljes and other karst-related features are noted on Figure 3. The proposed route skirts between these valued features and canyons, avoiding them so as to reduce the possibility of impacting them directly or indirectly.

No obvious evidence of karst-related activity was noted along the traverse or helicopter flights along or immediately adjacent to the proposed reroute. A sinkhole was mapped near KP051 (Parks 2006), but not seen in the field. A suspected sinkhole feature is visible on the imagery about 170 m south of the route, however (Figure 3). A sinkhole was observed near KP056, about 80 m south-southeast below of the route. The surrounding terrain appears to be subsiding as well in that location; thus, avoiding this terrain is prudent for the integrity of the road (Figures 3 and 6).

Bedrock was not encountered in any of the test holes in this section; however, it is anticipated to be relatively shallow, on the basis of the numerous bedrock outcrops that were noted. Locally, bedrock can be deeper, but it is anticipated that soil between about KP054.6 and KP058.6 is typically present as a discontinuous residual or colluvial veneer and/or reworked tills, thus often less than 1 to 2 m thick. Bedrock is more likely to be exposed along ridges, and surficial materials are likely to form infills between those ridges. Between KP048.8 and KP054, bedrock is likely to be deeper, given that outcrops were not noted directly adjacent to the route, and test holes at KP054 did not encounter bedrock within 2.5 m of the original ground surface.

5.1.6.3 Surficial Materials and Soils

Since bedrock was not noted between KP048.8 and KP054.6, nor encountered in the test holes between KP049.7 and KP054, no estimate of bedrock depth or surficial material unit thickness is possible in this section. However, there are some large exposed soil slopes that were encountered during the field work, many of which are related to loss of toe support due to erosion and undermining at outside creek bends. The soil debris slide downslope of KP050.5, for instance, is located on a slope of about 35 m in height (Figure 4, Appendix C). This slide is unlikely to affect the road with the present stream configuration. The treed area above the exposed sand slope is actually a ridge, behind which runs the road. The road would be at a point estimated at a slope of 4H:1V above the present toe of slope (drawing an imaginary line through the ridge). The treed slope just west of the exposed sand slope is an older failure currently growing in, since the stream has moved away from the slope toe. Further to the west in this route section, the route was moved away from the crest of the steeper slope during the field work, so as to reduce the hazard at the location of the road. Although only sandy soils were evident here and in the shallow test holes advanced along the route as far west as about KP049.7, the surficial geology mapping further to the east suggests that bedrock is probably relatively shallow in this area and therefore may also be present beneath the soils on this slope (Hawes, 1975). Mapping of glacial limits in NNPR indicates that this area was once covered by the Laurentide continental ice sheet, thus some glacial deposits should be anticipated here (Duk-Rodkin et al 2007).

Two main soil regimes were encountered along the route in the section shown on Figure 4. At the upper crossing of the KP049.7 stream, which was removed from consideration during the field work, 0.5 m of SILT, with some fine-grained sand and some clay was encountered at ground surface on the southwestern side slope of the stream, where slope instability was observed. Beneath the silt, a medium-plastic silty CLAY was encountered, at the surface of which was free water (Figure 4 and BH-01). Upstream and downstream, more instability was noted. While the slope failure appears to be fairly shallow, this location was deemed not optimal for development of a road and therefore the noted change in crossing location was made as a result of the field work.

Elsewhere along this section of the route, from KP049.7 at the lower crossing to KP50.5 near the large slope failure along the creek, surficial materials appear to consist of 80 to 150 mm of PEAT overlying fine to medium grained SAND, with trace to some silt. The soil was somewhat siltier towards the west end of this section, with silt content varying from some silt to silty. Minor gravel or cobbles was also noted in this section (TP-03). The presence of jack pine along the route reinforced the observations that the sandy soils are usually relatively dry and well-drained.

Just east of the Polje Creek crossing, a retrogressive thaw slump/flow was investigated. Here, the soils return to silt and clay with some variations noted (Figure 5, BH-05, TP-06 and TP-07). Underlying a PEAT layer of about 300 mm thickness, it appears there is a layer of colluvium, or perhaps reworked till, which shows evidence of having been modified by water, consisting of a layer of SILT, which varies from clayey to trace clay, with some sand to sandy, and trace gravel. This material is layered and sometimes varved (TP-07) with coarser particles interspersed between finer-grained layers. Also in TP-07, which was located at the headscarp of the thaw slump/flow, a layer of medium to coarse-grained sand and trace gravel, over a discontinuous layer of shale boulders was encountered. These layers were not seen downslope in TP-06, about 30 m above the toe of the thaw slump/flow. Beneath the silts, sands and/or boulders, silty clay was encountered, interpreted at TP-07 as CLAY TILL (or till-like, in any case). This material contained 61% clay, 38 to 39% silt, and up to 1% sand, and was high plastic.

LEGEND

- Observation Point
- Borehole
- Testpit
- Slide
- Swale
- Old Channel

Proposed All-Season Road

- Phase 1

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Polje Karst North Reroute KP048.8 to KP051

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:6,000

100 50 0 100

Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_Figure04.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 4

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LEGEND

- Observation Point
- Borehole
- Testpit
- Slide

Proposed All-Season Road

- Phase 1

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Polje Creek Retrogressive Thaw Slump/Flow KP054

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:4,000
50 25 0 50
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_Figure05.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 5

Soil moistures in the clay were 29 to 32% which, although high, and above the plastic limit (29), they are but well below the liquid limit (62) for this material. It is possible that this slope failure is related to thaw of permafrost following the 1996 forest fire (see further discussion under the heading Permafrost, below).

SLI (2012a) noted an historical landslide between about KP056.8 and KP057.4 (current stations), in the vicinity of their boreholes BH-M-01 through BH-M-04 (Figure 6). However, they did not mark the slide location on their figure, and no air photo coverage is currently available for the area, so the exact boundaries of the slide they observed are unknown. It seems that at least some of the boreholes were within the identified slide area, since SLI mentioned that the soils encountered were compact, suggesting to them that some consolidation had occurred after the landslide. SLI identified topsoil at ground surface in three of the four boreholes, varying in thickness from 0.2 to 0.3 m in BH-M-04 and BH-M-02, and up to 1.3 m thick in BH-M-03. In all cases, SLI described the topsoil with other constituents such as gravelly organic clay, clay, gravel, organic silt, and shale. In BH-M-01, SILT was encountered at ground surface, extending to 0.2 m below grade, beneath which was silty organic CLAY with trace shale. Silt was also found below the topsoil in BH-M-04, between 0.2 and 0.9 m below grade.

Beneath these finer-grained surficial layers, coarse SAND was found in all the holes except BH-M-03, with other constituents including gravel and silt in BH-M-01 and BH-M-04 (some gravel to gravelly, trace to some silt to silty). Trace to some shale was also noted. In BH-M-03, GRAVEL was encountered beneath the topsoil, with some coarse sand and trace silt noted. The material was generally moist, with soil colour in the boreholes varying from brown to black to dark grey. In BH-M-02, the soil was frozen at 1.96 m below grade, with free water encountered at the end of hole at 3.8 m depth, suggesting the presence of a thin layer of permafrost. Likely the thaw depth would have been at the approximate seasonal maximum at the time of drilling (September 24, 2012). Oddly, no frozen soils were observed in the borehole with the greatest organic cover (BH-M-03). It is possible that the soils were only marginally frozen, with drilling resulting in the thaw of the soils before it could be noted. This might be especially true of the soils in BH-M-03, which could have been the most difficult to drill due to significant coarse content.

Tetra Tech EBA identified three possible scarps just upslope of the route in this section, as well as a linear feature downslope (marked with a dashed line on Figure 6) that may be related. All of the scarps appear relatively well-vegetated on the 2012 imagery. No 1994 air photos are available in this road section to compare to. As a result of Allnorth's 2014 work, the route along the climb up from Polje Creek has been moved further upslope than it was previously in order to improve road grades, avoid downslope slope issues, and stay out of the gully that drains to the Third Polje below, but the section from KP056.5 to KP057.5 remains essentially on the 2012 route investigated by SLI (2012a). Therefore, the slope instability hazards have not been eliminated, but they have been reduced with the 2014 realignment of this section. There is an apparent slope failure downslope of the route between about KP057.4 and KP057.7, above the east end of the Third Polje. This may be the same mud slide observed by Dillon in September 2009 and presumed to have occurred on or about September 9, 2009, coinciding with a peak in water level in the WSC gauge at Blackstone River (Dillon 2009). Since the local slope gradients at this location vary from about 3% in most of the distressed area to 8% at the downslope extent of the debris lobes, it is possible that this recent failure is related to thaw of permafrost following the 1996 forest fire (Figure 6). This area appears to be located within a larger, older failure area, marked with dashed lines on the figure. Further discussion about the potential effects of fire is presented under the heading Permafrost, below.

Golder (2010) identified two large slope failures in glacial soils over shale/siltstone near the east end of the Polje reroute. Superimposing the features identified by Golder along the road route, Tetra Tech EBA identified a headscarp located within about 50 m southwest of and below the current road route (about KP057.8 to KP058.2), and where the route rejoins the winter road, there is a headscarp within about 25 to 50 m south below the route (about KP058.7 to KP059.2). Two suspected scarps were also noted above the road near KP058.2. The probable headscarp locations below the road are clearer than the suspected scarps above the road (Figure 6). This is because the terrain above the road is much flatter, and the suspected scarp locations above the road may only indicate a difference in the vegetation. About 150 m to the north of KP059, Golder also mapped a sinkhole (Allnorth's helipad HP60). The road route is located on nearly level terrain above the crest of slope which allows ample room, if needed, for fine-tuning the route during detailed design and layout. Behaviour of the slopes can be confirmed and appropriate setback distances from these features determined at that time. The next such feature, south of KP059.2 to KP059.9, is about 75 to 300 m south of the road, decreasing heading east. No air photo coverage was available to Tetra Tech EBA in this section, but the 2012 imagery shows the crests of slope in this area. Generally, the road is well-positioned to avoid this apparent slope instability.

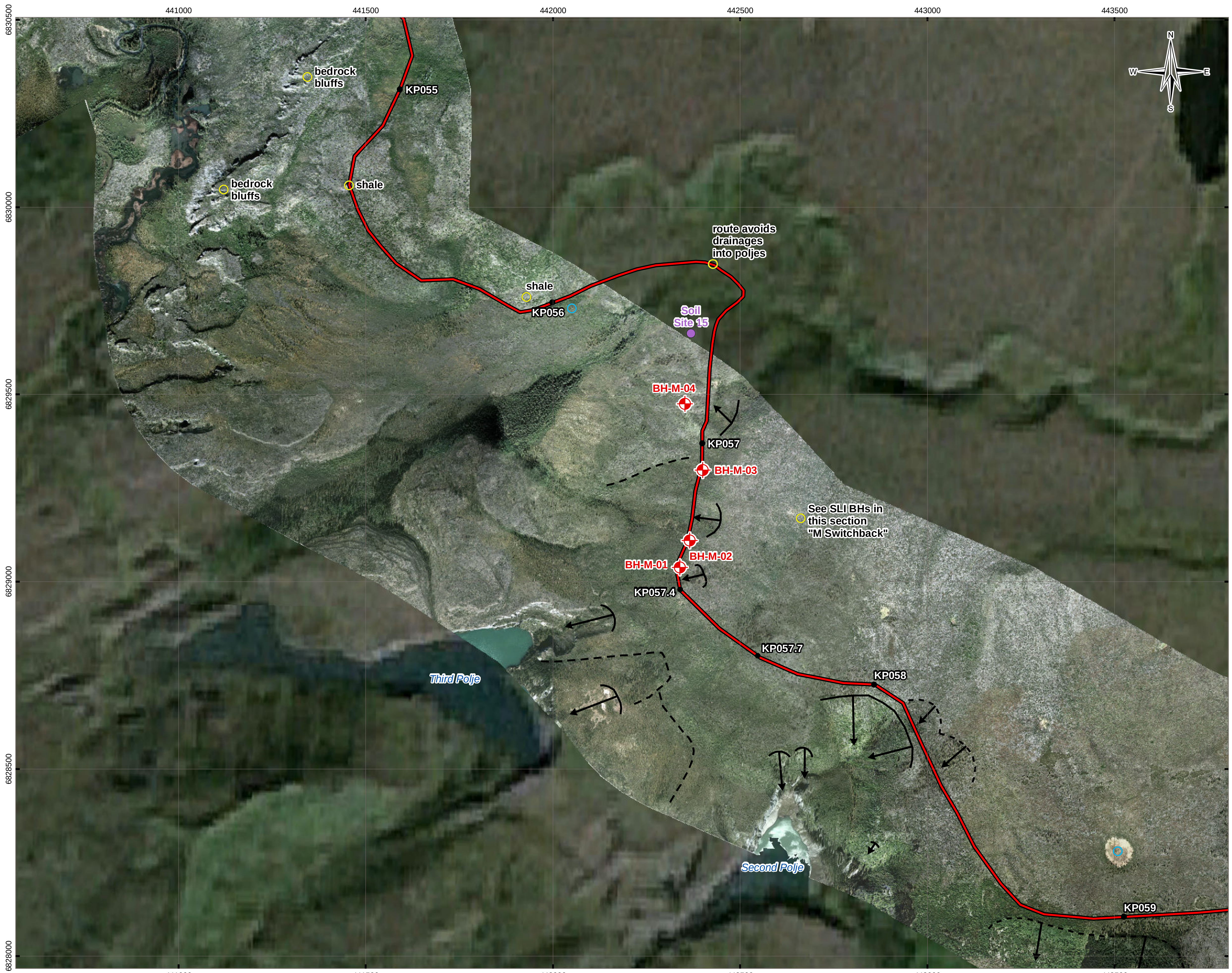
5.1.6.4 Permafrost

Some slopes are in shady valleys and/or have essentially north-facing aspects such as at BH-01 upslope of KP049.7, or have a relatively thick peat cover and evidence of suspected thaw-related failures, such as at KP054. These areas are suspected to have permafrost that needs to be protected against anthropogenic disturbance, or that should be avoided to prevent thaw-related issues from affecting the road. The road has been re-routed away from a few obviously unstable slope sections between about KP049.5 and KP055, some of which appear to have permafrost thaw-related failures, and some of which are more likely only erosion-related slope failures. The suspected slope instabilities along the road route between KP056.5 and KP057.5 may also be at least partly thaw-related. The hazard has been reduced somewhat as a result of the 2014 realignment removing the switchback lower on the slope.

Frozen soil was not encountered at BH-01, but due to the slope disturbance, the active layer is probably deeper now than it would have been prior to disturbance. Frozen soil, probably permafrost, was encountered in the thaw slump at KP054, in TP-07. Although no intact soil sample could be retrieved due to refusal of the auger, the overlying samples were very cold. In this case, the frozen soil was at about 2.5 m below original grade. Of this depth, 2.25 m was logged on the headscarp of the slide, and 0.25 m was logged in a borehole below grade. Because some time had elapsed between the slope failure and logging, the original depth to permafrost was probably less than 2.5 m, and might have been less than 2 m. While the 300 mm thick peat might suggest a thinner active layer on slope aspects that are either northerly, neutral or shaded (where the active layer might be as shallow as 1 m), on this broad open west-southwest facing slope, a 2 m or so active layer thickness may be more reasonable. It is also noted that there is considerable seepage through this slope section and a stream is mapped here, so the presence of water probably increases the active layer thickness somewhat. Climate warming may slowly increase the active layer thickness over time. Eventually, a talik or unfrozen zone is likely to develop between the seasonally-frozen soil and the remaining permafrost beneath, if/where present.

It is further noted that this entire road section runs through an area that burned in a forest fire in 1996. It is likely that the thickness and integrity of the peat has been affected in at least in at least part of this area, likely increasing the active layer thickness since the fire. Field observations suggest that where the fire appears to have been very hot, the surface of the peat holds less moisture and is less resilient or spongy than it probably was prior to the fire. This is an effect that seems to have persisted in the 18 years since the fire occurred. It also seems likely that peat thickness may have been reduced in some locations, based on prior observations of forests subjected to prescribed burns. Trees on sandy slopes that would likely have been drier at the time of the fire seem to have been most affected. In many locations, only the trees in the valley bottom or in cool wet gullies seem to have been preserved.

Because the area is mapped as extensive discontinuous permafrost (Heginbottom et al 1995), 50 to 90% of the terrain may have permafrost. This road section is at a somewhat lower elevation than the previous section, so there may be fewer areas where permafrost is present but there is also more organic terrain where permafrost may be present, protected under thick layers of peat. Where present, permafrost will be "warm" as discussed previously. On south or west-facing aspects, permafrost may be only marginally frozen, particularly in areas that have been subjected to forest fires and in which the peat has been damaged. The soils between KP049.7 and KP051.7 are likely to be warmer than the soils in shaded areas, or which are protected with a thicker layer of peat.



LEGEND

- Allnorth Soil Sample
- Sinkhole
- Observation Point
- SLI Borehole
- Slide
- Suspected Area of Movement

Proposed All-Season Road

- Phase 1

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Google; Landsat (2013).

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Slope Instabilities above Poljes KP055 to KP059

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:10,000
200 100 0 200
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_Figure06.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 6

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5.1.6.5 Borrow

Allnorth has proposed borrow sites at about KP050.3 (BP 50B), KP050.9 (BP 50), KP051.7 (BP 51), KP053.3 (BP 53). Tetra Tech EBA has not visited the latter three proposed borrow sites, but did traverse the route adjacent to BP 50B. It is understood from Allnorth's data that similar sand materials are anticipated at each of the borrow sites, with some variation in silt content. Coarser-grained granular borrow materials are anticipated at KP055.3 (BP 55) and KP056.7 (BP 56B). As frozen soil was not encountered in sandy soils during the field work, and only shallow holes could be advanced, the presence or absence of permafrost, the probable ice content, and permafrost characteristics could not be determined. Until such time as these characteristics can be confirmed, it is recommended that a buffer zone be maintained between the road and borrow areas. If the borrow area proves to have higher than anticipated ice content and subsequently thaws, the road should be protected by the buffer zone. It is noted, however, that this section of the route is largely south or southeast-facing, with some southwest-facing sections, and is therefore generally anticipated to be a relatively warm slope, and may or may not have permafrost in it. Irrespective of permafrost, however, caution is advised at BP 56B, due to the proximity of the existing slope problems noted above.

Borrow areas are also proposed in bedrock outcrop areas, such as at about KP054.7 (BP 54) in carbonate rock and KP055.9 (BP 56) in shale. Few or no issues associated with thawing permafrost are anticipated at these locations. Borrow areas should be further tested to determine the uses for which they are most suited and frost-susceptible soils avoided where possible.

5.1.7 KP058.6 to KP080.3

5.1.7.1 General

This section of the route is located along the existing winter road, which climbs away from the Polje terrain and follows a series of ridges to stay on high ground enroute to the Tetcela River drainage.

5.1.7.2 Geology

Shale was noted by Allnorth on the granular terrace at the northwest end of this section, and this area is mapped within the Horn River shale formation. Heading southeast the route crosses into the Fort Simpson formation which includes shale and siltstone and overlies the Horn River formation. These rock types are in turn underlain by limestone and dolomite of the Nahanni formation which shows its presence with the appearance of sinkholes located along the route, for example, between KP065 and KP066.3. Ponds near the road are generally noted to be located within deep, wide bowls. Several of the ridges along the route either appear to be comprised of bedrock or bedrock is probably near-surface.

5.1.7.3 Surficial Materials and Soils

Surficial materials in this section are mapped as residual or colluvial veneer up to about KP079, indicating that they should be a relatively thin layer over bedrock. East of KP079, this section is mapped as a colluvium or till veneer.

Soils with a till-like texture can be anticipated, either silty soils as encountered on the slope down to the Tetcela River east of this road section, or possibly some slightly coarser, less-weathered soils along the route. For example, Allnorth encountered fine sand at about KP070.9 and KP072.9, and sandy till-like soils at about KP077 and KP078.4. Glaciofluvial gravel may also be encountered in a few areas closer to the west end of this section, with Allnorth reporting fine glaciofluvial gravels at about KP064.9 and KP065.1.

Few areas of distress were noted along this part of the route, but there were a few short road sections crossing the heads of gullies that will need closer attention during detailed design and construction in order to properly route nearby streams and reduce the likelihood of sloughing into the gullies or onto steep slopes below. Examples of such gullies or slopes include the road from KP060.6 to KP061.6, KP068.5 to KP69.3, and KP070.2 to KP071.

A peaty wetland was noted at about KP072.8.

5.1.7.4 Permafrost

Permafrost is likely to be present in this relatively high elevation section of the route, with about 855 m elevation at the northwest end, climbing to 990 m and descending again to about 708 m at the southeast end of this section. However, because the surficial soils are generally expected to be relatively thin over shallow bedrock in much of this part of the route, the potential effects of thaw-sensitive permafrost, if present, are likely to be small. Sections of coarser grained soils, such as the granular terrace between KP058.6 to KP059.9 are also less likely to contain thaw-sensitive soils.

It is understood that there was a fire in the area from KP064 to KP110 sometime between 1940 and 1950. A more recent fire (date unknown) seems to be evident on the imagery between about KP066.5 and KP069.5, where portions of the route and parts east appear similar to burned areas along the Polje reroute. It is possible that a fire may have affected the organic layer and increased thaw of permafrost in this section; however, because the soils are probably thin here, the effects would likely be less than in the Polje area.

5.1.8 KP080.3 to KP086

5.1.8.1 General

The all-season reroute departs from the winter road at about KP080.3, staying north of the winter route and on higher ground (Figure 7). Where the route approximately parallels the top of bank above a major tributary of the upper Tetcela River, it is on mostly gently-sloping terrain (about KP083.5 to KP086). The re-route is proposed to run about 50 m south of a small stream traversed during the field work. SLI logged two test holes in this section for the proposed Tetcela Transfer Facility, near the winter road (SLI 2012a). Tetra Tech EBA logged three test holes in this section of the proposed reroute (TP-12, TP-12a, and TP-13). Numerous slope instabilities were noted below the road, on the slope down to the Tetcela River tributary (Figure 8, KP084-KP085).

5.1.8.2 Geology

The depth to bedrock is not known in this section, as it was not encountered in Tetra Tech EBA's hand-dug test holes near the all-season route (TP-12a, TP-12/BH-06, and TP-13/BH-07, up to 1.1 m depth), nor in SLI's boreholes near the winter road (3.1 to 4.6 m depth) (SLI 2012a). Surficial geology mapping suggests the presence of colluvial soils or till veneer over shale, siltstone or limestone bedrock (Hawes, 1975), however, so that suggests bedrock could be as shallow as 1 or 2 m.

Geology mapping indicates shale and siltstone of the Fort Simpson formation overlies shale of the Horn River formation, which in turn overlies limestone and dolomite of the Nahanni formation, and then the argillaceaous limestones and shales of the Headless and Funeral formations (Douglas and Norris, 1976a). Of particular interest are the formations that potentially affect slope stability along the Tetcela River above and below the route, which include the Fort Simpson, Horn River and Nahanni formations. A normal fault (the Tetcela Fault) is mapped just west of KP084, which is not apparent from the air in the vicinity of the road. There is, however, a prominent bluff on the north side of the Tetcela River tributary opposite KP084 which may be related to the fault (Figures 7 and 8).

LEGEND

Borehole

Testpit

SLI Borehole

Proposed All-Season Road

Phase 1

Phase 2

NOTES

Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Tetcela North Reroute KP080 to KP087

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:15,000

200 100 0 200

Metres

FILE NO.
Y14103320-01_Figure07.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 7

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5.1.8.3 Surficial Materials and Soils

At about KP080.3, the winter road begins its descent into, then across a gully, descending the east sidewall of the gully, then bending east to follow just above the valley bottom. This gully appears to consist of a shallow earth slide, with smaller old slope instabilities within the gully and just east of the gully. Suspected headscarps are more obvious on 1994 air photos than on 2012 imagery. A few short bare patches were noted by Mollard (1995) that seem to be related to cutslope disturbances, or possibly sloughing, seepage and/or sedimentation along this section of the route. These areas are clearly visible on the 1994 air photos, but not on the 2012 imagery. Streaky, sub-parallel runoff channels are present in the valley south of the road, as well as upslope along the proposed all-season route.

The proposed all-season route avoids the apparent slope instabilities seen along the winter road by staying above the crests of the steeper gullies/drainages (gradients locally to 40%), and on the ridges (gradients of 20% or less). From about KP080.8, the route descends a ridgeline south, switching back at about KP081.7, heading northeast and skirting above the steeper ground on the descent towards KP083, where the slope gradient lessens. The road is well-placed along the ridgeline, by staying on the higher ground. Areas that have few or no trees at about KP082.4, KP082.5 and KP082.8 below the route suggest seepage areas and the possibility of instabilities, so good control of water drainage will be needed along the road. The first two of these areas are seen on the 1994 air photos and the 2012 imagery, while the latter is on less-steep ground and is visible only on the 1994 air photos, so the vegetation has been able to grow back in the 18 years between sets of images. Between KP083 and KP083.9, slope gradients range between 7 and 13% in streaky terrain, becoming gentler eastbound. The streaky terrain is because of mostly inactive surface water drainage channels, but there are a few active streams too. Here, the all-season route is roughly parallel to and south of a small stream. The forest appears in decay here, with jack-strawed trees across the stream and considerable old and new deadfall.

From about KP083.9 to KP085.9, slope gradients range from about 4 to 7%. Potential slope issues exist near the crest of a north-facing slope above the Tetcela River tributary, which is mapped entirely as colluvium (Hawes, 1975). Most of this slope is off the LiDAR, but numerous slide paths are visible on the 1994 air photos. A recent ("fresh") slide path is clearly visible near KP084 on the 1994 air photos (A28094-259-260). From the air, it appears that there may be tension cracks above the crest of slope, areas of seepage and apparently slumping soil. Tension cracks have been interpreted along the crest of the slope on the 1994 air photos as well. Active slope erosion of the Tetcela River slope was interpreted between KP085.5 and KP086.5 - patches of the slope are devoid of trees. There is evidence of downslope block movement (Figure 8). The route is proposed to stay well south of the crest of slope above the Tetcela River, south of the small stream, and therefore is expected to avoid the slope stability issues that are seen on the slope below. The condition of the slope features will be confirmed during detailed design and layout. Despite much of the slope drainage running from west to east, the streams nearest the Tetcela River slope tend to veer north and run downslope to the river, including a drainage path interpreted on the 1994 air photos between KP085.2 and KP085.5, and mapped as a stream by Allnorth. There may be more streams or swales that similarly direct drainage over the slope that are as yet unmapped. Close attention to surface water drainage will be needed during road layout.

Soils encountered by Tetra Tech EBA in this road section included PEAT, to a thickness of 50 to 150 mm along a small stream about 50 m north of the proposed road. The peat was much thicker at 400 mm in the wet meadow at HP85, located northwest of the small stream at about KP083.5. Beneath the peat, SILT was encountered. The silt generally had a trace to some sand, and a trace of clay. Clay content and plasticity seemed to increase with depth, with clay content varying from some clay to clayey near the bottom of the deeper test holes. Traces of angular gravel, oxides and sand pockets were also noted in TP-12/BH-06, suggesting a till-like soil. The silt was stiff to hard, becoming very stiff by about 1 m depth with a slightly higher moisture content. Silty CLAY, with traces of sand and gravel were encountered just below 1 m depth in TP-13/BH-07, with the same gradation as the clay at the base of the thaw slump/flow at KP054. Moisture contents varied from about 11% in the silt to about 21% in the clay, with moisture contents at about the plastic limit for the clay. The clay was determined to be medium plastic, and stiff to hard in consistency. No free water or frozen soil was encountered in Tetra Tech EBA's test holes in this area.

SLI encountered silty CLAY in their boreholes for the TTF just north of the winter road, noting a firm to stiff consistency, becoming very stiff by 2.7 m depth (SLI 2012a). They also noted GRAVEL (loose rocks) below 3 m depth in their TTF-01, resulting in refusal at 3.16 m depth. A trace of shale fragments was encountered in SLI's TTF-02, but this borehole continued in clay until the end of hole at 4.6 m depth. The gravel could be indicative of shallow bedrock, or it could be just a gravel lens in till-like soils. Similarly, the shale fragments within the clay could also be indicative of till-like soils. A moisture content of about 27% was noted in the frozen clay, just below the water table. This moisture was well above the plastic limit of about 18, but still well below the liquid limit of 49. Thus, while it is wetter than would be useable for backfill without drying it, it is not necessarily indicative of excess ice.

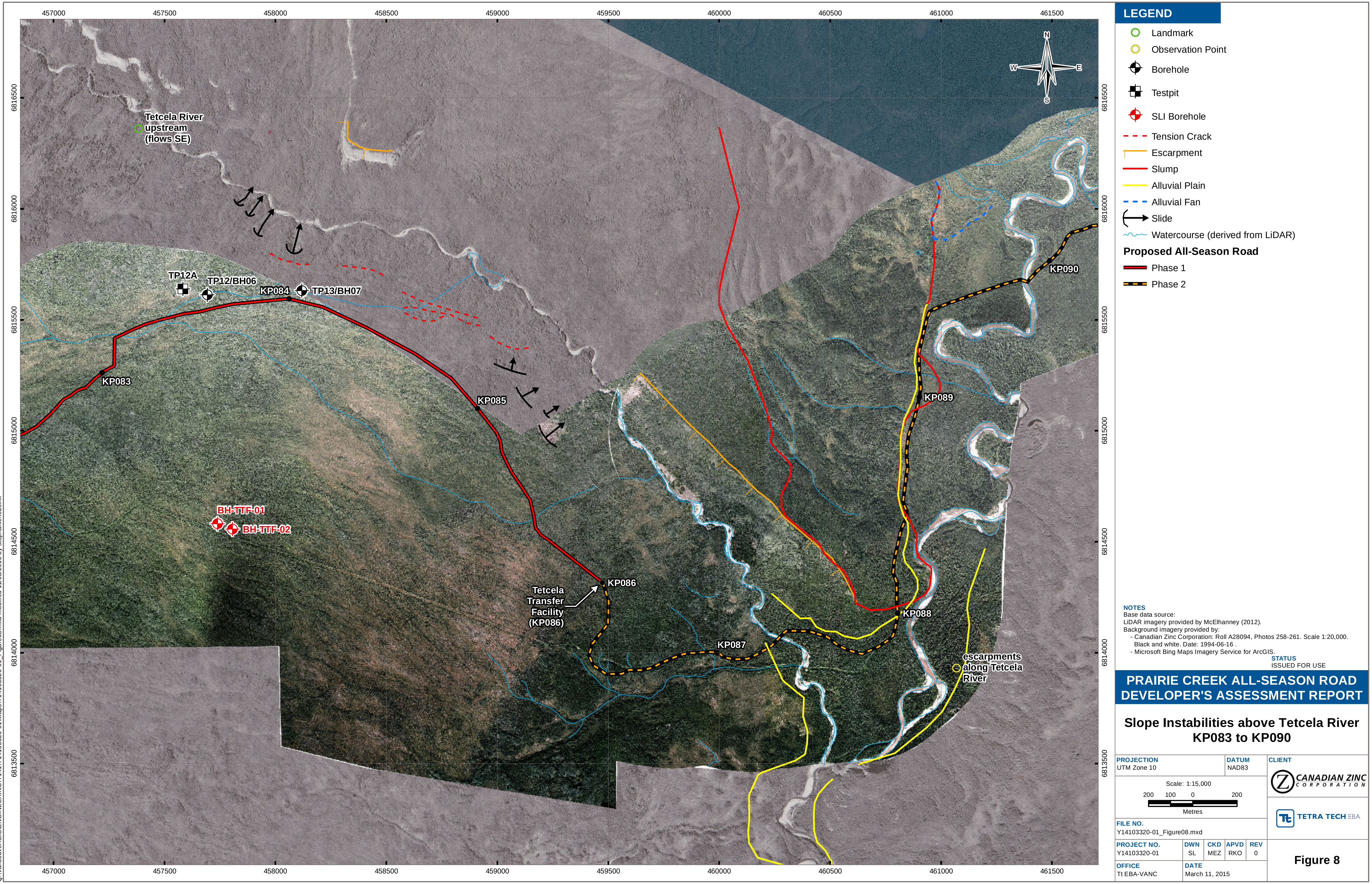
The route is intended to stay well back from areas of potential instability on or just above the Tetcela River tributary slope, including areas with tension cracks, significant seepage, large areas of die-off or fallen trees, or exposed soils or sloughing slope sections. Once the final road alignment has been confirmed, areas that appear potentially problematic will need to be confirmed and avoided where necessary. Care will be required to optimize drainage across the road, as there are a few streams that parallel the road and then cross it to flow down to the Tetcela River tributary.

5.1.8.4 Permafrost

This section of the road descends a gentle east-facing slope, so is not expected to be particularly warm. On the other hand, gradients on the main slope are relatively gentle (4 to 13%), so the shading effect is probably not as dramatic over much of the reroute as it would be on a steeper slope. North of the route, the slope down to the Tetcela River tributary has a north-northeast aspect, and therefore is expected to be cold.

Tetra Tech EBA did not encounter frozen soils. SLI, on the other hand, encountered frozen soils in both of their boreholes, with very cold soils noted near the surface of borehole TTF-01, and frozen soils noted at 1.07 m depth. No other remark noting that the soil was again unfrozen was recorded. However, the soil was again described as firm at 1.15 m below grade and the SPT N blow counts below are not indicative of frozen soils (ranging from 8 at 1.5, to 23 at about 2.2 m, and 22 at about 3 m depth), so this appears to have been a very thin frozen layer. However, it is also possible that the soils were only marginally frozen in this zone and that the act of drilling and sampling was enough to thaw them. More convincing was the record in TTF-02, where frozen soils were recorded at a depth of 1.5 m and unfrozen soils again at 3.5 m. It was late enough in the thaw season at the time of drilling (September 22, 2012), that the top surface of these frozen soils are considered to be probably top of permafrost. Again, SPT N blow counts are not extremely high, ranging from 19 to 34 in the frozen zone, suggesting that the soils were only marginally frozen. Interestingly, near the end of hole, the SPT N blow count was reported as 48, but there is no corresponding remark to suggest why it was significantly higher than the other tests. Water was encountered in both SLI's boreholes, at 1.07 m (top of frozen soil) in TTF-01 and 1.2 m (about 0.3 m above top of frozen soil) in TTF-02 (SLI 2012a).

SLI's field findings suggest that permafrost is likely present on this slope. Where water potentially runs year-round (perhaps in the Tetcela River or its tributary), there is probably a talik or unfrozen zone beneath the stream. SLI's findings suggest that the permafrost may only be about 1.1 to 1.5 m thick or slightly thicker on this slope. However, no peat was recorded at the surface of their boreholes, so it is likely that in areas where peat is present, such as on undisturbed slope sections and away from streams, permafrost may appear at a much shallower depth (possibly less than 1 m, depending on the peat thickness), and that permafrost may extend much deeper. Where permafrost is present, the ground temperature is likely to be only slightly below 0°C, especially in areas where the permafrost is quite thin as was encountered by SLI, because it is likely in the process of slowly thawing.



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NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by:
- Canadian Zinc Corporation: Roll A28094, Photos 258-261. Scale 1:20,000. Black and white. Date: 1994-06-16 .
- Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Slope Instabilities above Tetcela River KP083 to KP090

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:15,000
200 100 0 200
Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_Figure08.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0
OFFICE	DATE			
Tt EBA-VANC	March 11, 2015			

Figure 8

The soils encountered probably have a low to moderate sensitivity to thaw, because these soils have moisture contents that are either at the plastic limit, or above the plastic limit but below the liquid limit. This means that the soils could still creep or possibly fail if they thaw, for example, in the form of a slope failure, but the types of failures occurring would be much more limited than failures that would occur if the soils were ice-rich and hence wetter than the liquid limit.

Fires may affect ground temperature regimes and permafrost in the same way as has been observed at the KP054 thaw slump/flow, because similar soils appear to be present in this section, as well as streams on the slope, and the presence of frozen soils, apparently permafrost. This road section is within the area understood to have been affected by a fire sometime between 1940 and 1950. No recent fire has been noted in this section, but Tetra Tech EBA did observe that the forest in the area traversed on foot appears to be in decay, with many jack-strawed trees across the stream, and considerable old and new deadfall, with old deadfall being moss-covered. If a fire were to occur, it seems likely that there would be plenty of fuel for it.

While no obvious thaw slumps are present on or immediately adjacent to the route, the entire slope above the Tetcela River tributary north of the road appears to be subject to slope movements, which may or may not be related to permafrost thaw (Figure 8).

As noted above, the observed soil moisture contents are not extremely high, but conditions are similar enough to the KP054 area to be cause for concern. One anticipated benefit of keeping the all-season road on a gentle to moderate slope is to reduce the length of the road on slopes that might be more prone to failure upon thawing.

5.1.8.5 Borrow

The silty soils encountered along this section of the route are considered to be highly frost-susceptible, and the clay soils moderately so. Allnorth currently has proposed no borrow sites for this area, except near KP086.4 (sand) and KP086.5 (gravelly sand). If frost-stable fill is required here, it may need to be imported from elsewhere, if the supplies at these two sites are insufficient or prove unsuitable for the desired use. The active layer is likely to be deeper in the granular borrow than in the finer-grained soils upslope along the route. Further study is recommended for these sites as they are sandwiched between streams and are mapped within an area with the potential for slope movements. A buffer zone is advisable between the borrow areas and the road. No sample/test data is currently available for these sites.

5.1.9 KP086 to KP095.7

5.1.9.1 General

The south Tetcela re-route, south of the existing winter route was initially proposed to avoid one stream crossing and keep the route mostly on an upland area (Figures 9 and 10). Leaving the TTF at KP086, the all-season route rejoins the winter route at about KP 86.6. As a result of the September 2014 field work, this section was subsequently divided into two sections by Allnorth: KP 86.6 to 90.6 (staying on the winter route from Tetcela River up to KP 90.6) and about KP 90.6 to 95 (reroute south to toe of uplands area, skirting around the west and south sides of C-Lake and then east to the existing winter alignment). Tetra Tech EBA logged six test holes in this section, including one on the currently proposed route. From west to east, the test holes included TP-14, BH-08, TP-18/BH-09, BH-10, BH-11, and BH-12.

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LEGEND

- Observation Point
- Borehole
- Allnorth Testpit

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Tetcela to Fishtrap Reroute
Tetcela River to C-Lake
KP087 to KP094

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:15,000

200 100 0 200

Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_Figure09.mxd				
PROJECT NO.	**DWN**	**CKD**	**APVD**	**REV**
Y14103320-01	SL	MEZ	RKO	0
OFFICE	**DATE**			
Tt EBA-VANC	March 11, 2015			

Figure 9

5.1.9.2 Geology

Over half of the route between KP086 and KP095 is located on the existing winter road (Figures 8, 9 and 10). One section where the underlying bedrock may be playing a role in slope stability is the section from the crossing of the Tetcela River tributary valley, to the crossing of the Tetcela River main stem, from about KP088 to KP089.4. The bedrock in the section immediately west of the river is mapped as a narrow north-south strip of calcareous siltstone and silty mudstone, possibly partly Mississippian (Douglas and Norris, 1976a). This layer continues east under the Tetcela River in a syncline beneath a formation including shale, mudstone, and limestone, and eventually under the Silent Hills. Upslope to the west, bedrock layers are as described in the previous section. Depth to bedrock is not known in this section, as no test holes are available.

A large old slump in sands and silts is mapped extending a considerable distance upslope of the road, between about KP088 and KP089.4 (Hawes, 1975) and is readily visible on both the 1994 air photos and the 2012 imagery. It is notable that while a scarp is marked on the east side of the valley in this section, no similar scarp appears on the west side, though there are also scarps marked further upstream on the west side. The scarp in this area may have been obscured by soils sloughing over the scarp, materials which are now being traversed by the winter road and/or have been modified by the Tetcela River. This slumped material will be further discussed in the next section.

5.1.9.3 Surficial Materials and Soils

Between KP086 and KP090.6, the all-season route follows the existing winter road, crossing a large Tetcela River tributary at about KP087.4 (Figures 8 and 9). From about KP088.0 to KP089.4, the route skirts the lower edge of a large slump (mentioned in the previous section) and the outside edge of the Tetcela River floodplain, up to the crossing of the Tetcela River main stem. KP088 is just north of a knife-edge ridge along the north crest of the Tetcela River tributary. At the valley bottom, the existing winter road heads north along the Tetcela River, over the toe of the debris from the large slump originating upslope and to the west. The main Tetcela River channel has cut into the toe of the debris east of the road. Sands and silts are anticipated here (Hawes, 1975). The floodplain is generally well-vegetated, and shows some scrolling and the occasional oxbow.

There are no obvious signs of distress along the winter road itself in this section, although there are two short bare sections at KP088.1 and KP088.3 possibly related to short steep rolling grades on essentially disturbed and possibly looser soils due to the slump (likely the same bare patches noted by Mollard in their 1995 report).The slope above appears generally well-vegetated, with some openings or areas with smaller trees and brush along streams and apparent slump scarps. These appear also to be related to areas of possible seepage or local wetter topographic lows. The adjacent stream and stream crossings show considerable movement/deposition of bed material. At about KP088.8 to KP089.2, there is a possible old incursion from the large slump to the west into the Tetcela River floodplain, although there is little change in elevation here, suggesting subsequent modification by the river. A few more recent instabilities are evident, with apparent exposed soil noted on the steep north sideslope of the stream gully at KP089.2, about 300 m upslope. As well, between about KP088.3 and KP088.9, the lower slope of the slump above the road shows numerous narrow fall-line strips that indicate the potential for periodic debris slumps or flows, although there is little evidence of debris on the existing winter road along most of this section (Figure 8). At about KP089.4, the road bends east towards the river, crosses the floodplain, and crosses the river at about KP089.9. There appears to be more than one existing route approaching the east bank of the Tetcela River. The road route threads between these apparent old approaches and what appear to be abandoned channels on the east side of the river. The road leaves the floodplain at about KP090.2.

The all-season route leaves the winter road at about KP090.6, heading upslope and southeast into higher, drier terrain. The route is directed to run primarily along ridges, knolls and hummocks along the periphery of this upland area, skirting around the crests of suspected old slope failures and local steep slope sections. Drainage is to the north and northeast, with crossings of streams or swales generally made near the crests of steeper slope sections.

Terrain is similar to that characterized further south. The route hereby avoids the more significant thermokarst ponds observed within the peatland terrain downslope of the proposed all-season route from KP092.8 on. At about KP093.9, just north of the north end of C-Lake, the route gradually descends and bends to the east around the south end of C-Lake. The route crosses into the alluvial plain and thermokarst terrain at about KP094.2, rejoining the winter road just west of the crossing of Fishtrap Creek and KP095 (Figure 10).

The hummocks and ridges along the upland section are anticipated likely to consist of SAND with silt content varying from trace to some silt to silty, with a trace of gravel, and silts with a trace to some sand. SILT is also likely to be encountered in the lower-lying areas between hummocks, with CLAY encountered at depth. These materials appear till-like, particularly the underlying clays (BH-08, TP-18/BH-09, BH-10, BH-11, and BH-12. The upper soils may be reworked tills, since the upslope area is mapped as sand/silt glaciolacustrine, ridged and hummocky. This deposit may be 2 to 5 m thick.

5.1.9.4 Permafrost

Permafrost and ice-rich soils have not been identified in the road section between KP086.6 and KP090.6, and although permafrost may be present, the winter route seems to have been performing reasonably well in this section. Ground temperatures may be moderated by the presence of the adjacent Tetcela River, and this section may also have some coarser-grained soils. The intent of the KP090.6 to KP095 reroute is to avoid most of the ice-rich and thermokarst-prone areas along the existing winter road to the northeast.

Most of the current reroute between KP090.6 and KP95 follows just above the toe of slope on higher ground, with the intent of accessing better-drained terrain with lower ice contents. No obvious patterned ground has been noted in the reroute, suggesting thermokarst issues should be minor here. The only potential exception noted on the aerial coverage is located in the vicinity of KP094.2 where the route crosses back into thermokarst terrain in order to cross the Fishtrap Creek valley and reach the Silent Hills (Figure 10). The potential of thermokarst terrain in this area seems to be confirmed in the soils encountered at the base of BH-12 at about KP094.4, with 10 to 20% excess ice observed.

However, despite the lack of visual indicators of thermokarst terrain upslope, permafrost may also be encountered along the upslope part of the reroute. Ice crystals (5 to 10% by volume) were noted in frozen peat in TP-14, located on a north-facing aspect east of the Tetcela River tributary, along a Tetcela reroute option considered earlier, well south of the current reroute. Ground temperature measured in the frozen peat in TP-14 was approximately 0°C at 0.6 m depth and, this late in the season, is indicative of permafrost, not just seasonal frost, despite the shallow depth. Soil moisture in the peat was measured at 298%. Because the ground temperature was essentially at the freezing point, this result probably reflects significant unfrozen soil moisture content. Suspected permafrost was also encountered at a depth of 1.2 m in BH-08, also located near the west end of the proposed earlier reroute, but a little higher on a west-facing slope. The base of BH-11 was frozen, with an estimated 10% excess ice in the form of laminations in sandy, silty clay soils.

Relatively well-drained soils on ridges and hummocks may mean that the top of the permafrost, where present, may be at depths of up to about 1.8 to 2.0 m. Permafrost depth in the low-lying areas will likely be consistent with other areas having similar soils and peat coverage, often in the range of about 1.1 m as seen on the uplands south of the route in BH-11 (Figure 9) and, as shown by TP-14, potentially as shallow as 0.6 m depending on peat thickness and slope aspect.

The primary area along the existing and proposed route with soils that are the most thaw-sensitive in the section is the portion between about KP094.2 and KP095, where the route re-enters the thermokarst area. The “inter-mound” soils between ridges and hummocks, however, should also be approached with caution, using embankment fill-only, as the frozen soils at the base of BH-11 were visually identified as having up to 10% excess ice, as noted above. This observation is consistent with the mapping of "low" ice-content soils (Heginbottom, 1995), but still potentially high enough to be problematic if not managed with appropriate construction techniques. Permafrost with similar characteristics may also be present at depth within the ridges and hummocks, but there the buffer thickness is likely to be somewhat greater due to a thicker active layer and better-draining soils.

Ice contents are not known in the borrow areas, nor is it known whether permafrost will be encountered at the proposed borrow sites. The Tetcela River floodplain may or may not have permafrost, depending on proximity to the river and continuity of coarse-grained materials that would allow groundwater to easily reach the proposed borrow area. Upland areas may also have permafrost, but this will depend on thickness of peat, slope aspect, and soil characteristics which will be confirmed for specific sites when borrow requirements are better known. Borrow types consisting of sand or gravel mean that the active layer is likely to be deeper, hence more borrow would be available for extraction and use in one season.

This road section is within the area understood to have been affected by a fire sometime between 1940 and 1950. No recent fire has been identified in this section, and no obvious fire-related evidence of changes in the organic layer were seen in the test holes in this road section.

5.1.9.5 Borrow

Other than the above-noted sands and silts on both the alluvial plain and the glaciolacustrine uplands, alluvial gravels and sands are likely to be encountered at and near the crossings of the Tetcela River. Allnorth proposes borrow sites at the following locations: about KP087.5, just east of the Tetcela River tributary, consisting of alluvial gravel and cobbles, and at about KP090.4 (BP 90), KP091.5 (BP 92), KP093 (BP 93A and 93B), KP093.6 (BP 93C) and KP094.2 (BP 94), all consisting of sand/silt mixtures. Permafrost, including thaw-sensitive permafrost, is more likely to be found at these latter sites than at the river. Other limitations for this material type include the possibility of too-wet material at depth that would need drying to be usable, and use of this material being practical only in summer when it can be properly compacted. These scenarios become more likely with higher silt or clay contents.

5.1.10 KP095.7 to KP101.7

5.1.10.1 General

The road is to be re-routed on the west flank of the Silent Hills, west of Wolverine Pass, and incorporating some switchbacks, where small- to large-sized slope failures were noted by Golder. In 2012, SLI advanced 10 shallow boreholes in this section, designated "Silent Hills Switchbacks" (SLI 2012a). Tetra Tech EBA logged two confirmatory test holes in this section (BH-13 and BH-14; Figure 10). We noted that the pond at the HP99 helipad appears to be a sinkhole, and that another pond and a marshy area nearby may also be sinkholes. Because these features have the potential to affect a road in this area, the route was realigned to avoid them. Various slope instabilities and locations of suspected sinkholes are shown on Figure 11.

5.1.10.2 Geology

Topography and geology in this section are important in terms of karst features. Geology on this west-facing slope is mapped as approximately the eastern half of a large syncline. The two major units that may affect the likelihood of sinkholes are the Clausen formation (shale and thin limestone), and the Flett formation (argillaceous limestone, shale, sandstone and dolomite). Sinkholes have proved to be an important consideration along the proposed all-season road, which needed to be routed to avoid these features (Figure 11). Several sinkholes were successfully avoided with the previously proposed route. As a result of the 2014 work, further realignment of the switchbacks was done. The new route now also avoids the sinkhole identified in the pond at the helipad north of the route (HP99).

The suspected sinkholes at the nearby marshy area to the northwest and the marshy pond to the north are also avoided.

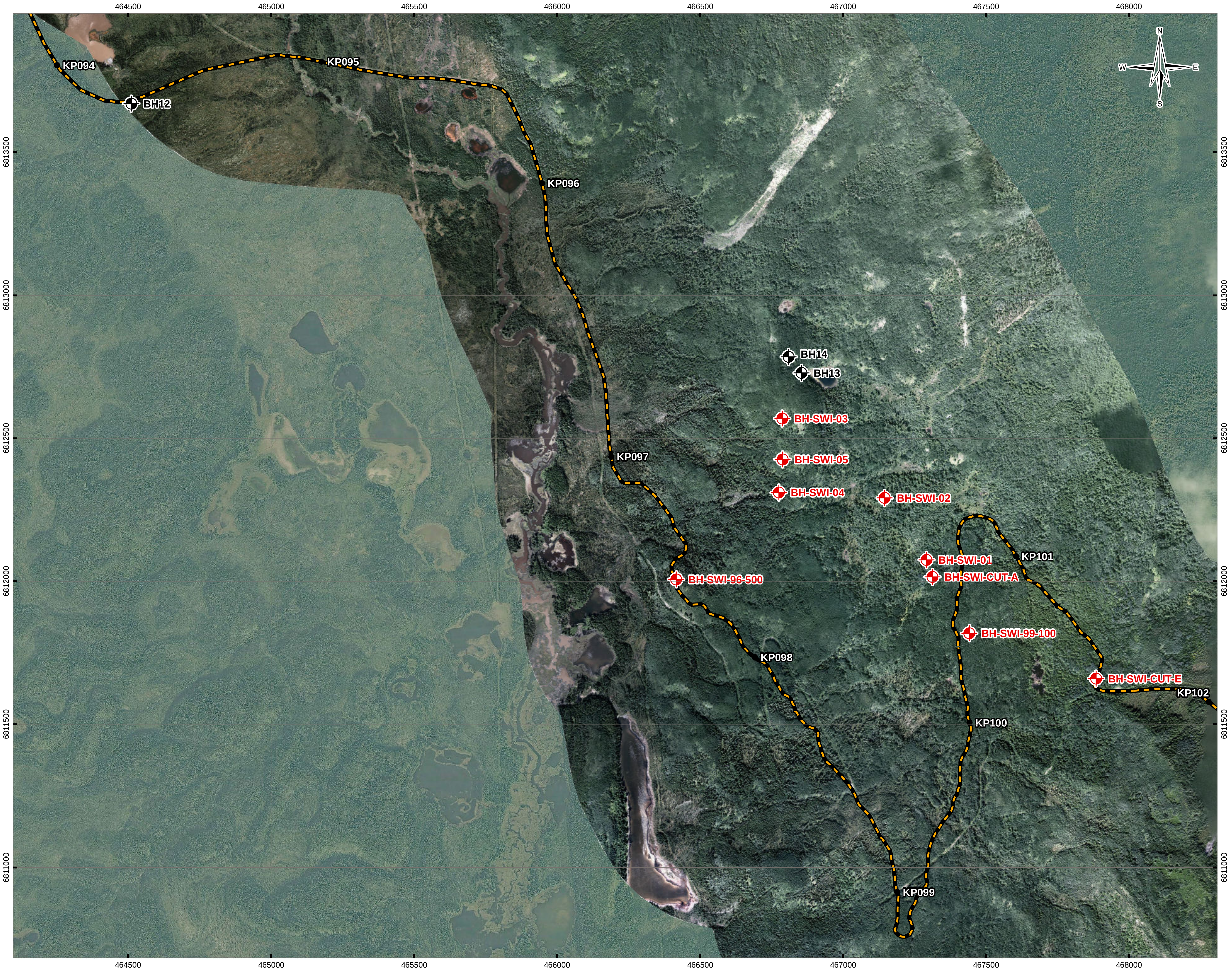
Bedrock also proves to be important in that bedrock outcrops and ridges are generally steeper, and where there is near-surface bedrock, such features tend to be trigger points for sloughing of shallow soils and potentially of weathered rock, which then tend to contribute to debris flows. Numerous features of this type are noted on the slope, most of which are minor, but some of which are significant. All of these features seem to be long-lasting, as all the features seen on the 1994 air photos are still visible on the 2012 imagery, and some new features are noted as well. The proximity of bedrock may also be related to the large numbers of debris flow features on the slope, including a few major ones. To the north of the route, for example, a large debris flow runs diagonally downslope. This is a reactivated feature mapped previously by the Geological Survey of Canada (Hawes, 1975), and mentioned as a recent event in Golder's 2010 report. Similar large features exist south of the route, and also appear to be related to near-surface bedrock at the head of gully features. Within the route, one debris flow gully that crosses the road at KP097.4 also has near-surface bedrock suspected within the starting zones (Figure 11). The upper reaches of this gully have been avoided with the realignment of the switchbacks.

Depth to bedrock is not known. GSC mapping shows the Silent Hills as having shale and limestone bedrock, overlain by a discontinuous residual or colluvial veneer of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels (Hawes, 1975). Fractured shale rocks were also noted within the soil samples recorded by SLI, with borehole depths ranging between 1.0 to 4.8 m (SLI 2012a). The presence of these fractured rocks suggests possible shallow bedrock, but bedrock has thus far not been proved in any test holes. Bedrock outcrops can be expected on ridgelines as evidenced by subparallel linear features seen on the aerial imagery, and it is likely that bedrock is near-surface on the steeper convex slopes. Hollows in the bedrock, or toes of slopes where the gradient flattens have likely become infilled with soils, whether till or colluvium. Since the road route is avoiding the steeper slopes, it is also likely avoiding the shallowest bedrock areas.

5.1.10.3 Surficial Materials and Soils

Peat/organic soils are generally encountered at ground surface in this route section. Tetra Tech EBA encountered fibrous peat with layer thicknesses of up to 0.25 m. In most cases, SLI's boreholes encountered organic soils with thicknesses ranging from less than 0.1 m, up to 0.3 m, but in the case of the BH-SWI-04 series of boreholes located just north of the KP097.4 debris flow gully, a thickness of up to 0.8 m of very loose, silty "topsoil" was noted (SLI 2012a). Despite this great thickness, only cold soils were noted, not frozen ones. Again, this may be a result of warm permafrost thawing upon drilling and thus not being observed, but SPT N blow counts are also quite low (7 to 11). Beneath the peat/organics, Mollard (1995) describes the surficial material as till, and soil descriptions by SLI in 2012 and observations by Tetra Tech EBA in 2014 indeed suggest a till-like material. Soils encountered included various silt and clay mixtures, with varying proportions of sand and gravel, gravel increasing with depth. Gravel sizes of up to 100 mm were noted by Tetra Tech EBA at shallow depths, with a flat and elongated configuration. Thickness of this unit is not known, but likely varies locally. As noted above, the presence of fractured rocks in the soil suggest possible near-surface bedrock, but some of SLI's boreholes noting such rocks were advanced up to 4.8 m deep.

Aside from the above-mentioned soil debris slides and debris flows, which appear to be associated with near-surface bedrock, there are also numerous wet or seeping areas, typically with slope gradients of 20% or less (Figure 11). Occasionally, these appear to be oriented in the same direction as nearby apparent bedrock exposures, so there may be preferential planes, bedding or jointing planes, along which the underlying bedrock has weathered or been eroded or scoured (for example, by glaciers), and subsequently infilled again with till or colluvial soils. Level or gently-sloped areas may then become wet or marshy, particularly if drainage from upslope leads into them. The switchback between KP098 and KP101 does cross a few small streams and some possibly wet areas, but these are considered less risky than sinkholes and multiple debris-flow gully crossings.



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LEGEND

- Borehole
- SLI Borehole

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Fishtrap Creek and Silent Hills Switchbacks KP094 to KP102

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:13,000
200 100 0 200
Metres

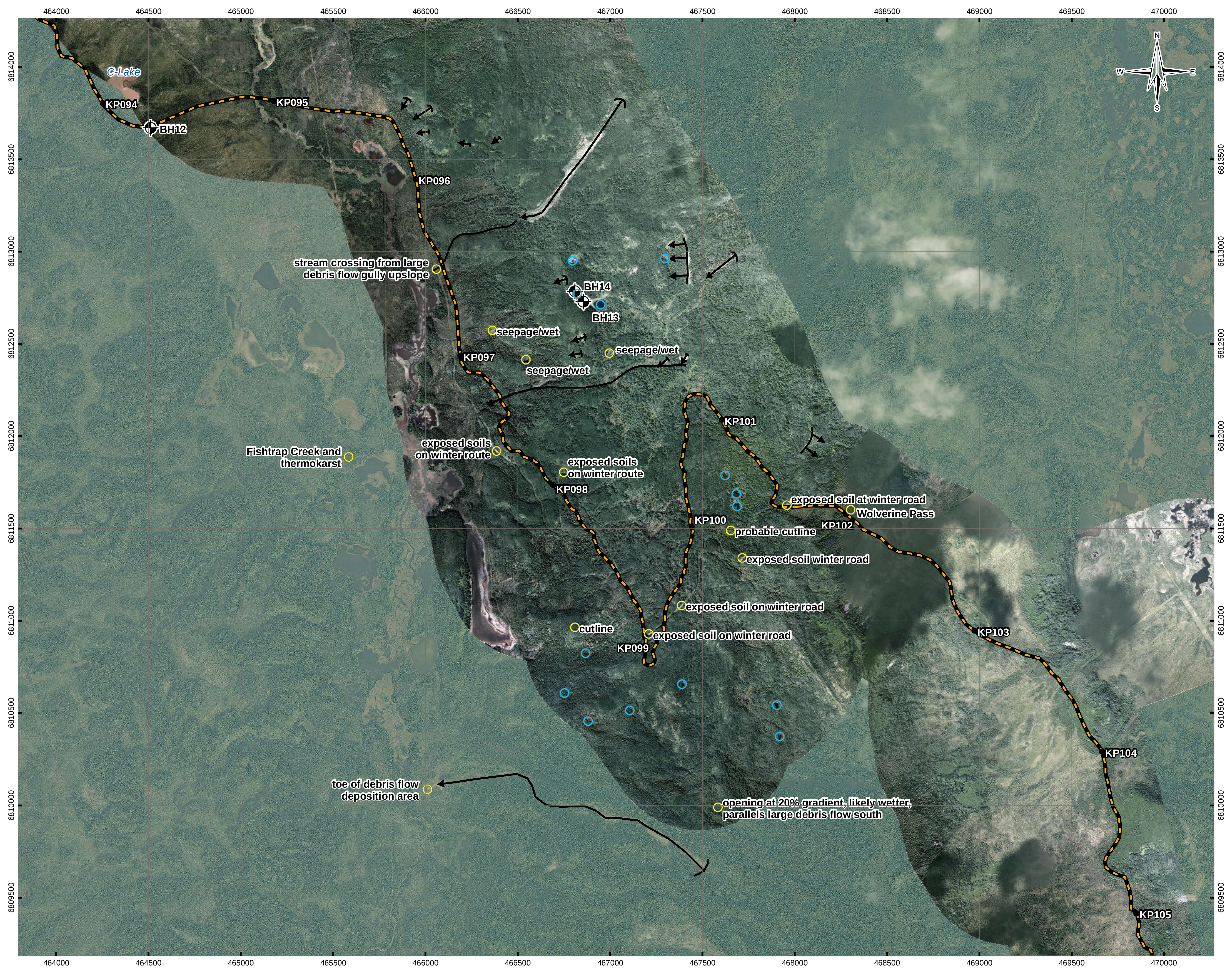
FILE NO.
Y14103320-01_Figure10.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 10



LEGEND

- Observation Point
- Sinkhole
- Borehole
- Slide

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Fishtrap Creek and Silent Hills Switchbacks KP094 to KP105

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_Figure11.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0
OFFICE	DATE			
Tt EBA-VANC	March 11, 2015			

Figure 11

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5.1.10.4 Permafrost

Permafrost may be present in areas with thick peat cover, and in locally low-lying areas. The route generally appears to stay out of low wet areas, while also staying off the steeper ground. The presence of thick peat and fine-grained soils tends to favour the development of permafrost. Therefore, the apparent lack of permafrost in holes advanced so far could be due to the slope's west-facing aspect as mentioned above, or because the route is already avoiding the areas most likely to experience permafrost conditions. If encountered, permafrost temperatures are likely to be just below freezing, and the soils may be slowly thawing.

Active layer thickness (and/or depth of seasonal frost) is expected to range from about 1 m to 2.5 m depending on organic cover, soil types and aspect. Some sections of the route may be shaded at least part of the time by local topographic features such as knolls. Soils encountered to date in this road section appear to have moisture contents at or below the plastic limit, so it is anticipated that they should not be thaw-sensitive.

Thaw slumps have not been specifically noted in this road section.

Ice content and presence/absence of permafrost are not yet determined at the borrow sites. Cold soils were noted in several of SLI's boreholes along the proposed route, but none were identified as encountering frozen soils or permafrost (SLI 2012a). It is noted that these sites are on a slope with a west-facing aspect and as such are likely relatively warm. Permafrost, if present, may be fairly deep, especially in areas with thin organic cover. As well, the drilling method may have obscured the presence of permafrost. If the permafrost is only marginally frozen, the action of the drill or sampler can thaw the soil before the logger is able to observe it.

This road section is within the area understood to have been affected by a fire sometime between 1940 and 1950. No recent fire has been identified in this section, and no obvious fire-related evidence of changes in the organic layer were seen in Tetra Tech EBA's test holes in this road section.

5.1.10.5 Borrow

A few borrow sites are proposed by Allnorth on this section of road, and they have anticipated the types of materials likely to be encountered based on material types encountered nearby and/or photos. These sites are located at KP096 (BP96, likely silty sand), just south of KP097 (BP97, likely silty sand), KP102 (BP102, likely fine sand, based on photo of cutslope by SLI) and east of KP101.7 (BP102B, likely silty sand). These sites have not been investigated by Tetra Tech EBA. Allnorth is understood to have field-checked BP102, which on the air photos appears to have an exposed soil area alongside the winter road, and SLI drilled a borehole in 2012 just west of BP102 which encountered silt with a trace of gravel (BH-SWI-CUT-E, Figure 10). It is noted that the local silt soils are frost-susceptible, however, and the sandy soils can also be frost-susceptible if they have more than 10% silt. Proposed borrow areas should be tested to confirm suitability for their proposed uses.

5.1.11 KP101.7 to KP118.0

5.1.11.1 General

The all-season road is to be relocated west of the old winter road and along the east flank of the Silent Hills so as to avoid much of the ice-rich terrain anticipated by Golder along the valley bottom. Allnorth obtained some soil samples in this section on behalf of Tetra Tech EBA after our departure from site (Allnorth testpits EK-1, EK-2, and EK-3, located as shown on Figure 12). Note that due to recent changes in the route in the KP095.7 to KP101.7 (old KP102) section, some of the station numbering referenced in the following sections may be offset by up to 0.3 km. However, locations are identifiable by landmarks.

5.1.11.2 Geology

Bedrock in this road section is part of the Yohin Syncline. Based on topographic mapping superimposed on the geology mapping, it appears that the ridgeline along the top of the Silent Hills consists of thinly-bedded sandstone of the Yohin formation, which is a relatively resistant layer that results in the outcrops seen upslope at various points along this section of the route. Immediately east of the sandstone and underlying it, are black fissile shale, mudstone and limestone, possibly partly Mississippian. This layer is not evident at ground surface.

Progressing further to the east, and in turn beneath the possibly-Mississippian layer, there is a layer of calcareous siltstone and silty mudstone. This layer is at about the correct distance from the ridgeline such that the knolls seen along the proposed road route are probably the remnants of this relatively more-resistant layer outcropping near the downslope edge of the main slope. Further confirmation of rock types can be anticipated if and when specific knolls are selected for potential borrow areas. Finally, the Fort Simpson formation, consisting of shale and siltstone, is mapped east and beneath these layers.

Limestone appears to be a minor enough component of the anticipated rock types that karst topography is considered unlikely in this section. No obvious sinkholes or other characteristics were noted in the area for which stereo coverage is available (to about KP115, at the edge of the air photos). A small bedrock outcrop is mapped just east of the alignment within the floodplain at about KP117.1 (Figure 12), and is visible on Bing coverage (Hawes, 1975; Bing 2014). The bedrock at this location is likely part of the Fort Simpson formation. A potential borrow source is proposed there (BP 117).

Depths to bedrock are not known in soil-covered areas, but there are numerous bedrock outcrops along this route section.

5.1.11.3 Surficial Materials and Soils

From about KP102.2, the route follows the southerly turnoff of the winter road to KP102.4, where it departs from the winter route, crossing it again three times by about KP103.9, and then heading south while the winter route turns east (Figure 11). The existing winter road tends to skirt along toes of steeper slope sections, and the all-season route is on higher ground. From about KP102.7 to KP103, and KP103 to KP103.3, the proposed all-season route skirts across the toes of two small alluvial fans originating from upslope, first staying a little lower on the slope and then a little higher on the slope compared to the winter route, staying closer to on-contour between KP102.7 and KP103, and thereafter descending and crossing the winter route again to meet the next low ridge. The alluvial fans are mapped as consisting of silt, sand and gravel. They are reasonably well vegetated but there are some areas with little or no trees. Exposed rock near the peak of the ridge suggests activity could resume under the right conditions.

From KP103.3 to KP109.5, the route runs upslope of the knolls. Surficial geology is mapped on the upper slopes and near the knolls as residual or colluvial veneer of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels, and between and/or upslope of the knolls as colluvium (Hawes, 1975). Based on similar mapping along the Front Range (Hawes, 1975) and soil samples obtained there and along the upper proposed route at KP116, till-like soil textures are anticipated on this slope.

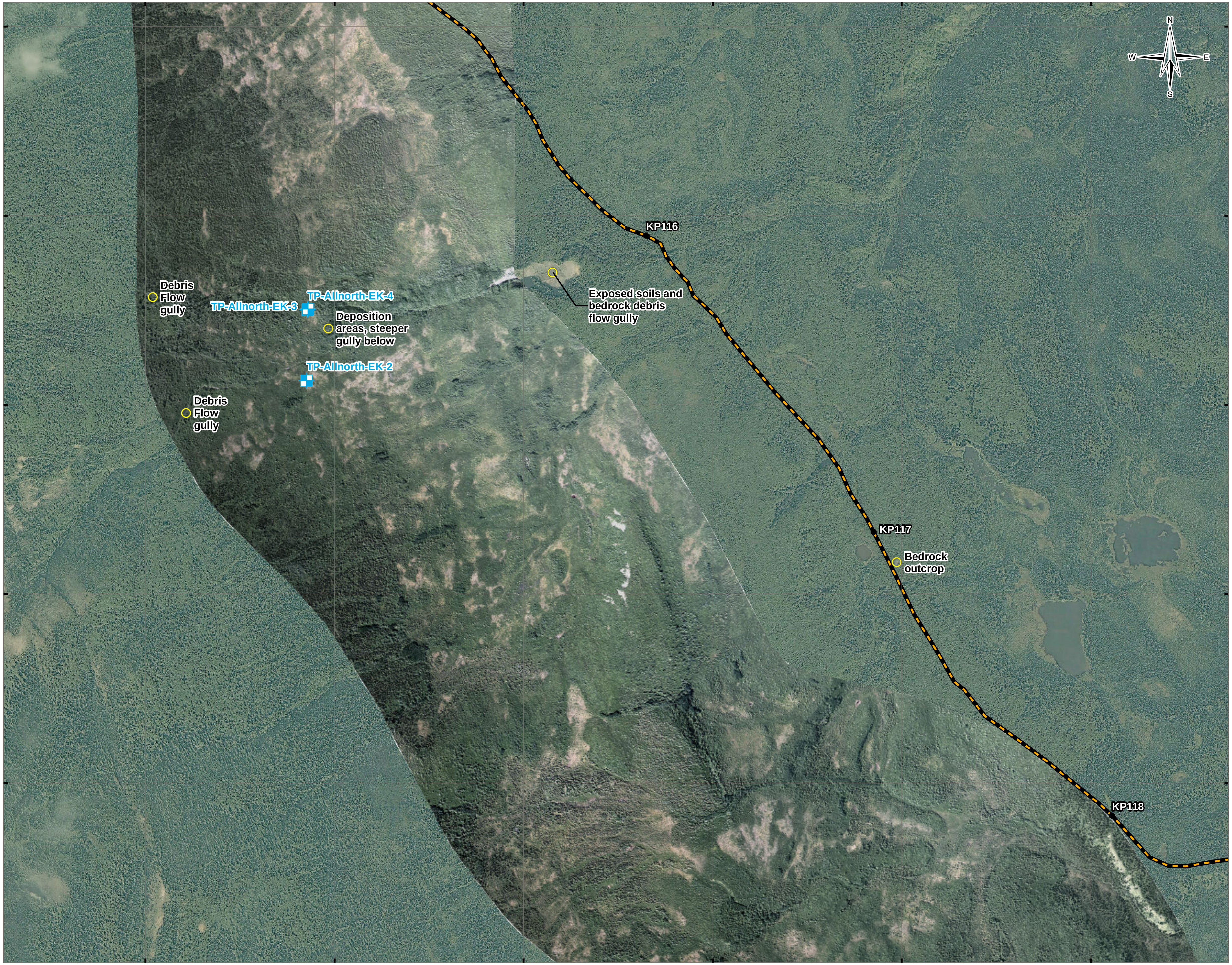
From KP103 to KP105.8, the route stays on the higher ground where possible and skirts the upslope toes of the knolls. Between KP105.8 and KP106.6, the route is just above the toe of the knoll and just below some apparent surface sloughs. Probably these sloughed areas are bedrock-controlled, given the location, and they appear to be relatively small. It is anticipated that some of the hazard will likely be removed when the bedrock is utilized for borrow, reducing the slope height and proximity to the alignment. From KP106.6 and KP107.1, the route minimizes its length in the drainage crossing, which could be related to an old cross-slope meltwater channel starting at

KP105.9 above the knoll and draining south, subsequently modified by downslope flow and possibly slope movements, leading to a gully at KP106.8 (old KP107). Topographic mapping (NTS 1:50,000) shows this gully to have a large bowl-shaped area draining to it from the south and west, which appears to be mapped as colluvium. Vegetation in the bowl is patchy, with areas of little or no trees or brush, and some very occasional small areas that might be exposed soil, mostly along the main channel. The west fork of the stream appears steeply gullied with exposed ground at about 2 km upstream of the road route, which suggests that this stream could experience debris flows at times. This is a case where a feature is not easily avoided. However, the crossing is in a reasonable location away from the steepest ground. The possibility of debris flows will have to be accounted for in the detailed design. Between KP107.1 to KP109.5, the route skirts the upslope toes of knolls and stays above gullied terrain.

From about KP109.5 to KP115, the route runs upslope of the large knolls, and soils mapping continues as described above. Between KP109.5 to KP110, the route skirts the upslope toes of knolls and stays above gullied terrain. From about KP110 to KP110.8, the route skirts around the lower edge of a bowl-shaped area. This area may be an old slope failure scar, from KP110 to KP110.2, but may also be bedrock-controlled, due to a ridge just north and the knoll south. The route continues on the upslope side of the knoll, and upslope of drainage gullies at about KP110.6 and KP110.8. Between KP110.8 and KP112, the alignment avoids a wet area and climbs on and off the north end of a large knoll, crossing an upslope swale at about KP111.8. From KP112 to KP114, the route skirts around the upslope toes of knolls and stays just upslope of gullied terrain. Good control of drainage will be required in this section. Between about KP114 and KP114.5, the route traverses along the crest of a small ridge and then descends to a stream crossing. Near-surface bedrock is suspected on this ridge, as its orientation is sub-parallel with the exposed crest of the knoll at KP113. A slight realignment just west of the ridge-top could be considered to increase the distance from an apparent slough on the downslope side. This can be fine-tuned during final design and layout.

Between KP115 and KP116, the route descends from just above the large knolls down to the glaciofluvial plain, crossing a swale with probable multiple small streams in it at about KP115.5. Soils encountered during terrain-typing upslope of KP116 were identified as silty sandy CLAY with trace gravel. These soils are consistent with the mapping and the expectation of till-like soils. The clay is low plastic, with a plastic limit of 15 and a liquid limit of 27. Soil moisture content varies from 15 to 18 to 26%. It is further noted that the area visited for terrain-typing (Figure 12) is within a suspected local deposition area on two upslope forks of a large debris flow gully. The highest moisture content of 26% suggests that this material could remobilize if additional water is added, due to infiltration from rainfall, for example. Since it is already in a deposition area, this probably means further spreading out of the deposit, but also potentially means that it could continue downstream. Downstream reaches of the gully are also prone to scouring, and effects of debris flows could occur well onto the floodplain. A large area of exposed soil and layers of apparent bedrock is noted along the north slope of the gully, just upslope and west of the proposed road route. This scoured and/or failed slope is up to about 220 m long by 75 m wide (Appendix C, KP115 to KP116). The exposed rock may be composed of calcareous siltstone, which may be why it appears relatively resistant to scouring.

The immediate vicinity of the KP116 stream crossing and further downstream currently appears well-vegetated, but the prevalence of deciduous vegetation in this area suggests these vegetation types are likely indicators of disturbed terrain at this location (Figure 12). Therefore, the road design will need to consider suitable plans for managing a debris flow at some point during its service life, whether it is to build a bridge, or install a crossing over which debris flows can flow without either scouring out the road or having it inundated with debris, install upslope containment measures, or even to install a sacrificial crossing. The most suitable design will depend on the type of event most likely to be experienced at the crossing – scour or deposition – and whether the likelihood of scour or deposition may vary according to the size of event or according to whether successive events change the site configuration, requiring further adaptations in the future. It is noted that ortho-imagery and LiDAR are not available over the full length of the gully, and more detailed topographic data will be needed for detailed design. The route skirts the edge of the glaciofluvial floodplain between KP116 and KP117.5, where the terrain begins to moderate.



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LEGEND

- Observation Point
- Allnorth Testpit

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

East Side of Silent Hills KP116 Debris Flow

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:10,000
200 100 0 200
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_Figure12.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 12

From KP117.5 to about KP118.5, the route crosses the glaciofluvial plain (gravels and sands) between the slopes of the Silent Hills to the west and a large meltwater channel to the east. The ascent/descent on the west approach to the meltwater channel is from about KP117.9 to KP118.5 alongside the stream south of the road.

As noted above, there are debris slides and slumps, as well as debris flow gullies on this slope, but most of these features are either avoided, or crossed in what appears to be the most manageable location, that is neither a main scour area, nor a main deposition area. Where such features are unavoidable, mitigations can be designed on a site-specific basis, and good surface water management will assist in this effort. It is noted that not all slope events can be controlled. For example, debris flows from upslope are entirely natural events, and it may not be possible to prevent all possible impacts from such events on the road route.

5.1.11.4 Permafrost

There are no obvious signs of permafrost patterned ground or thermokarst in this road section; however, there is a small round pond just southwest of KP117 that may be of thermokarst origin. Other nearby ponds to the east in this area seem to be associated with meltwater channels. There is a small opening at KP118 which could be a low wet area, and a small pond just north of KP118.2.

This east-facing slope is likely to be somewhat cooler than the west-facing slope of the Silent Hills. Permafrost is therefore more likely. Locally, low-lying areas would have thinner active layers, with permafrost potentially present at depths of about 1 m in fine-grained soils such as silts and clays, possibly shallower if a thicker peat layer is present, or deeper if there is less peat. In coarser-grained soils, active layers of 2 to 3 m could be anticipated, more if there is little or no organic cover. The active layer in bedrock is likely to be much thicker due to higher conductivity, but in most cases, it is less important whether the bedrock is frozen or not. Ground temperatures in permafrost are likely to be slightly below freezing.

There is no obvious evidence suggesting the presence of ice-rich soils in this section of the proposed road. Thaw slumps do not appear to be present in this road section.

Given the anticipated bedrock types, there is potentially more weathering and thus potentially higher ice content. For the currently-proposed bedrock borrow sources, however, most of these sources are elevated above the surrounding terrain, so would be less likely to contain excess ice. At BP 103, however, the characteristics of the clay till material anticipated by Allnorth are not known. If thaw-sensitive permafrost is present here, this will affect the usability of this source.

The north end of this road section, up to about KP110, is within the area understood to have been affected by a fire sometime between 1940 and 1950. No recent fire has been identified in this section.

5.1.11.5 Borrow

Generally, Allnorth is proposing that the knolls downslope of the route be used for borrow. These sites are anticipated to consist mainly of bedrock, but may have some useable surficial deposits as well. Several proposed sites are located at about KP102 (BP 102), KP102.2 (BP 102B), KP103.7 (BP 103), KP104 (BP 104), KP106.6 (BP 107), KP111.7 (BP 111), KP116 (BP 116), and (BP 117).

It is noted that BP 103 was observed by Allnorth to consist of potential clay till material overlying probable carbonate rock. Aside from the potential for thaw-sensitive permafrost within the clay, other limitations for this borrow source include the possibility of too-wet material that would need drying to be usable, and use of this material being practical only in summer when it can be properly compacted. Since the priority at BP 103 is the underlying carbonate rock source, overburden material that is not suitable for fill will be stockpiled for re-use in reclamation.

A borrow area is proposed between the road and the scoured slope along the debris flow gully at KP116 (BP 116), but this site will have to be further investigated to confirm whether suitable borrow materials are present, and whether they can be excavated without increasing the risk to the road from future debris flows.

5.1.12 KP118 to KP159.4

5.1.12.1 General

This road section extends from west of Grainger Gap, east through the Gap (Figure 13), then south to the Liard River (Figures 14, 15, and 16), so as to meet the old Nahanni Logging Road east of the Liard River. Tetra Tech EBA logged 14 test holes along this section (TP-04, TP-05, and TP-15 as shown on Figure 13; TP-16, TP-17, TP-25, BH-15, and BH-16 as shown on Figure 14, TP-22, TP-23, and TP-24 as shown on Figure 15; and TP-19, TP-20, and TP-21 as shown on Figure 16). Note that due to recent changes in the route, some of the station numbering in the following sections may be offset by up to 0.4 km; however, locations are identifiable by landmarks.

5.1.12.2 Geology

Bedrock exposed at Grainger Gap from west to east consists of the Nahanni formation, the Landry formation, and the Arnica formation. The Nahanni formation consists of limestone, grey, finely crystalline to bioclastic, thickly bedded; and dolomite, finely crystalline. The Landry formation consists of limestone, grey, finely crystalline, thickly bedded. The Arnica formation consists of dolomite, finely crystalline, partly finely porous and vuggy (coarse pores lined with crystals of other minerals), banded dark and medium grey weathering; brecciated in part (Douglas and Norris, 1976a). Colluvium above the route at about KP123 may be due in part to steeply-dipping bedding planes in the Nahanni formation above the route at this location.

On the east side of the Nahanni Range, and east of Grainger Gap, there is a thrust (reverse) fault running roughly north-south, with the above-described carbonate strata thrusting over the shale and siltstone to the east (Douglas and Norris, 1976a). This thrust fault conceivably contributes to periodic toppling failures of the carbonate strata located upslope to the west of the road alignment, although such failures may also have other contributing factors including erosion by water and loosening of talus blocks due to frost-shattering. On occasion, such failures can also result in debris flows, with the most likely contributing factor being seepage from groundwater recharge along the ridge entering open joints and bedding planes. Seepage could also contribute to additional ice building up in debris deposits, leading to the deposit slowly creeping downslope. One example of this type of failure includes the rock glacier at about KP126.4, where new material falling at the top tends to push the earlier debris further downslope. Groundwater seepage has likely frozen in the debris, allowing creep of the ice in the interstices of some potentially very coarse-grained materials, based on the sizes of talus blocks seen at various locations on the slope (some blocks of up to 1.5 m by 2 m by 5 m were noted). More such features are present heading south along the Front Range. While much of the carbonate strata seem to be exposed, most of the shale strata seem to be obscured by surficial sediments.

The bedrock strata become more complex further south along the route. Just north of Bluefish Lake, upslope of about KP144.5, for example, another north-south thrust fault begins. Here, the Landry formation becomes the Manetoe formation, which is its approximate equivalent, being formed of dolomite that is coarsely crystalline, vuggy, and massive. The double thrust along with various anticlines and synclines have resulted in multiple exposures of the same rock types, continuing south for about 10 km with the thrust faults eventually meeting upslope of about KP153. Here, a new thrust fault begins to the west, resulting in another double set of rock exposures, as well as a new exposure of the Horn River formation between the two sets of exposures, forming Nahanni Butte (mountain). The exposed L-shaped bluff above the route between about KP157 and the Liard River is another source of debris falling on the slopes below, with faulting resulting in a rotational slide (and potentially also toppling along this steep bluff), and subsequent debris flows downslope (Hawes, 1975; Douglas and Norris, 1976a). Again, seepage from groundwater recharge originating upslope probably drives the debris flow process.

Such rockfall or rotational rock slides, and the accompanying debris flows are natural features, and will occur whether or not the road exists.

Except where exposed as outcrops, depth to bedrock is not known along the route, as none of the test holes were deep enough to penetrate to it.

5.1.12.3 Surficial Materials and Soils

Between KP118 and KP122.9, the all-season route traverses a wide glaciofluvial plain (gravel, sand) and skirts below the toe of a large alluvial fan to the southeast (Hawes, 1975). Significant ridged features are not obvious, but the route crosses relatively high ground compared to the terrain northwest and southeast, avoiding bogs. There is one significant stream crossing at about KP122.4, which appears to originate from the boggy area upslope, above which is a large alluvial fan (Figure 13).

Between KP122.9 and KP123.3, there is a small elongated lake to the west, whose outlet drains east. This area drains a larger lake (Gap Lake) located to the northwest of Grainger Gap. The outlet stream has three beaver dams south of a large alluvial fan originating from the north (current winter road route and north of the all-season route), located between about KP122.85 to KP123.3, and these dams tend to cause flooding in the local drainage to the west. The all-season road will not be affected by the beaver dams as it will be well upslope to the south. The currently-proposed stream crossing is about 50 m downstream east of the eastern-most beaver dam and adjacent to a large rock bluff. Allnorth proposes a full bench cut in rock. The affected slope is densely treed with small trees, most of which are less than 5 cm in diameter and generally less than 10 to 15 cm in diameter. Tetra Tech EBA logged two test holes on this slope, with peat varying from 50 to 300 mm in thickness, and mineral soils varying from silty gravelly SAND to SILT with a trace to some gravel and a trace of sand. At the east end of the bluff, a steep bedrock outcrop was noted. The streambed is formed of cobbles, whereas the floodplain is silt, sand, and gravel and is overgrown with willow where vegetated. The winter route meets/separates from the all-season route at about KP122.5 at the west end. The all-season route crosses apparent colluvial terrain from upslope south between about KP122.9 and KP123.2. This area is a series of old failures, probably post-glacial. From about KP123.2 to KP123.3, the terrain may also be colluvial but there appears to be shallow bedrock control at the edge of the feature (Figure 13). Due to the bedrock control, the road appears to be ideally situated in this section.

The all-season road turns south at KP124.8, leaving Grainger Gap (Figure 14). The overall intent of the all-season road is to stay above the low wet ground along the Grainger River, as well as to obtain a more direct route to the Nahanni Butte Access Road. The route will more closely follow the winter route for about 2 km south of Grainger Gap, to about KP126.4 on the Grainger River floodplain, then climbing gradually south and away from the winter route, out of the floodplain. The floodplain is mapped as a gravel alluvial plain, with materials consistent with those seen upstream in the meltwater channel forming the Grainger Gap. For a few kilometres south of KP126.4, the winter road roughly parallels the all-season route, as further described below.

Soils upslope and west of the Grainger River floodplain are mapped as a discontinuous residual or colluvial veneer of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels (Hawes, 1975). SAND with some gravel, to gravelly, was encountered at TP-15, in a slope failure at the toe of slope just west of about KP124.8. Layers or lenses of silty sand and cobbles/boulders were also noted. Talus and scree were noted further south along the toe of slope. Ravelling is expected from upslope, especially between about KP125.2 and KP125.6. There is potential also for larger rocks tumbling or toppling from the bedrock exposed above the scree/talus slope. Periodic debris flows are anticipated on the alluvial fan at KP125.6 to KP126.

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LEGEND

- Observation Point
- Testpit
- Peatland Permafrost
- Slide

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Grainger Gap
KP121.5 to KP125.5

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:10,000
100 50 0 100
Metres

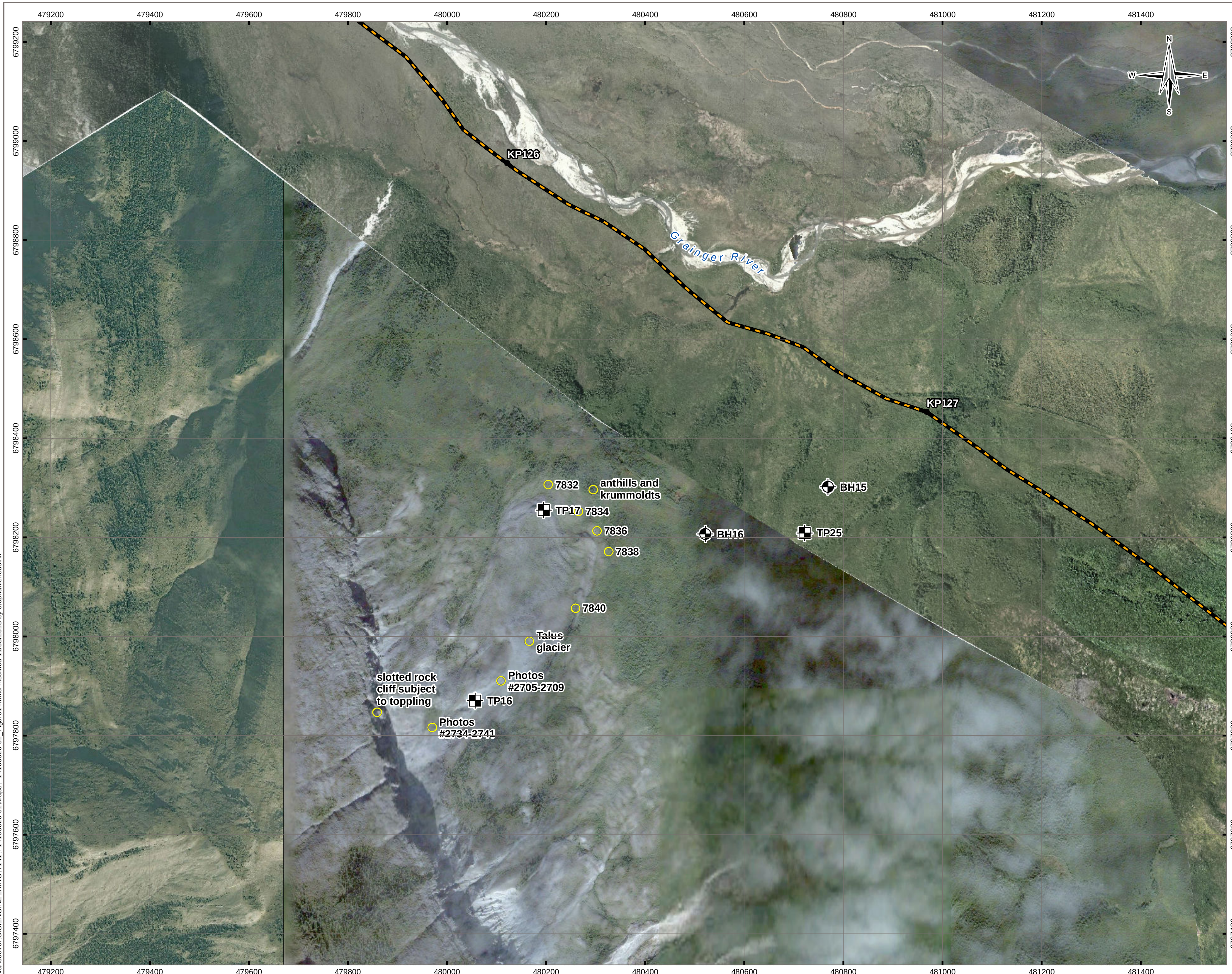
TETRA TECH EBA

FILE NO.
Y14103320-01_Figure13.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 13



LEGEND

- Observation Point
- Borehole
- Testpit

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Google; DigitalGlobe (2007);
Microsoft Bing Maps Imagery Service for ArcGIS.

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Proposed Borrow on Talus Glacier Near KP126.4 and Terrain Units to KP127

PROJECTION		DATUM		CLIENT
UTM Zone 10		NAD83		CANADIAN ZINC CORPORATION

Scale: 1:7,500
100 50 0 100
Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_Figure14.mxd				
PROJECT NO.	**DWN**	**CKD**	**APVD**	**REV**
Y14103320-01	SL	MEZ	RKO	0
OFFICE	**DATE**			
Tt EBA-VANC	March 11, 2015			

Figure 14

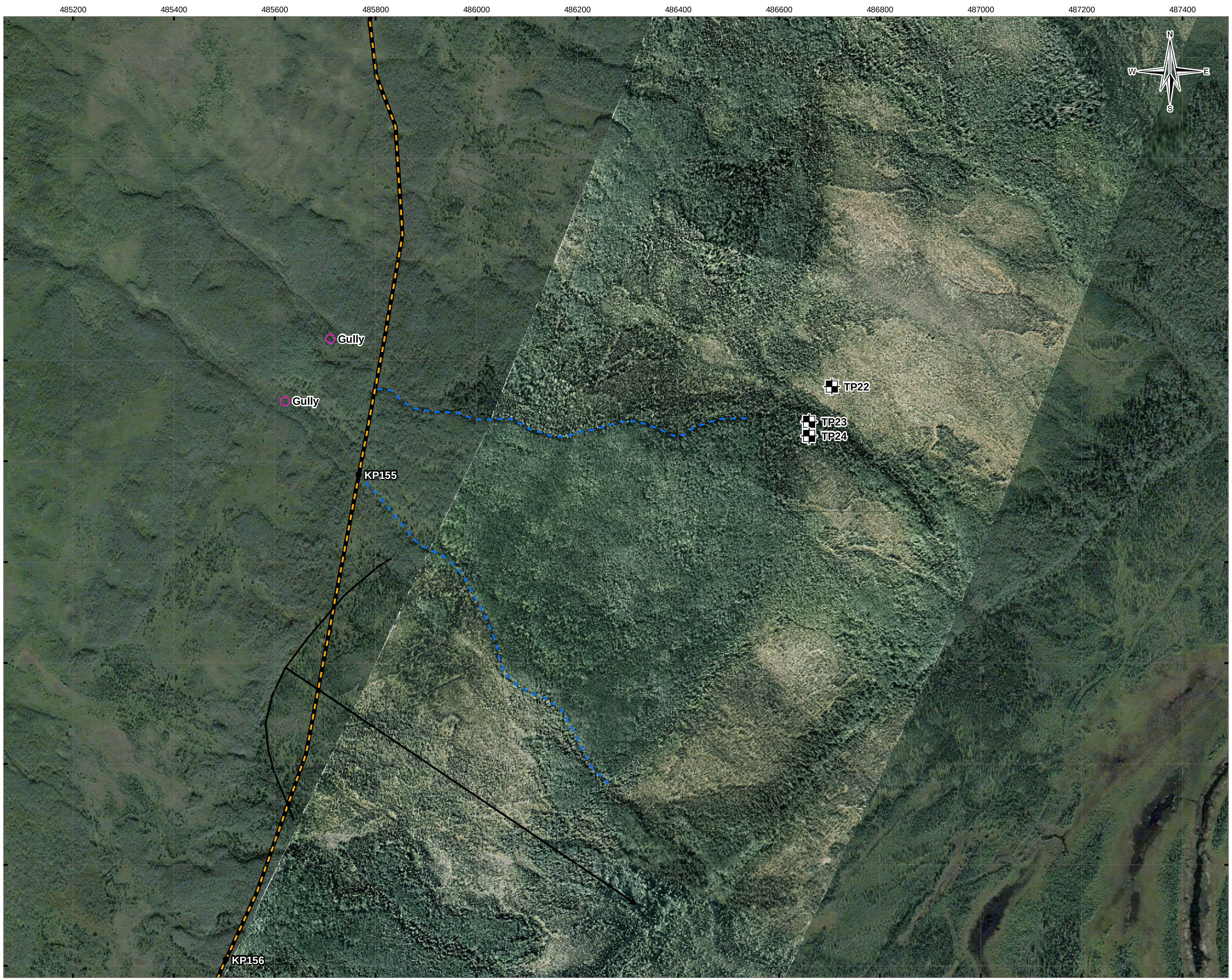
For these reasons, it appears that the route of the winter road would be more favourable between about KP124.8 and KP126.4, in order to avoid what are likely to be ongoing upslope hazards. Allnorth has therefore made some alterations to the route in this area to avoid some problematic terrain features, both upslope and downslope, but is considering the area along the toe of slope as possible locations for granular borrow and/or a quarry (telephone correspondence, January 20 and 22, 2015; E.Kragt, R.Kors-Olthof). Since these slopes are already ravelling, extraction of borrow might mean additional ravelling or outright slope failures in talus/scree, as well as failures in bedrock. If the sources are proposed for use, detailed plans would be needed to extract materials safely.

Near-surface soils encountered during terrain-typing upslope of the route between about KP126 and KP126.8 (Figure 14) include SANDs in ridges (TP-25), silty sand CLAYs or clayey sandy SILTs with some gravel in lower-lying areas, and increasing gravel with depth; till-like (BH-15, BH-16). These soils appear to be generally consistent with the above-mentioned mapping, though finer-grained near the ground surface. Granular debris was encountered further upslope, varying from crush-like GRAVEL near the upslope end of the rock glacier at TP-16 and BLOCKS and BOULDERS in a talus mound within the rock glacier at TP-17. The rock glacier is about 200 m wide and 700 m long, with the toe about 380 m upslope of the proposed route and the TP-17 area about 550 m above the route.

After crossing a tributary of the Grainger River at about KP126.6, the route gradually climbs out of the floodplain into till moraine terrain with flutings and drumlins, crossing another tributary at about KP127.1. The route remains in till terrain to about KP128.3, skirting along the downslope side of a long ridge, just below the transition between near-surface bedrock and residual/colluvial soils upslope and the till terrain downslope, then traverses across a swale on the upslope side of the ridge. Due to the variable terrain, good control of surface water drainage will be important in this section; however, the road generally avoids low wet terrain in this traverse.

From about KP128.3 to about KP140.0, the alignment generally skirts along and across the transition between terrain units mapped as near-surface dolomite or limestone bedrock (as described in the previous section) with residual or colluvial veneers or rubble of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels upslope, and thicker tills downslope. The tills generally vary from drumlinized and fluted, to subdued rolling moraine with hummocks and ridges. Gravel is common in the upslope tills. The route skirts along the toes of alluvial fans and cones, as well as rock slumps or rock glaciers similar to the above-mentioned KP126.5 rock glacier (Hawes 1975). Mollard (1984) also mapped some low flat-topped ridges between about KP131 and KP134.5 that may be till and/or granular materials, and some possible slumped kame terraces between about KP134.5 and KP141.

The all-season route was re-aligned to avoid two possible slope failures about 100 m upslope of the road at KP129.6 to KP129.8 and KP129.8 to KP130.0). Possible exposed soil along a stream about 550 m upstream of KP136.5 indicates the potential for debris flows. However, slope gradients are less than 7% above the road to the suspect area, and the stream channel otherwise looks well-vegetated, so such events probably do not reach the road elevation very often. Exposed ground (soil or rock) along upstream reaches of the channel above KP137.2 is probably more indicative of near-surface bedrock there, but could result in debris flows. Slope gradient is about 10% for 200 m above the road. Debris flows at KP136.5 and KP137.2 can affect the road by either scouring or deposition, depending on the mobility of the material. Aerial coverage indicates old slope movements ended below the road (Google Earth 2007). Debris flow channels may also shift from current locations. The route skirts along/over the toe of possible rubble in a talus lobe at KP137.2 to KP138, mapped by Hawes (1975). This site may overlap with Mollard’s (1984) mapping of a slumped kame terrace. If this material is ice-rich, then the road should be constructed with embankment fill only, but if it is not ice-rich, it may be a useful source of borrow material. A possible debris flow lobe is seen at about KP138.1.



LEGEND

- Gully
- Testpit
- Alluvial Fan
- Slide

Proposed All-Season Road

- Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Google; DigitalGlobe (2007).

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Terrain Units and Slope Features Near KP155

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:7,500
100 50 0 100
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_Figure15.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 15

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Between about KP140 and KP144.5, the route traverses a moraine plain with drumlins to the outlet of Triangle Lake, and then a moraine plain with flutings to KP146.8. The road route follows the east side of a small meltwater channel between the south end outlet of a small lake north of Triangle Lake at KP142.3 and the north end of Triangle Lake at KP143.4. A smaller meltwater channel with a pond upslope of the road joins the channel at the south end of the small lake. Allnorth's sampling at the road crossing over the channel indicates sandy gravel soils, but the drainage appears poorly defined. The route generally stays out of the meltwater channels except for the crossing area. A drumlinoid ridge or fluting is mapped sub-parallel and southeast of the small lake between about KP142 and KP143, and east of the alignment. The contours suggest that there may be some water drainage towards the road between ridges or flutings. Drainage locations and directions will be confirmed during detailed design and layout in this area.

From about KP146.8 to KP150, the route crosses a till moraine plain. At KP146.9, the road crosses a stream draining east from a wetland to the west.

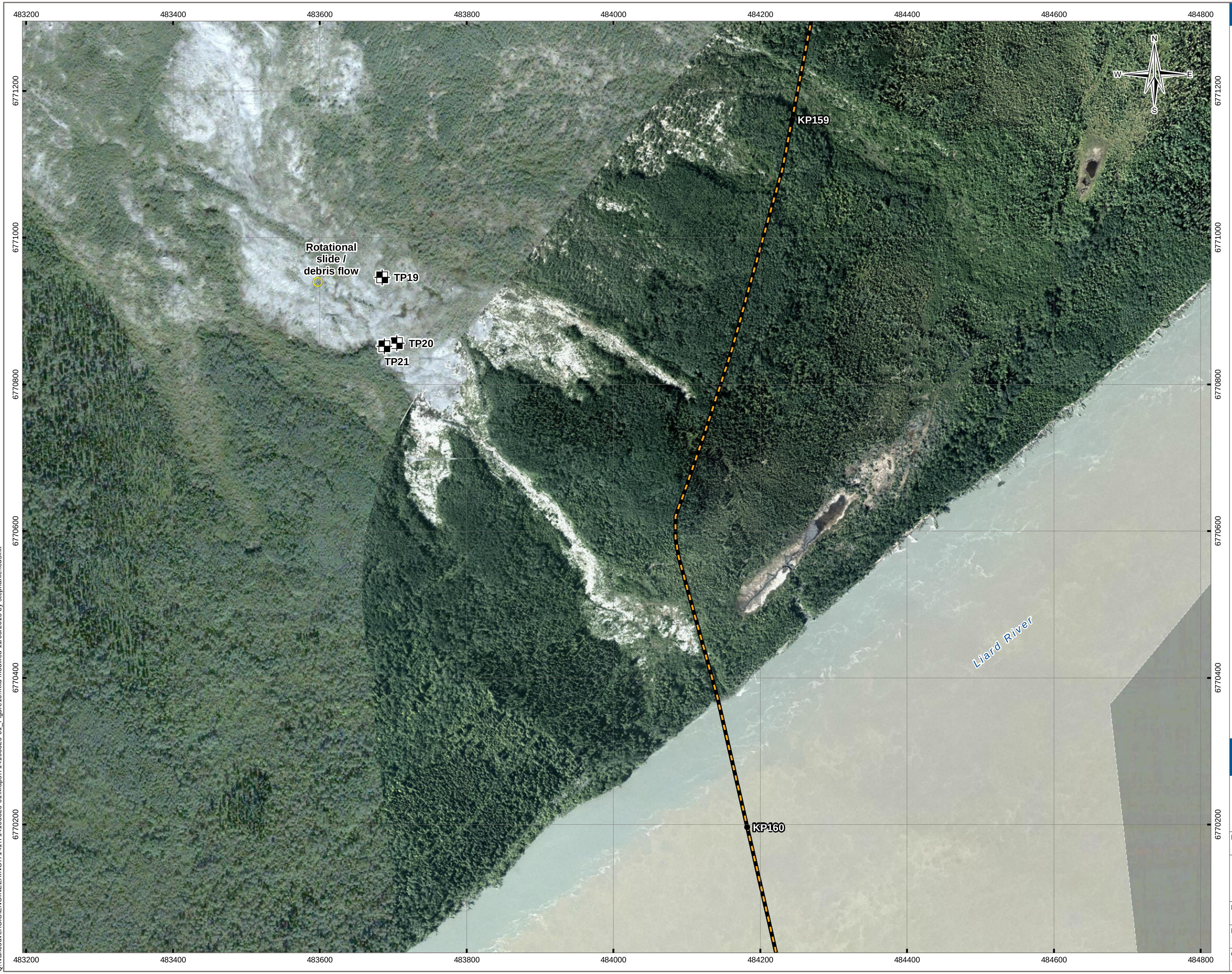
From about KP150 to KP159.5, the route is primarily within till moraine veneer of less than 1.5 m in thickness, with 16 to 49% of the terrain mapped as colluvial complex of 1 to 6 m in thickness. Colluvium can be derived from all types of surficial deposits (Hawes 1975). Between about KP151 and KP154, the route runs approximately parallel to, and 300-400 m downslope of, a mapped linear escarpment. The transition between till veneer and colluvium upslope and till moraine plain downslope is not certain here (Hawes 1975). The linear escarpment is clearly visible on Google Earth 2007 imagery. The proposed road crosses near the apexes of alluvial fans at KP151.6 and KP152.6, the former of which is proposed as borrow. The presence of these fans indicates the likelihood of future debris flows. Crossing at the apexes is good for limiting the length of road potentially subjected to impact by debris, but does include a possibility of the road being scoured out at these crossings.

A suspected old alluvial fan is present below about KP155, with two gullies crossed near the apex at this location (Figure 15). There is a possible old slope failure from about KP155.2 to KP155.7 where the road route crosses below and then above the suspected headscarp. Indications of a fairly recent debris-flow crossing the road alignment occurs at KP158.9 to KP159.0 (Figure 16).

A rotational slide / debris flow is mapped above the road alignment near the Liard River, originating from Nahanni Butte at the southeast peak, flowing down in a three-pronged fork almost to the road alignment and alongside it (Figure 16; Aylsworth and Traynor 2001). The northeast prong ends about 25 m above the road alignment according to 2007 Google Earth coverage, and its extent appears to be similar on the 2012 imagery. The toe of the prong is presumably a deposition area, but future flows could overrun the road or plug culverts, resulting in maintenance and/or safety issues. The middle fork has a stream mapped in it on the LiDAR. Repeated slide / debris flow events have potential to reach the road and/or the Liard River. The 2012 imagery suggests recent events have come within 50 m of the river, and a less recent event (revegetated) has reached the river. The route skirts the left (northeast) flank of the debris toe for about 150 m, climbing out of the valley bottom. The road is likely to be a deposition area or it may be subject to scour from debris flows.

5.1.12.4 Permafrost

The north- and east-facing slopes and/or shaded areas along this route section are likely to be somewhat cooler than west-facing slopes at the same elevation, similar to the east-facing slope of the Silent Hills. Permafrost is therefore more likely than on west-facing slopes, particularly at the higher elevations, since the road climbs up from the Grainger River at 480 m to a high point above about 640 to 670 m between about KP132 to KP138 before it descends again to the Liard River at about 180 m.



LEGEND

Observation Point

Testpit

Proposed All-Season Road

Phase 2

NOTES
Base data source:
LiDAR imagery provided by McElhanney (2012).
Background imagery provided by Google; DigitalGlobe (2007).

STATUS
ISSUED FOR USE

PRAIRIE CREEK ALL-SEASON ROAD DEVELOPER'S ASSESSMENT REPORT

Proposed Borrow Upsplope of KP159.4

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:5,000

100 50 0 100

Metres

FILE NO.
Y14103320-01_Figure16.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01	SL	MEZ	RKO	0

OFFICE	DATE
Tt EBA-VANC	March 11, 2015

Figure 16

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The lower the elevation, the greater the depth of the active layer. Locally, peat-covered low-lying areas would have thinner active layers, with permafrost potentially present at depths of about 1 m in fine-grained soils such as silts and clays, possibly shallower if a thicker peat layer is present, or deeper if there is less peat. In coarser-grained soils, active layers of 2 to 3 m could be anticipated, more if there is little or no organic cover. The active layer in bedrock is likely to be much thicker due to higher conductivity, but in most cases, it is less important whether the bedrock is frozen or not. Ground temperatures in permafrost are likely to be slightly below freezing.As the road descends toward the Liard River, the proportion of terrain underlain by permafrost is likely to decrease, and this is apparent in the decrease of permafrost-related features, particularly in about the last 10 km north of the river.

About 60 m south of the proposed road, and south of HP123, the KP122.4 stream becomes wider for about 200 m. This area could potentially be thermokarst (Figure 13). The upslope bog area is identified as peatland (potentially ice-rich permafrost) between KP122 and KP123 southeast of the proposed alignment. The alignment avoids this sensitive organic terrain.

There is also a cross-slope drainage feature between the alluvial fan and the bog that looks like a possible small meltwater channel. A narrow untreed area about 50 m long is noted just north of the alignment at about KP122.5. Contours suggest a local low area that could be a pond or possibly thermokarst that drains to the stream just west at KP122.4. The areas in question can be checked during layout and detailed design. Otherwise, there is no obvious patterned ground or thermokarst in the road section between KP121.5 and KP123.3.

From about KP125.5 to KP126.7, a series of small beaded streams are seen between the toe of slope and the Grainger River. The currently-proposed all-season route approximately follows the existing south branch of the winter road and avoids the streams (Figure 14). These beaded streams are indicative of thermokarst and hence ice-rich permafrost ground. Otherwise, no obvious thermokarst or patterned ground is noted.

There is possible thermokarst at and near the lake outlet from about KP141.9 to KP142.3 in beaded channels parallel to the lake shore and longitudinally along the outlet, about 80 to 160 m east of the road. However, these features may in this case merely be due to wetlands filling in a shallow lake. The route appears to avoid this terrain. A beaver dam is noted about 260 m west of the road at about KP143.5, at the south end of a pond within the meltwater channel north of Triangle Lake. Potentially, flooding from beaver activity can affect permafrost integrity if frozen areas are inundated with water.

No obvious evidence of forest fires was noted in the field, except upslope of KP127, where 40% of the terrain burned in 1994 (RES 1994). Based on the fire and vegetation mapping in this area, the area of the forest fire extended as far south as about KP130.5.

Recent thaw slumps do not appear to be present in this road section; however, there are some debris slides and slumps, as well as debris flow gullies on this slope. Where such features are unavoidable, mitigations can be designed on a site-specific basis, and good surface water management will assist in this effort. It is noted that not all slope events can be controlled. For example, debris flows from upslope are entirely natural events, and it may not be possible to prevent all possible impacts from such events on the road route.

Tetra Tech EBA's test holes at the proposed borrow site above KP159.4 did not encounter frozen soils, so it is not known whether or not permafrost may be encountered at depth. Important considerations will include whether or not materials can be extracted without affecting the adjacent road sections and downslope terrain.

5.1.12.5 Borrow

An alluvial fan deposit at KP151.6 and debris slide/flow deposits upslope of KP158, KP159, and KP159.7 are proposed as borrow sources. Current field work results are inconclusive, as deeper test holes are needed to assess the quality of the materials and feasibility of development. Only shallow test holes have been advanced so far in the apparent deposition area upslope of the road at KP159.4.

5.1.13 KP160 to KP174.1

5.1.13.1 General

From the south side of the Liard River crossing at KP160, the route follows the old Nahanni logging road to KP174.1 where it meets the Nahanni Butte Access Road. The logging road parallels the east/south side of the Liard River for most of this section.

5.1.13.2 Surficial Materials and Soils

Prominent scrolling is noted on the Liard River floodplain in this road section. Occasional areas of fenland are present in narrow scrolled strips from about KP167.6 to KP169.2. Fenland is present on the north side of Bay Creek between KP169.2 and KP170.3. The creek itself, between KP170.3 and KP174.1 also modifies the terrain with its meanders and oxbows.

Soil types encountered along the Nahanni logging road are likely to be similar to those in the community of Nahanni Butte, including clays, silts and sands as follows:

Clay: This layer contained between 65 to 84 percent silt and 5 to 24 percent clay, and was generally classified as a silty clay based on behaviour, with Atterberg limits indicating that the material is low to medium plastic. The clay ranged from 1.2 to 3.0 m in thickness, with moisture contents ranging from 13 to 37 percent. The material was classified as stiff to very stiff based on Standard Penetration Test (SPT) N values of 11 to 17, with an average of 14 in unfrozen materials. This layer grades into silt in many areas of the community, usually containing enough clay to be considered low plastic. Lenses of silt or sand may also be present within the clay.

Sand: The sand was fine to medium-grained, with silt content varying from trace to some silt, with a trace of clay being specifically noted only occasionally. Two distinct units were noted in the sand: an upper, damp to moist, unfrozen layer; and a lower, frozen to unfrozen layer. The upper sand unit had moisture contents that ranged from 3 to 11% and averaged 5%, and SPT N values of 10 to 26, and an average of 18 above the water table and an adjusted N of 16 below the water table, indicating compact soils. The lower sand unit extended to the full depth of the boreholes, and included both frozen and unfrozen soils.

5.1.13.3 Permafrost

Permafrost has been encountered in various locations in Nahanni Butte. Ground temperature measurements have been rare in previous geotechnical investigations. Where ground temperatures have been measured, the permafrost has been very warm. For example, a hand-probe soil temperature of -0.13°C was measured in frozen soil samples at the Community Assembly Building (current Band Office) in 1993. Likely the measured temperature was somewhat warmer than the actual temperature, due to the heat generated from auger drilling. But, because the mean annual air temperature has been estimated at only -2.6°C over the past 30 years, and there has been an estimated 1.2°C of warming over the past 20 years; it is anticipated that some of the areas that had permafrost at the time of drilling may no longer have permafrost, or the permafrost may be slowly thawing.

Permafrost is likely to be relatively deep along the logging road and if consistent with the community, the top of the permafrost could be up to about 6 m deep, and the base of the permafrost may be only 9 m deep, the depth at which groundwater was encountered in the community. The relative elevation of the river in comparison to the road will affect the depth of groundwater, as groundwater is likely very close to river level.

5.2 Borrow – General Observations

Borrow sources identified by Allnorth are highly variable in material type. Site soils consisting of silts and clays are frost-susceptible. If they are frozen with a high soil moisture content, these soil types are also likely to be thaw-sensitive. Coarse-grained soils such as sands and gravels should be frost-stable, as long as they contain less than 10% fines. Similarly, bedrock is likely to be frost-stable and not thaw-sensitive, unless weathered bedrock has ice in it. Ice in bedrock can be present in joints or bedding planes or between fissile laminations.

5.3 Climate

Trends in climate are anticipated to be similar to the climate in Fort Simpson since it is nearly at the same latitude; however, some differences in absolute temperature are expected as a result of local mountain climate variations as well as the differences in elevation along the route.

Climate data for Fort Simpson has been available since 1964 and is taken for the purpose of this study to be the closest approximation of climate between the Prairie Creek Mine and Nahanni Butte. Climate data is available for the Prairie Creek Mine site from 2005, but the record is not long enough to discern long-term trends. Tetra Tech EBA has evaluated climate conditions at Nahanni Butte and at Rabbitkettle River in Nahanni National Park Reserve for two recent projects carried out in 2014 (Tetra Tech EBA 2014a, 2014b). These two sites bracket the route and are expected to be reasonably representative of the variation in climate conditions along the route at similar elevations (180 to 615 m). Colder winter conditions would generally be expected at higher elevations, up to about 1525 m at the Funeral Creek to upper Sundog Creek pass near KP017. Local effects of water bodies on terrain and permafrost will be important for bridge foundations and other stream crossing types.

The mean annual temperature in the Boreal Cordillera High Boreal Ecoregion, where the proposed route is located, is reported as ranging from -4 to -5°C (ECG, 2010), but the timeframe of measurement is not defined. The mean annual temperature in the Boreal Cordillera (Ragged Range Valley Mid-Boreal) Ecoregion at Rabbitkettle River is reported in the same range, and the temperature in the Taiga Plains Ecoregion (as far south as the British Columbia and Alberta borders) is reported as ranging from about -1.0 to -4.4°C depending on location (ECG 2009b). Over the period of record, the mean annual air temperature at Fort Simpson has averaged -3.1°C. However, the climate has exhibited a warming trend over that time. The mean annual air temperature has averaged -2.6°C over the 30 years ending 2012.

Over the period of record, the rate of warming has averaged 0.06°C per year. This trend is consistent with other sites in the western Northwest Territories, with trends ranging between 0.02°C per year and 0.08°C per year depending on the community and the period of record. Rates of warming are significantly higher in the last 30 years than over the period of record. This observation was confirmed by Nahanni Butte elders in recent conversations with CZN. It is anticipated that similar warming trends exist everywhere along the proposed road route, irrespective of the probable variations in local temperatures along the route at the time of this study. The noted climate warming has come about primarily as a decrease in winter temperatures, and summer temperatures have remained more consistent. Over the 30 years ending 2012 in Fort Simpson, the average freezing index has been about 2940°C-days per year, and the average thawing index has been about 2030°C-days per year. Over the period of record, we note that there is a decrease in the freezing index of about 15 C°-days per year and a smaller increase in the thawing index of about 6 C°-days per year over the period of record.

As for precipitation, snow seems to be becoming wetter and denser than it used to be in Canada's North, based on data from sites where the snow water equivalent is actually measured (Auld, 2010). This phenomenon tends to result in a thicker snowpack that lasts longer into late winter / early spring. Tetra Tech EBA has confirmed this phenomenon at other sites in the Northwest Territories (EBA 2011, 2013), although Nahanni Butte elders reported to CZN in January 2015 that snow cover disappears earlier than in the past (personal communication: D.Harpley, R.Kors-Olthof; March 9, 2015).

The practical implications of an increased snowpack thickness along the Prairie Creek road include potentially increased snowmelt in spring, and correspondingly greater surface water runoff and infiltration. As well, a thicker snowpack suggests the possibility of a thicker insulating layer over the permafrost (where present), resulting in less cooling over the winter and hence progressively warmer permafrost and a thicker active layer. In areas where the permafrost is already close to thawing, this change may be enough to eventually trigger thawing.

5.4 Permafrost

Nahanni Butte is mapped near the southern boundary of the "extensive discontinuous" permafrost zone and the route appears to be entirely within that zone (Heginbottom et al. 1995). Within this zone, 50 to 90% of the land area may be underlain by permafrost. Locally, the likelihood of permafrost will depend on elevation, but also on local soil and ground cover conditions. The very small scale of Heginbottom et al.'s permafrost map makes it difficult to discern the transitions between the areas where anticipated ground ice content is mapped as low (<10%), and where it is mapped as medium (10-20%), or low to medium. Based on estimated landmark locations, it appears that the terrain on the east side of the Front Range is more likely to have a low to medium ice content, and the terrain between the Front Range and the Tetcela River is more likely to have a medium ice content. However, there is enough local variation that actual ice content will depend on a series of local factors including the grain size of the soils encountered, ground cover, and local slope aspects.

Where present, the average temperature of the permafrost is expected to be very close to 0°C in the lower elevation areas, and probably less than about -2°C at higher elevations along the route. Therefore, in silty or clayey soils, there may be high unfrozen moisture content (Heginbottom et al. 1995). As well, it is anticipated that locally silty/clayey soils may incorporate some ice lenses or laminations, while granular soils should have relatively low ice content. Rivers or streams or lakes and ponds that have unfrozen water year-round likely moderate the local ground temperature (typically within 10 to 50 m of the shoreline), as well as providing a potential source of water for ice lens formation. Depending on the type of groundcover, thickness of organic soils, underlying soil types (fine-grained or coarse-grained), degree of site disturbance, and proximity to waterbodies, the active layer is estimated to range between 0.6 and 3 m thick.

Where streams or ponds are ephemeral or freeze to the bottom every winter, it is anticipated that permafrost could be present regardless of soil or rock type. Where water flows and/or is deep enough to remain unfrozen year-round, a talik or unfrozen zone is likely to be present beneath the stream. The smaller creeks evaluated by Hatfield Consultants Ltd. were considered to have the potential to freeze to the bottom every winter. Even the larger channels were considered to have a high potential of freezing, although these streams might also have some deeper, unfrozen pools, for example, Sundog Creek, Polje Creek, Tetcela River, and Grainger River. Locations where there is a bedrock substrate would be more likely to retain unfrozen pools. Streams in gravel along the route appear to have greatly-reduced water levels even before the onset of winter (email communications, March 5, 2015; D.Harpley, C.Jaeggle, R.Kors-Olthof).

As noted above, fires may affect ground temperature regimes and permafrost due to changes to the protective organic layer over the frozen mineral soils, particularly if the fire burns hot and damages the organic layer. The loss of a forested canopy can also reduce shade and allow the ground to become warmer, accelerating thaw. On steeper slope sections, it is also important to consider the potential for fires resulting in dead trees and the subsequent loss of root strength in helping to retain near-surface soils.

Climate warming can also affect ground temperatures and permafrost characteristics, and might be expected to have a greater effect on a usually cool slope than on a slope that is already warmer due to slope aspect, especially if that warm slope already has less permafrost.

6.0 CLIMATE CHANGE CONSIDERATIONS

The impacts of potential climate change need to be considered in the final design of the all-season road. Climate change considerations are referenced in MVEIRB's TOR Section 8, Items 1 and 4, with respect to the potential effects of climate change on the permafrost regime. Climate change considerations are also a normal part of Tetra Tech EBA's geotechnical assessments in permafrost regions.

The generally adequate performance of the existing winter road over the past 35 years should not be misinterpreted as an indication that the route is resilient to climate change, nor as an indication that the terrain beneath an all-season road will perform similarly, irrespective of whether or not it is influenced by climate change. Both types of road potentially affect the ground temperature regime due to the removal of vegetation and/or disturbance of the organic layer whether it is stripped off (something to be avoided in thaw-sensitive areas), or merely compacted by traffic or placement of fill, depending on the road type. However, an all-season road embankment has numerous different effects on permafrost compared to a winter road, and the effects of an embankment can be much more far-reaching. Items including poor drainage, inadequate embankment thickness, ground disturbance, and other design and construction issues in thaw-sensitive areas, snow-drifting on embankment side-slopes warming the underlying permafrost, or even the change in reflectivity of the ground surface due to the presence of the road can result in permafrost thaw even without climate warming. Climate change merely increases the potential for permafrost thaw. Potential effects of the road on permafrost, irrespective of climate change, are further discussed later in this report.

That said, two key factors play a role with respect to climate change and its probable effects on permafrost along proposed all-season road:

- Climate change has been ongoing for many years and is expected to continue during and beyond the service life of the road; and
- Already-warm permafrost will continue to get warmer, and is likely to either continue slowly thawing or start slowly thawing.

A procedure for screening the vulnerability of a development to climate change is outlined by the Canadian Standards Association (CSA, 2010).

The sensitivity of an area to climate change is governed by the characteristics of the permafrost in that area. The all-season road route is in an area of extensive, discontinuous permafrost, with average anticipated ground temperatures just below 0°C at lower elevations and likely warmer than -2°C at higher elevations along the route. The subsurface soils are of highly variable origin along this 184.5 km route, but permafrost with possible ice-rich lenses or layers has been encountered at various locations along the route. Tetra Tech EBA therefore characterizes the site sensitivity to be "high" along route sections with fine-grained soils. This entails most of the route, except for the initial 39 km from the Mine to Cat Camp, and about 2 km in Grainger Gap where granular soils are more prevalent. Along the remainder of the route, some short sections within granular soils likely have “moderate” to “low” sensitivities to climate change, particularly where ground temperatures are likely to be moderated by nearby large water bodies, and where permafrost is less likely to be present. Tetra Tech EBA estimated that about 73 km likely has least some thaw-sensitive permafrost, and another 24 km may also have thaw-sensitive permafrost, but slope aspect or elevation makes it slightly less likely.

Under a “moderate” green-house gas scenario, the mean annual air temperature is estimated to increase about 0.8 °C over the next 30 years. For the proposed 20-year service life for the road, the mean annual air temperature would rise by a total of about 0.5 °C. Under a “high” green-house gas scenario, the mean annual air temperature is estimated to increase about 1.1 °C over the next 30 years. For the 20-year proposed service life for the road, the mean annual air temperature would rise by a total of about 0.7°C (CSA, 2010).

Road embankment and structure design and construction need to account for the likely change in ground temperature over the service life of the project. In cases where direct correlations between air temperature and ground temperature are not available, ground temperature is assumed to change in step with air temperature. Therefore, the ground temperature in 20 years could be at 0°C or potentially warmer than 0°C where permafrost is currently very close to 0°C, and may be warmer than -1.5°C where the permafrost is currently estimated to be warmer than -2°C.

For the “moderate” green-house gas scenario, the increase in air and ground temperatures may be enough to encourage the start of thawing where the permafrost along the route is already near-thawing. Where permafrost is already slowly thawing, further thawing is expected. Such thawing is less important in areas with near-surface bedrock, coarse-grained soils with relatively low soil moisture contents, or even finer-grained soils with relatively low moisture contents, because thawing probably will not result in much noticeable change in the ground conditions in those areas. Areas that have higher soil moisture contents in the form of ice can be affected in two general ways. On the one hand, thawing will probably be slower, because extra energy is required to turn ice to water. On the other hand, areas that do thaw may experience slope instabilities, similar to the retrogressive thaw slump/flow at KP054, or settlement and ponding of water.

Other areas may not actually thaw during the life of the road, but could be prone to higher rates of soil creep, potentially pushing road sections out of alignment or, more seriously, pushing bridge abutments out of alignment and causing distress to the structure. This is a phenomenon which has also been considered in ground that is colder than the project site, for example, on the Inuvik to Tuktoyaktuk Highway.

Based on the review of available information and the 2014 ground-truthing, it is anticipated that the permafrost in some sections of the route may contain layers or lenses of soil that have excess ground ice. The practical implication is that thawing with resulting settlement and ponding could occur in the subgrade along the toes of the road embankment, the numbers or areas of thaw-related slope failures could increase, thaw settlement beneath culverts could cause water flow to be blocked with potential accompanying slope stability issues, and settlements or potentially even failures of road grades could occur. Settlement and ponding are common along the toes of road embankments in warm permafrost, for example, along the reconstructed section of Yellowknife Highway 3 between Behchoko and Yellowknife, where there are also several road sections with relatively severe differential settlements. The nearby Liard Highway 7 has had significant issues and requires significant maintenance efforts, and is constructed in very similar terrain in terms of ground and permafrost conditions as much of the proposed route. Although it is recognized that the territorial highways have different operating and service life requirements as compared to a resource road, and they have not necessarily all experienced the same construction methods and conditions, they do offer some useful comparisons. Accordingly, potential issues with thaw-sensitive permafrost along the proposed Prairie Creek all-season road would be expected to become more frequent as the permafrost becomes warmer, and more likely to start gradually thawing.

Therefore, the consequences of permafrost thaw can be potentially significant, and they are characterized as potentially "major" for structures supported by shallow or deep foundations within fine-grained permafrost with excess ice, but likely "minor" for structures supported on frost-stable granular soils or bedrock beneath the surficial sediments. Such structures would include bridges and culverts along the route in locations where permafrost is present. For road embankments, the consequences of permafrost thaw could be "major" where thaw settlement under culverts goes unnoticed for a long period of time potentially blocking natural water flow, and "minor" for road surfaces that can be readily re-levelled with more fill. These consequences can be mitigated by a reasonable inspection and maintenance schedule.

Considering the site-specific permafrost sensitivity and the associated consequences together results in a risk level "C" (low risk) as defined in CSA (2010) for structures such as bridge and major culverts supported by foundations on or in frost-stable soils or bedrock. With respect to permafrost, this level of risk warrants a qualitative analysis and the use of expert judgement to develop design parameters for a project with routine design parameters.

For structures supported by foundations on or in thaw-sensitive soils, the site-specific permafrost sensitivity and associated consequences together results in a risk level "A" (high risk) as defined in CSA (2010). This level of risk warrants a quantitative analysis to evaluate the ground thermal regime expected to develop beneath the proposed structure over its lifetime. The initial step to proceed with this level of analysis would be to improve the site characterization by conducting a site investigation with boreholes deep enough to determine depths and thicknesses of permafrost. This type of analysis is also useful in optimizing embankment designs in road sections traversing permafrost. It is anticipated that major structures will require a site investigation to determine geotechnical design parameters in any case, irrespective of the anticipated absence or presence of permafrost.

7.0 EFFECTS ASSESSMENT – ACCIDENTS AND MALFUNCTIONS

7.1 Environmental Causes

- The MVEIRB TOR Section 7.2.2, Item 7, requires consideration of how the environment may contribute to potential accidents, malfunctions, and spills. Tetra Tech EBA has considered the ways in which flooding, overland flow, landslides and ground movement, seismic activity, and avalanche activity can affect the integrity and/or operation of the road, which in turn can have an effect on potential accidents, malfunctions and spills. These potential environmental contributors are discussed below, and the risk matrix and specific road design and construction mitigations to be used to manage these events are discussed in the following sections. Although not directly assessed as a separate environmental cause, it is recognized that climate change can contribute to all of the listed types of events except for seismic activity. Climate change itself is relatively slow, but climate change effects tend to result in events that happen with little or no warning in areas previously not subject to such events, for example, thaw slumps or flows. Climate change considerations are discussed in the preceding section.

- **Flooding:** Flooding is relevant to stream crossings, road sections along low-lying areas that may be prone to flooding, as well as the crossing of the Liard River. Tetra Tech EBA has undertaken specific studies of flood levels for the major crossings along the route (see elsewhere in the DAR), providing 1-in-100 year design flows and water levels (Tetra Tech EBA 2014c; EBA 2012). The Government of the Northwest Territories, Municipal and Community Affairs (MACA) has an online mapping resource (MACA, 2014) that provides some useful information for the nearby community of Nahanni Butte. Since the elevation of the proposed ferry crossing is at essentially the same elevation as the community, this information is directly relevant. Nahanni Butte is known to be flood-prone. Normal summer water levels are mapped a little below 177 m elevation, whereas the 2012 LiDAR carried out for the project indicates water levels of about 180 m at the community and at the Liard River crossing, indicating at least 3 m of flood waters at that time. Portions of the Nahanni Butte access road were also inundated at the time of the LiDAR. MACA's flood mapping suggests that terrain below an elevation of

182 m is within the floodway, and terrain up to 183 m elevation is in the floodway fringe, where the ground elevation is 1 m or less above floodwater elevation. Ice-jamming is a common cause of flooding, and it is quite possible that higher water levels can occur due to ice-jamming than occurs during floods without ice effects. Water levels cannot be directly correlated to flow when there is ice in the stream (WSC 2014a). Parks Canada also reports that while the South Nahanni River usually has its highest flows in June, associated with the spring thaw, high flows also occur in July, August and September, when the river is also subject to flash floods due to precipitation. The tributaries of the South Nahanni River are understood to have similar characteristics, with peak flows in late June due to snow melt (Parks 2009). Although not specifically mentioned by Parks in this reference, some of the north-flowing streams and associated tributaries along the route have visually similar characteristics to the South Nahanni River and its tributaries, and should be considered likely to experience similar conditions.

CZN observed high water levels in 2006 and 2007 on Prairie Creek with estimated flows of 200 to 400 m^3/s in 2006. A return period of 200 years for a flood of 250 m^3/s had been previously estimated for Prairie Creek. The Probable Maximum Flood (PMF) was subsequently re-evaluated, and CZN noted that the observed flow was not as high as the re-evaluated PMF. Due to the short period of record at the measuring station (WSC 2014b, 2014c), there was some uncertainty as to the return period of the observed flood flows (NRCan 2011). There is some anecdotal evidence suggesting that 2006 and/or 2007 may have been record years for precipitation, depending on location, based on the climate summaries that Tetra Tech EBA compiled for geotechnical projects in a few other communities in the Northwest Territories, including Fort Liard (Tetra Tech EBA 2014d, EBA 2011).

Flooding may also occur along other low-lying road sections, for example, along Polje Creek and the Tetcela River, as can be seen by comparing the 1 in 100-year flood events at the stream crossings to the adjacent terrain elevations along the road (Tetra Tech EBA 2014c, EBA 2012). Some areas of the winter road were noted to have ponded water on them, particularly in the Tetcela to Fishtrap Creek section, and it is possible that sections of the route could be periodically flooded at natural grade, since the elevations appear to be consistent with elevations at the Tetcela River. However, the higher ground along the Tetcela to Fishtrap realignment appears unlikely to flood.

In addition to roads, culverts, and even bridges being inundated with floodwater, there is also the possibility of damage to road fills and bridge foundations from scouring, and to crossing structures as a result of debris being washed downstream and jamming against foundations or under or within crossing structures. Streambed movement is common and can result in building up of sediment or woody debris in new areas that can then flood more easily in following years, due to reduced stream capacity in those areas. High water levels and rapid runoff can also result in erosion that causes the loss of road sections, even when the water is not high enough to inundate the road. Such events appear to be more likely in the Funeral, Fast and Prairie Creek drainages, and also potentially in the Sundog Creek drainage. The Tetcela River, Grainger River and other streams powerful enough to move gravel, cobbles and boulders have enough energy to be erosive when moving their bedload.

- **Overland flow:** Overland flow is relevant to the possibility of surface water drainage backing up at culverts or running in unanticipated or undesirable places, potentially causing physical/thermal erosion and/or slope stability issues. Slopes that already have existing slope instabilities and the potential for new instabilities, including areas such as the Silent Hills west slope, and the Polje reroute can be affected. Even relatively gentle or flat areas can be potentially affected, as there may be subtle terrain features that influence water flow that are not easily seen on the ground or from the contour data. Sections of road fill that become saturated due to ponded water could become too soft or unstable to hold the anticipated truck loads, or sections of road could flood if the ponded area becomes too deep.

- **Landslides and ground movement:** Landslides and ground movement that impact road sections or stream crossings can result from rock slides, rock fall, debris slides, slumps and flows that do not involve permafrost but that could involve higher than normal inputs of ground surface water, either from natural events occurring above the road, or due to some event along the road. For instance, debris flows can scour out road sections located on steeper ground, or deposit debris on the road in gentler ground, or plug culverts preventing upslope drainage along the road. Ground movements can also be related to thaw slides, slumps or flows retrogressing into the road alignment, or new thaw slides or flows forming upslope or downslope that affect the road alignment. Ground movements can also result from settlement or loss of ground at areas of suffosion or subsidence in karst terrain. Changes in the ground surface and/or slope failures can also occur as a result of flooding, for example, from deposition, or scouring, or rapid drawdown.
- **Seismic activity:** Seismic activity potentially could disrupt the road grade through ground displacement, or loss of the road grade due to fill slope failure, or collapse of upslope materials onto the road grade. While the road route does cross terrain with a relatively high seismic hazard with a peak ground acceleration (PGA) of 0.246g at the Mine and 0.241g at Nahanni Butte (NBCC, 2014), no large seismic-related failures of rock slopes have been documented on the existing route along Prairie Creek, Funeral Creek or Sundog Creek (Golder, 2010). Golder remarks that while smaller rock slope failures may have a seismic-related component, such failures would be difficult to distinguish from rock slope failures occurring for other reasons. Golder considers the likelihood of large-scale rock slope failures occurring as a result of seismic activity to be very remote along the route. Though not specifically mentioned in the context of seismic activity, Grainger Gap is also included in Golder's overall assessment of anticipated rock fall activity.

  The 1985 North Nahanni earthquakes had a significant effect on rock slopes in the North Nahanni River valley, at the English Chief Anticline (part of the Nahanni Formation), and on a till-like colluvial slope at Little Doctor Lake where saturated sand and silt soils liquefied (BGC, 2005), however, suggesting that such events are not impossible along the all-season route. This judgment is supported by the similarities in peak ground acceleration in this region, with a PGA of 0.239g at Little Doctor Lake, and a PGA of 0.245g further north along the North Nahanni River and English Chief River (NBCC, 2010). Local factors including rock types and bedding/jointing characteristics will play a role in possible rock slope failures, of course, as will soil characteristics at any particular location along the route. Tetra Tech EBA anticipates that seismic site class as defined in the National Building Code of Canada can vary considerably along the route with a probable range from Site Class B in competent bedrock (limestone, dolomite, some sandstones); Site Class C with very dense soils (sandy, gravelly tills) and/or soft rocks (mudstone, shale), or well-bonded frozen soils; Site Class D with stiff or dense soils including silty clays, dense well-graded sands and gravels; and Site Class E on any site that has more than 3 m of very wet soft soils, particularly fine sands and silts that are prone to pumping and liquefaction. The latter case may be more likely in areas of wet thermokarst terrain, or generally wet valley bottoms outside the alluvial plains where gravels and sands are more common. Where the bedrock is fractured, weathered and/or has unfavourably-dipping bedding or jointing planes, the site class may not be as favourable as it might appear at first glance.

  Based on the review of site overview photos and a paper on the English Chief failure, it is noted that of two seismic-related rock slope failures documented after the 1985 North Nahanni earthquakes, the North Nahanni River valley failure may be a toppling failure, with the bedding planes nearly level or slightly dipping into the slope, resulting in the addition of debris to what appears to have been an existing talus/scree slope. The rock slope at the English Chief Anticline failed along a fault that cuts through the out-dipping bedding planes on the upper part of the failure, and along the bedding planes on the lower part of the failure, resulting in a large slab of the mountain sliding downslope to the northeast (BGC, 2005; Evans et al, 1987). One of the outcomes in studies of the 1985 earthquakes was the realization that faults previously considered inactive might not be inactive after all.

Comparing to a few of the bedding plane orientations seen along the proposed road route, toppling failures might be more common along the Front Range and at the east end of Grainger Gap, while bedding plane sliding failures might be anticipated along Prairie Creek, at the west end of Grainger Gap, and portions of the route through the Gap. Anticipating the more-likely types of events becomes more complicated as the stratigraphy becomes more complicated, with faulting and folding producing multiple layers of the same rock types, dipping in different directions. For example, rotational slides are also mapped on the Front Range (Hawes, 1975). The bedrock mapping shows much more faulting at the west end of the route in the mountains, between about KP000 and KP039, resulting in the potential for toppling, slab-type or other failure types (Douglas and Norris, 1976b). One possible benefit in this road section might be that because much of the road runs along east-west valleys, at least some of the out-dipping bedrock may be avoided. Nevertheless, just as the possibility of small-scale rock fall/slide events cannot be ignored in this section, the possibility of large-scale events should not be discounted either. Seismic considerations also need to be accounted for in structural and foundation design for bridges and other major stream crossing types along the route.

- **Avalanche activity:** Avalanche activity is important to consider, particularly in the Prairie Creek, Funeral Creek and Sundog Creek areas, from about KP000 to KP039. An avalanche assessment and maps (Appendix D) were prepared previously by Alpine Solutions Avalanche Services (2012). Alpine Solutions concluded that avalanche hazard potentially affecting the road exists from the Mine site to Cat Camp at Km 40, and on the east side of the Grainger River at Grainger Gap, but avalanches were not estimated to affect the road alignment there.

Given the possible types of events or hazards described above, a qualitative risk assessment is useful to evaluate their likelihoods, consequences and resulting risks. Appropriate road design and construction considerations will help to reduce or mitigate many of the risks. There may be some residual effects, as discussed below.

7.2 Qualitative Risk Assessments

7.2.1 Definitions of Assessment Parameters

Tetra Tech EBA has carried out a qualitative risk assessment for the Project. With respect to slope stability, we have evaluated the stability of various slopes along the route on the basis of the following types of information, where available: a review of 1994 air photos and the 2012 LiDAR and ortho-imagery coverage, on slope characteristics based on topographic mapping and measured slope angles at selected locations, and on the basis of field and laboratory observations of shallow soils only, carried out by Tetra Tech EBA and others. Exposed soils were logged by Tetra Tech EBA within the KP054 retrogressive thaw slump/flow area and at the KP124.8 soil debris slide. Similarly, aerial coverage and field observations were utilized in evaluating the potential for ground subsidence or suffosion at specific locations along the route. Seismic site class was determined for several locations along the route, based on typical anticipated soil characteristics and thicknesses; and the seismic hazard value for the region is noted (NBCC, 2010). Tetra Tech EBA defers to the expertise of Alpine Solutions Avalanche Services and their assessment of avalanche activity as presented in the avalanche hazard index map (2012). Modelled stream flood levels were compared to nearby sections of the existing or proposed road route for a rough estimate as to whether those road sections might be likely to experience flooding. Overall topography, slope gradients and anticipated soil types were evaluated to determine which sections of road might be more likely to experience problems due to overland flow.

As recommended in MVEIRB's TOR Section 7.2.2, Item 8, Tetra Tech EBA referred to the document "Failure Modes and Effects Analysis (FMEA)" (Robertson and Shaw, undated) for this risk assessment, modifying the charts to make them specific to the types of failure modes being evaluated and the qualitative level of risk assessment. Definitions for the following discussion (adapted from British Columbia, Ministry of Forests, 2004, and consistent with the methodology presented in CSA PLUS 4011-10) are presented as follows, using ground and slope conditions as the source of the hazard potentially affecting the road in this example:

- Hazard – a source of potential harm, or a situation with a potential for causing harm in terms of human injury, and/or damage to property, the environment or other things of value. In the case of the proposed road, hazards include slope instabilities along or adjacent to the route, areas of subsidence or suffosion due to underlying karst topography, and thawing of ice-rich permafrost.

- Likelihood – a qualitative estimate of the probability that a landslide, subsidence, or thermokarst area will occur, or expand, referred to as a probability rating, and described with relative qualitative terms such as “low” to “high.”

- Elements of value (valued components), or elements at risk – including human life and well-being, public and private property (such as buildings or land), transportation or utility rights-of-way, domestic water supply, and/or parts of the environment such as wildlife habitat. In our case, land and streams along the road route; the all-season road itself; and proposed structures enroute, for example, the Tetcela Transfer Facility, and/or construction camp(s); and the people working or visiting there are the “elements.”

- Consequence – the effect on human well-being, property and/or the environment, that is, the change, loss or damage caused to the elements by a landslide, subsidence, or thermokarst event. For example, what could happen to the road if a retrogressive thaw slide reaches it?

- Risk – the qualitative evaluation of a potential loss, defined as a measure of the likelihood of an adverse event and the consequence of that adverse event.

- Risk tolerance – the inclination for land managers, authorized road users, and/or the general public to accept or not accept a particular risk. Risk tolerance is not addressed in the risk matrix, but should be recognized as a necessary component in making land management decisions, particularly in co-management areas where there may be several stakeholders.

The following table is applicable to determining risk from hazard and consequence, where hazards and consequences are determined to be low, moderate or high. Likelihoods of hazards are listed along the left-hand side of the table, consequences across the top, and the resulting risk within the table. These are qualitative values based on a review of the existing information and the 2014 field work where applicable. Colour-coding is as follows: red indicates “very high” risk, orange is “high” risk, yellow is “moderate” risk, green is “low” risk, and blue is “very low” risk (adapted from British Columbia Ministry of Forests, 2002).

Table 7.2.1-1: Risk Matrix – General

Risk to Element		**Consequence of hazard if event occurs**		
		Low	**Moderate**	**High**
Likelihood of hazard affecting the element	**Low**	Very Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very High

7.2.2 Risk Matrix

The following Table 7.2.2-1 summarizes the residual risks to the road associated with hazards related to flooding, overland flow, landslides and ground movement and seismic activity, assuming that mitigative measures have been taken. For instance, if flooding risks can be reduced by designing appropriate road grade elevations above estimated flood levels, this is assumed to be done in detailed design. Similarly, if risks from thaw slumps or flows can be mitigated by moving the road or if rock fall risks can be reduced with scaling and/or signage and awareness training, these are assumed to be done. If risks from avalanches can be mitigated with an avalanche control program incorporated into the road operations plan, this is assumed also to be done, and so on. These are just a few examples of possible mitigative strategies that can be considered to reduce the risk of environment-related events affecting the road. Strategies are further described in Section 7.2.3 following the risk summary.

Note that Table 7.2.2-1 is not a direct assessment of spill risk, but we anticipate that it will assist CZN in assessing the spill risk due to environmental factors along the route.

It is further noted that this risk matrix is based on the assumption of the current route alignment being within +/-50 m of what will be the eventual route location, based on Allnorth's current proposed route (Allnorth, 2015). To facilitate the overview, the route has been divided into sections by approximate terrain-type boundaries or zones, marked by kilometre posts. For each road section, the likelihood of the specified **hazard (H)**, the **consequence (C)**, and the resulting **risk (R)** are shown in the column for that hazard with the colour codes applied as shown in the general risk matrix in Table 7.2.1-1 above. In cases where a range of hazards or consequences is possible, the average is presented. Some hazards tend to be seasonal, for example, avalanches in winter or early in spring, flooding and overland flow in spring and summer, debris flows or thaw slumps in summer or early autumn.

Generally, the table shows that although the likelihood of a hazard affecting the road can be high in some areas, with the appropriate mitigative measures, the consequences of those hazards can often be reduced sufficiently so that the risk remains low to moderate. There are only a few high risk areas noted, all related to potential slope stability issues. With further adjustment of the road alignment ROW within the currently-proposed 100 m wide corridor, it may be possible to further reduce the risk in some of these areas.

In the case of seismic activity, the overall likelihood of the hazard is considered low, but consequences of a seismic event can be moderate or high in some instances. The consequences are considered more likely to be high in places where the bedding planes dip out of the slope, such that larger volumes of failed rock could potentially fall onto the road. Due to the anticipated relative rarity of large seismic events, this results in a low to moderate risk from seismic activity. As mentioned in Table 7.2.2-1, the slope failures that were attributed to seismic events in 1985 were less than 10 to 15 km from the epicentre. The largest of these events were of magnitude 6.6 and 6.9. The nearest point on the proposed road (about KP054) was 65 km from the 1985 epicentres; therefore, effects on the road would have been unlikely. Since 1985, only events smaller than magnitude 4.0 have been recorded near the Mine and road route. Since the area of the 1985 seismic events has the same seismic hazard rating as the road route (NBCC, 2010), however, larger seismic events could also happen near the road route. If a similar-sized seismic event were to be centred closer to the road, then there would be a greater likelihood of noticeable effects.

Table 7.2.2-1: Risk Matrix Summary (Residual Risks with Mitigative Measures in Place)

Kilometre Posts	Valued Components (Elements, as applicable)	Flooding			Overland Flow			Landslides/ Ground Movements			Seismic Activity			Avalanches[2]			Comments
KP000 – KP006.5	▪ Camp & Mine ▪ Road & bridge ▪ Personnel	H[1]	C[1]	R[1]	H	C	R	H	C	R	H	C	R	H	C	R	Prairie Creek, Fast Creek, and Funeral Creek all seem to have sections prone to erosion by flood flows, with some sections also prone to the effects of debris flows and/or alluvial deposits originating from streams upslope. The Casket Creek bridge crosses an alluvial fan where the existing main channel is prone to shifting, and where material carried downstream could overrun the road. Erosion would be dealt with by placing riprap. Otherwise, coarse-grained materials in the mountains suggest this road section is less prone to erosion or other effects of overland flow not going where it should. Mapping and photos suggest out-dipping bedrock, so if a seismic event happens, it is more likely that consequences will include rock landing on the road. The recorded seismic-related rock slope failures that affected English Chief and North Nahanni River in 1985 were less than 10 km from the epicentre, with several small mudflows recorded as far away as 15 km. The nearest point along the proposed road (about KP054) was 65 km from the 1985 epicentre. If a similar-sized seismic event were to be centred closer to the road, then there would be a greater likelihood of noticeable effects.
KP006.5 – KP013.4	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Estimated according to the avalanche mapping as to extent of avalanche terrain and "potential" avalanche terrain on the route. More avalanche terrain means higher hazard. Consequence stays low if CZN et al carry out avalanche control and release avalanches while they're still small. If we consider this section as "high" hazard, because avalanches from slopes on north side can run up onto south side, and we therefore have potential hazards originating from both sides of creek, then risk would be "moderate."
KP013.4– KP017.1	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Road cuts through steep active talus/scree.
KP017.1– KP023.1	▪ Road & bridge ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	The hydrotechnical analyses suggest that much of Sundog Creek and its tributaries are less prone to flooding than the streams to the west. Half of this section is up to moderate hazard for landslides/debris flows where road is on terraces. High hazard where road cuts talus/scree and/or rock fall above.
KP023.1 – KP028.4	▪ Road & bridges ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Ice plug builds at Sundog Canyon (KP023.4 crossing), causes spring flows at higher elevation. High crossing elevation allows passage of high water, thus low hazard. Hazard due to landslides/ground movements/avalanches would be high if we hadn't moved 4 km of road to the south side of Sundog (away from talus/scree). Avalanche hazard remains moderate, due to potential run-up from north side avalanches, which appear to cross creek on mapping.
KP028.4 – KP033.55	▪ Road & bridge ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	This road section is scree/talus nearly end-to-end, plus a few debris flows. However, bedrock looks nearly level. Allnorth observed that the KP029 to KP030 section may be more prone to flooding based on the lack of vegetation along the existing route, and proximity of floodplain / road elevation to channel elevation.
KP033.55 – KP036.5	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Continued steep talus/scree interspersed with bedrock outcrops.
KP036.5 – KP038.9	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Talus lobes and apparent bedrock failure scarps suggest high hazard in this section.
KP038.9 – KP039.9	▪ Road & bridge ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Slightly elevated due to higher flood level at tributary compared to Sundog Creek.
KP039.9 – KP040.1	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	
KP040.1 – KP041.5	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Because this section is mapped with an old slump, it may be more susceptible to movements. Control of surface water runoff will be important.
KP041.5 – KP045.5	▪ Road & bridge ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	A few minor creeks, anticipate small road lengths affected.
KP045.5 – KP046.3	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	A few minor creeks, anticipate small road lengths affected.
KP046.3 – KP048.8	▪ Road, drainage ▪ Personnel	H	C	R	H	C	R	H	C	R	H	C	R	H	C	R	Sections on steep slope above creek, some with undermining at creek.

[1] H = Likelihood of specified hazard, C = Consequence, R = Risk. Colour codes are defined as follows:

Very Low	Low	Moderate	High	Very High

[2] Avalanche hazard based on existing avalanche hazard maps (ASAS 2012)

Table 7.2.2-1: Risk Matrix Summary (Residual Risks with Mitigative Measures in Place)

Kilometre Posts	Valued Components (Elements, as applicable)	Flooding		Overland Flow		Landslides/ Ground Movements		Seismic Activity		Avalanches[2]		Comments
KP048.8 – KP050.8	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Sections on steep slope above creek, some with undermining of slope toe at creek.
KP050.8 – KP053.5	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Overland drainage on alluvial fans.
KP053.5 - KP053.7	▪ Road & bridge ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Wide floodplain at Polje Creek.
KP053.7 – KP054.6	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Area of thaw slump/flow at KP054 is sensitive to overland flow, and prone to further movements.
KP054.6 – KP055.8	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	
KP055.8 – KP057.7	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Slope instabilities above and below road (above Third Polje).
KP057.7 – KP059.9	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Slope instabilities below road, and possibly above road (above Second Polje & upstream).
KP059.9 – KP062.6	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Southeast approach to gully at ~KP060.5 runs in swale with tributary stream, slope sensitive to overland flow. Another steep-sided gully ~KP061.6.
KP062.6 – KP066.3	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	
KP066.3 – KP071.7	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Some steeper slopes with marginally vegetation or exposed soils, or raveling.
KP071.7 – KP079	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	
KP079 – KP083.9	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Traversing near crests of steeper slopes, swales or gullies.
KP083.9 – KP087.3	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	All flagged items are due to mapping of colluvium, lots of surface water, evidence of slope failures downslope.
KP087.3 – KP088	▪ Road & bridge ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Tetcela River tributary and floodplain
KP088 – KP089.4	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	All flagged items due to mapping of large slump upslope west of route.
KP089.8 – KP090.2	▪ Road & bridge ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Tetcela River Crossing
KP090.2 – KP094.2	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	All flagged items due to likelihood of at least some thaw-sensitive permafrost.

[1] H = Likelihood of specified hazard, C = Consequence, R = Risk. Colour codes are defined as follows:

Very Low	Low	Moderate	High	Very High

[2] Avalanche hazard based on existing avalanche hazard maps (ASAS 2012)

Table 7.2.2-1: Risk Matrix Summary (Residual Risks with Mitigative Measures in Place)

Kilometre Posts	Valued Components (Elements, as applicable)	Flooding		Overland Flow		Landslides/ Ground Movements		Seismic Activity		Avalanches[2]		Comments
KP094.2 – KP095.7	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Thaw-sensitive permafrost, low-lying wetlands.
KP095.7 – KP101.7	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Most slope and sinkhole issues avoided by new route, still some residual issues and uncertainties re permafrost.
KP101.7 - KP106.75	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Alluvial fans between Wolverine Pass and ~KP103. Small surficial sloughs in borrow area ~KP106.
KP106.75 – KP106.85	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Debris flow gully originating upslope.
KP106.85 – KP115.7	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Skirting above or below gullied terrain.
KP115.7 – KP115.9 (was KP116)	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Major debris flow gully originating upslope.
KP115.9 – KP123	▪ Road & bridge ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Some low wet areas, areas of potential thermokarst, and where overland flow may be important. East end of this road section has high seismic consequence due to out-dipping bedrock layers at beginning of Grainger Gap section, but average for section moderate.
KP123 – KP126.2	▪ Road & bridges ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Avoiding beaded streams and upslope hazards. Consequence high for seismic due to some sections of out-dipping bedrock layers.
KP126.2 – KP133	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Seismic consequence slightly elevated due to presence of existing slope features that may be more prone to movements.
KP133 – KP138	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H	R	Due to debris flow features and edge of debris/deposits of uncertain origin and behaviour.
KP138 – KP150	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Seismic consequence slightly elevated due to presence of existing slope features that may be more prone to movements.
KP150 – KP154	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Due to debris flow features where debris can be deposited on the road or plug culverts.
KP154 – KP159.4	▪ Road, drainage ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Due to debris flow features that can either deposit at road or scour out road, plus some other slope issues.
KP159.4 - KP160 Liard R	▪ Ferry landings, ice bridge	H C	R	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Installations on the Liard River are likely to be subject to flooding and possibly ice-jamming (scouring), and almost certainly elevated water levels due to ice-jamming downstream.
KP160 – KP174.15	▪ Road & bridges ▪ Personnel	H C	R	H C	R	H C	R	H C	R	H C	R	Based on flooding seen along Nahanni Butte Access Road and contour elevations in this area.

[1] H = Likelihood of specified hazard, C = Consequence, R = Risk. Colour codes are defined as follows:

Very Low	Low	Moderate	High	Very High

[2] Avalanche hazard based on existing avalanche hazard maps (ASAS 2012)

Based on the qualitative risk assessment, Tetra Tech EBA estimated that about 7.2 km of the terrain along the proposed all-season route represents a high risk to the road route with respect to slope instabilities or other ground movements (by thawing, sliding, flowing, falling, settling or collapsing), and 54.9 km represents a moderate risk, out of a total of 174.1 km evaluated. The Liard River crossing represents a high risk with respect to flooding, and 20.65 km of the route represents a moderate risk. Other moderate risks included 4.3 km of the route for overland flow, 29.6 km for seismic activity, and 17.8 km for avalanche activity. Since there is considerable overlap in the moderate risk designations, a total of 76.7 km was estimated to represent a moderate risk to the road, and 7.4 km was estimated to represent a high risk to the road.

7.3 Mitigation and Residual Effects

7.3.1 General

The following sections describe the anticipated physical mitigations and the site-specific contingencies for road sections along which additional provisions are required. Physical mitigation strategies need to be incorporated into an integrated design and construction approach that includes consideration of traffic volume and vehicle type, vertical and horizontal roadway geometry, applicable codes and standards for road use (according to the applicable road section), control features during operation, maintenance requirements, safety, cost, and other considerations. Additional contingencies are intended to enhance the safety of personnel on the road, and improve the conditions under which the loads of concentrate and supplies are being transported, for situations in which road design and construction considerations may not be sufficient to achieve those goals.

7.3.2 Anticipated Mitigations Incorporated into Road Design

Numerous mitigations can be incorporated into the road design and construction. Although these mitigations can provide no guarantee that no failures will occur, they are consistent with Best Management Practices for construction, including erosion and sedimentation control measures, and Best Management Practices specific to permafrost and the mitigation of thermal erosion (TAC, 2005 and 2010).

- **Flooding:** A hydrotechnical engineer has been consulted for the major stream crossings to evaluate the local and regional hydrology of the streams and provide information useful in determining recommended minimum bridge elevations and freeboard, as well as sizing for major culverts and arch culverts (Tetra Tech EBA, 2014c; EBA 2012). Tetra Tech EBA understands that the September 2014 field survey program looked for out-of-channel high water marks such as debris or damaged vegetation, but did not find any. Tetra Tech EBA considers that although there is no evidence to indicate that conditions with ice will govern, the potential for such effects should be considered further during detailed design. To check areas that may be subject to periodic flooding, it is anticipated that projected stream design water levels (Tetra Tech EBA 2014c; EBA 2012) can be used to help design suitable road embankment elevations along adjacent road sections. Sections of road in low-lying areas along the route, or along sections of streams prone to flooding, should be designed to protect against flooding under design flood conditions. Similar provisions will be needed along the section between the Liard River crossing and the junction with the Nahanni Butte Access Road. Actual required fill thicknesses and designs will depend on available fill types and behaviour under anticipated flooding and loading conditions. Such provisions may complement the thicker road sections initially suggested to help protect crossings of potential thermokarst or generally ice-rich subgrade soils, and vice versa, subject to the results of further investigation. Some route sections may need further upgrading in the future if fill thicknesses prove insufficient. Road sections directly adjacent to streams that have proven to be prone to erosion will benefit from riprap erosion protection to reduce the likelihood that part of the road may need repair as a result of heavy spring or storm runoff, and to reduce the likelihood of erosion and sedimentation in excess of background levels. Appropriate erosion protection may also help protect the road grade even if it is overtopped by flooding at such locations.

- **Overland flow:** Generally, surface water drainage across the road needs to be sufficient to appropriately manage overland flow. Good practice is to install sufficient drainage measures such that water does not flow in channels where water would naturally flow as sheet flow. Where water naturally flows in channels, the channel should not be overwhelmed with much more water than it would ordinarily have carried prior to development. This means that stream channels will consistently need culverts, and many swales without permanent streams will likely also need culverts. Careful culvert placement and sizing will be especially important on slopes that already have significant existing slope instabilities and the potential for new instabilities.

  In areas of switchbacks, any road location that receives a culvert on an upslope reach of a stream should also receive a culvert or culverts on the road sections downslope that re-cross the same stream, and water should not be allowed to flow off the ends of switchbacks into inappropriate areas. In road sections where culverts may be prone to plugging with debris or freezing in, a series of multiple culverts at different levels may be useful to maintain seasonal flow. This technique may be particularly valuable in road sections where existing stream locations may not always be reliably in the same place, such as on or along alluvial fans. In long sections of road without obvious drainage crossings, additional culverts may also be needed to prevent ponding of water on either side of the road. Hydrotechnical engineering will also be necessary for stream crossings not involving bridges or major culverts.

  Areas of flat ground also need good management of overland flow, even where the direction of flow is not easily seen. Regular placement of drainage measures including permeable embankments and culverts will help to reduce the likelihood of hazards relating to ponding water and associated problems of flooding or subgrade integrity.

- **Landslides and ground movement:** Where possible, the road routing attempts to avoid such features as rock slides, rock fall, debris slides, slumps and flows, and thaw slumps/flows, as well as sinkholes. For example, the route has been moved north and east to avoid the thaw slump/flow at KP054. Other locations include avoiding upslope impacts from rock slides, by moving the road out from the slope toe between KP125 and KP126, for example, or moving either up or down alluvial fans to avoid long stretches of road that could be subject to repeated and unpredictable debris flows, between KP29 and KP32, for example. Other management techniques include the above-mentioned control of overland flow, particularly as it relates to the preservation of relatively natural water flow patterns, because water has an enormous influence on stability. In areas of anticipated rock fall where moving the road is not possible, physical mitigations (engineering controls) may be required.

- **Seismic activity:** The likelihood of large-scale rock slope failures occurring as a result of seismic activity was considered by Golder (2010) to be remote along the route. However, Tetra Tech EBA notes that large-scale seismic events are difficult to predict, and equally difficult to protect against. The possibility of such events occurring along the road should be taken into account. Routing for the avoidance of smaller-scale rock fall or rock slide events may help to some extent to protect against somewhat larger events, and this approach has been employed on numerous sections of road. Known trouble spots will also be avoided where possible on slopes that have soils instead of bedrock at ground surface.

However, there may be no reasonable preventative means of protecting the road from a truly large-scale event, particularly in the tight rocky valleys from KP000 to KP039, and in Grainger Gap and its approaches, though there is slightly more room there. Therefore, if a significant seismic event occurs, it would be prudent for a pilot vehicle to inspect the road before trucks resume travelling on it, just as the road would be inspected following prolonged and intense rainfall, for example. It is understood that structures will be designed in accordance with current design codes. During detailed design, additional mitigation options may present themselves for further consideration according to site-specific requirements.

- **Avalanche activity:** It is anticipated that the avalanche assessment and map prepared previously for the road by Alpine Solutions Avalanche Services (2012) will be incorporated into an appropriate Road Operations Plan.

It is noted that the above-described mitigations are useful not only for reducing the likelihood of risks due to environment-related triggers of spills, accidents and malfunctions, but are also integral to the overall performance and safety of the road and its immediate surroundings. Additional discussion of effects of the road on the environment and related mitigations are presented in Section 8.0 below.

7.3.3 Residual Effects and Site-Specific Contingencies for High Risk Zones

Although the proposed physical mitigations described above are expected to help enormously in reducing problems related to the described types of risks, it is not possible to completely eliminate the hazards, and so the residual risks must be dealt with in other ways, for example, using administrative mitigations (administrative controls). Such controls could include signage, personnel procedures and training, inspection and maintenance schedules, and notification and reporting protocols. Site-specific contingencies for high-risk areas are as follows:

- Carry out at least monthly visual inspections for areas designated high-risk due to potential slope stability or ground stability issues until seasonal baselines for behavior of the area are established;
- When the baselines are established, carry out regular visual inspections for areas designated high-risk due to potential slope stability or ground stability issues. A suggested schedule for inspection of those areas would include at least one inspection prior to spring freshet to confirm that culverts are free-draining, then monthly during the thaw season, and at least once during the winter for areas with hazards that exist also in winter (for example, for rock fall that is freeze/thaw-related; and
- Carry out inspections for high-risk areas within 24 hours of major rainfall events, abnormally high spring thaw events or significant seismic events, and/or prior to mine traffic travelling the road.

Where problems are detected, they would be repaired or corrected in a timely manner, and prioritized in accordance with the urgency of the problem.

It is possible that road sections not originally designated as “high risk” may become high risk as a result of an environmental event. Regular users of the road, such as truck drivers, become a valuable part of the road monitoring system when they are encouraged to report events or observations that seem at all out of the ordinary, no matter where it is along the road, or at what time of day. Early corrective action can help prevent a small problem such as a plugged culvert from turning into a big problem like a slope failure.

8.0 EFFECTS ASSESSMENT – OTHER

8.1 Terrain, Soils, Permafrost and Karst

8.1.1 Potential Effects Due to Road Construction Activities

The proposed road development is described in detail in earlier sections of this report. In general, construction activities will include:

- Development of winter access roads;
- Road construction in winter, summer or fall;
- Set up and operation of camps;
- Drilling for geotechnical investigation along the alignment and in the borrow sources and quarries;
- Stripping and stockpiling of organic material from borrow sources and quarries;
- Removal of material from borrow sources and quarries; preparation of material if/as needed for use; stockpiling;
- Hauling and placing of borrow material for the all-season road;
- Installation of bridges and culverts;
- Grading and compaction of constructed embankment; and
- Placement of surfacing gravel.

All of these activities require travel across the ground (as described above in terms of the terrain, geology, soils and permafrost) along the route and to borrow sources, or working in an area of open cut in a borrow source. The ground is in its most vulnerable state in the spring, summer and fall when the air/surface temperature is increasing, and the active layer is thawing or thawed. Travel over ground with tracked or wheeled equipment when the ground is in this vulnerable state can potentially cause deformation of or damage to the soil and vegetative surface (particularly in areas of soft, fine-grained soils and peat), compaction of organic peatlands, pumping of water to the surface or collection of surface water in deformations to form areas of standing water.

In areas of ice-rich permafrost, the change in ground surface characteristics could result in an increase in ground surface temperature and a corresponding increase in the depth of the active layer and subsequent thaw slumps, thawing of ice-rich soil, slope and soil instability, erosion and subsidence in the permafrost. Subsidence or the presence of new low-lying areas or surface channels can also change the surface water drainage, even beyond the area of vehicle travel. With thermal and physical erosion comes the likelihood of sedimentation.

Constructing roadway cutslopes in thaw-sensitive permafrost would require the removal of the organic layer, and cutting into the ground, both of which potentially expose permafrost, which in areas of ice-rich permafrost could cause subsidence and water ponding along the cutslope and embankment toe, excessive erosion and sedimentation, thaw that progresses from the cutslope and then under the road, causing excessive settlement or complete loss of the road embankment, or even a retrogressive thaw slump or flow that results in the ongoing failure of the slope continuing above the original cutslope. The same issue applies to the extraction of construction materials from borrow sites. If such borrow sites are located adjacent to the road, these issues are likely to also affect the road. Where borrow areas are not located in permafrost, there may still be the potential for erosion and sedimentation occurring, or sloughing and collapse of over-steepened borrow pit slopes.

The all-season road has the potential to disturb existing slope instabilities or to create new instabilities, both large and small. Although such features can reactivate on their own, disturbance can increase the likelihood of reactivation. For example, if the road reroutes surface water drainage into a marginally-stable area, slope instabilities could result. Or, if the road cuts into the supporting toe of an old landslide, that cut could result in the slide reactivating, even if it is not a slope in permafrost soils. Cuts in rock slopes or talus or scree can also result in loss of toe support. As well, if large fills are placed in marginally-stable areas, the additional weight of the fill may reactivate old instabilities, whether it is an outright slope failure, or merely an increased rate of slope creep.

Road construction can also result in general soil disturbance and an increase in erosion and sedimentation compared to natural levels.

8.1.2 Potential Effects Due to the Physical Presence and Operation of the Road

The ground (terrain, geology, permafrost and karst) can also be affected by the physical presence of the all-season road including embankment, bridges and culverts after it is built. There are significant issues and challenges in constructing and operating a road in discontinuous permafrost terrain.

The perception that the existing winter road is in relatively good condition may suggest that much of the ground is not too sensitive to permafrost thaw. However, a properly constructed and operated winter road, even in highly thaw-sensitive permafrost terrain, should lead to little or no disturbance of the ground surface and no permafrost degradation. There are numerous examples of successful winter roads throughout northern Canada, many on winter road routes that have been operated for decades. In contrast, places where disturbance from winter road operation has been observed can all be linked to terrain disturbance during either winter road construction when there is still insufficient snow cover, or operation of the road too late into spring, after thawing has already started. The relatively good condition of the existing winter road is probably more indicative of the two winters of use it experienced, along with reasonable winter road construction and operating practices, followed by 33 years of vegetation regrowth.

As noted above, permafrost and ice-rich soils are highly sensitive to changes in ground temperature, and this is particularly true of the warm permafrost found along the route. Even slight changes can cause an increase in the thickness of the active layer, instability, thaw settlement and subsidence due to loss of permafrost. Introducing a new material on the ground surface could change this balance. For example, in warm permafrost, the edges of the embankment tend to allow the permafrost beneath to thaw, typically causing ponding along the embankment toe, while in the middle of the embankment, the permafrost may be preserved or even grow. Snow drifting tends to increase this effect. Although the road grade is plowed, the sides of the embankment tend to build up drifted or plowed snow, which insulates the ground and reduces the amount of heat escaping from the ground in winter. This means that the permafrost on the edges of the fill does not cool as much in winter as it would without an embankment, while in the middle of the road, it might even be colder than normal because it is plowed all winter. The snow drifting/plowing effect can potentially reach well past the toe of the embankment.

The road fill can also form a barrier to the movement of unchannelized surface water, resulting in another source of surface water that can accumulate or pond along the toe of the embankment, which in turn can contribute to additional thermal erosion (thawing), and also potentially to slope stability issues. Similarly, the embankment can also create preferential paths for surface water drainage that do not match with the natural surface water drainage pattern, where water runs along the toe of the road fill for some distance instead of across it. In this case, the water can also contribute to physical erosion. Locations where the water is finally directly downslope can also be affected, by erosion and even slope instabilities. Even subsurface water flow in the active layer can be affected if the depth of thaw is greater at the edges of the embankment than at the middle, as this creates another way in which cross-road drainage can be blocked. Culverts can also contribute to heave in the winter and thaw settlement in the summer in soils that are frost-susceptible and thaw-sensitive, and can result in thermal erosion in ice-rich terrain.

As mentioned previously in the discussion on climate change, the challenges of constructing and operating roads in warm discontinuous permafrost terrain are very evident on Highway 3 (Yellowknife to Behchoko) and Highway 7 (Liard Highway), both of which have been plagued by continuous settlement issues and instabilities, even after a significant reconstruction in the case of Highway 3. While it is noted there are some differences in the operational, service life and construction characteristics of the territorial highways as compared to the proposed Prairie Creek all-season road, there are some useful comparisons. The similarities in permafrost characteristics and terrain characteristics indicates that particular care needs to be taken in the design and construction of the all-season road, in order to mitigate the anticipated effects of road presence and operations.

8.1.3 Mitigative Measures

Numerous mitigation strategies are provided in documents from the Transportation Association of Canada (TAC 2005 and 2010) and from AANDC (INAC 2009, 2010a) to avoid or reduce adverse environmental effects due to road construction and borrow acquisition in the North. AANDC also has guidelines for camp and support facilities (INAC 2010b). Numerous resources are also available in the form of guidebooks, reports and other publications from the British Columbia Ministry of Forest, Lands and Natural Resource Operations (BCMF 2014a, 2014b), which include such topics as forest road engineering, best management practices for hillslope restoration, and karst management. The Karst Management Handbook may be particularly useful in parts of the route that traverse on or close to karst terrain (BCMF 2003). Parks is also preparing a National Parks Caving Directive which may have further information of value in karst terrain. Staff from NNPR should be contacted directly for information, since the directive is currently in draft form.

Construction will be managed such that travel across the ground does not occur when it is in its most vulnerable state. Currently, winter construction is proposed to take place when the ground is frozen, and construction access will be by winter road. Most of the existing winter road alignment in the vicinity of the proposed all-season route appears to have performed very well. Portions of the road that could have performed better provide good information on the types of terrain that require extra caution for the construction of the all-season road, for example, in the thermokarst terrain in the Fishtrap Creek drainage between about KP094.2 and KP095.7. Embankment fill-only (overlanding) techniques are proposed for these thaw-sensitive permafrost areas, meaning that no cut will take place and that the entire road grade will be composed of fill soils (TAC 2010).

Summer/fall construction is proposed to take place when the ground is seasonally more likely to be relatively dry. The benefit of summer/fall construction in terrain that is not thaw-sensitive is that the construction team will be able to see more clearly where the cross-drainage installations should be placed, and backfill placement and compaction will be greatly improved.

Summer/fall construction of the subgrade is not recommended for thaw-sensitive permafrost terrain, however. If construction of a working pad in thaw-sensitive permafrost terrain does not take place in winter, the only other opportunity to access that terrain would be very early in the thaw season. That is, the initial fill placement for a working pad along the route potentially could be done after the snow has gone, but before the subgrade starts to thaw. It should be noted, however, that the success of this method depends greatly on the contractor's ability to control his schedule, and leaving the construction of thaw-sensitive sections until winter is anticipated to be more reliable for protecting thaw-sensitive permafrost, and is therefore preferred. Fill material would be forward-hauled and placed so that no machinery comes into direct contact with the organic layer to be protected.

Because the road embankment can itself affect permafrost, the first strategy is to avoid thaw-sensitive terrain, where possible. If thaw-sensitive terrain cannot be avoided, embankments can be designed and constructed with thickness and width based on terrain type. In warm permafrost, a thicker embankment may not stop thaw of the permafrost, but it provides an additional buffer to reduce flexing of the underlying subgrade, and the additional width will help to keep early thaw at the embankment toes further away from the highest loaded area.

In areas where snow drifting proves to be an issue along the road, strategies to reduce snow drifting can be examined, designed and installed. It should be recognized that permafrost thaw is unlikely to be prevented, but it may be possible to mitigate the effects of thaw and settlement (TAC 2010).

Cutslopes in thaw-sensitive terrain should be avoided if at all possible. If cutslopes in thaw-sensitive terrain are unavoidable, mitigative solutions are limited and are accompanied by a much greater need for vigilance in monitoring and maintenance to avoid the types of situations described in Section 7.1.1 above. Depending on the site characteristics, it may be possible to protect some cutslopes with a drainage blanket to help mitigate the effects of thaw and meltwater (TAC 2010), or design near-vertical cutslopes to allow the organic layer to be draped over the cutslope to shade and protect it (INAC 2010a). However, these possibilities are not considered to be universal solutions.

Careful placement of culverts even where there are no obvious stream channels will help reduce the likelihood of ponding water alongside the road embankment. Permeable embankments may also be an option in some locations, particularly in areas of ice-rich permafrost, and these can be supplemented with an overlying culvert to pass spring flows (TAC, 2010). It is anticipated that regular inspections of drainage measures after installation will help to identify areas that might unexpectedly pond water, and corrective actions can be taken. The same applies to flowing surface water, and regular inspections will help identify areas where surface water drainage provisions need to be changed or improved.

The development, working and restoration of borrow sources will be carefully planned and carried out to reduce or avoid negative effects including permafrost thaw and soil erosion, in accordance with regional and national guidelines (INAC 2009, TAC 2010). Some general guidelines for borrow sources are as follows:

- Minimize the surface area of the open cut;
- Grade slopes to reduce slumping;
- Grade material storage and working areas to promote drainage and avoid standing water;
- Restore the borrow source when construction is completed by grading slopes to match the natural ground and drainage of the surrounding area, and replacing overburden.

A Sediment and Erosion Control Plan (SECP) can be prepared for the project. The proximity of watercourses, as well as fish habitat, wildlife habitat, and riparian areas downslope and within the road alignment reinforce the need for good erosion and sedimentation control during the course of construction and through the service life of the project. As well, disturbance of permafrost terrain, and subsequent permafrost thaw, are typical consequences of site development, so the SECP needs to mitigate the potential results of that disturbance.

The SECP would be based on the regulatory and Best Practices guidelines applicable to the project. It includes the following elements:

- A review of the applicable regulatory guidelines;
- An evaluation of existing site conditions and a summary of proposed conditions upon the completion of construction;
- Requirements for environmental monitoring including personnel, frequency of inspections, reporting and corrective actions;
- Best Management Practices for construction, including erosion control measures and sedimentation control measures; and

- Best Management Practices specific to permafrost and the mitigation of thermal erosion.

In general terms, all work needs to be conducted and completed in such a manner as to prevent the release of silt, sediment or sediment-laden water, construction wastes or other deleterious substances into streams, ponds or lakes.

8.1.4 Residual Effects

The road alignment, design and construction practices proposed are intended to help reduce the footprints required for the various construction requirements and operations, including borrow sources. As well, the currently proposed alignment is intended to take advantage of the most competent and least sensitive ground available along the general route, which should help to further reduce the impact.

It is anticipated that with careful surface water management that most if not all of the residual effects will be restricted to the footprint of road and borrow areas. Even the on-road effects can be reduced by good decommissioning practices that will allow the relatively rapid regrowth of vegetation, including scarifying the road surface to loosen the soil and allow moisture to infiltrate and rooting to occur more easily. The existing winter road also shows that where moisture and nutrients are available, excellent opportunities for regeneration are present and vigorous regrowth of trees is seen.

9.0 CUMULATIVE EFFECTS ASSESSMENT

Effects to terrain, soils, permafrost and karst from construction and operation of the all-season road may be cumulative to those from winter road construction and operation. However, for the most part, if the all-season road is approved, the winter road alignment will also be the all-season road alignment, and therefore there will be no cumulative aspect. As noted above, there will be approximately 9.4 km of winter road alignment that would not become the all-season road alignment. The KP024.3 to KP028.3 reroute will leave a winter road section on the north side of Sundog Creek. This section mostly crosses talus that naturally ravels, and thus is self-reclaiming for the most part, as has occurred since 1981. The KP090.6 to KP095 realignment avoids wetland terrain, and will leave a winter road section crossing sparsely vegetated wetland. This section appears to be naturally reclaiming by gradual encroachment of vegetation from both sides of the ROW, and would do so again after renewed winter use. The KP122 to KP123 realignment also avoids wetland terrain, whereas the winter route will naturally revegetate when no longer in use. In addition to these realignments, there is the original winter road footprint marked by absent or different vegetation which has long wetland sections that will not be used for the new winter road. In general, these appear to be naturally reclaiming by gradual encroachment of vegetation from the sides of the ROW. Therefore, in summary, no significant cumulative impacts to terrain, soils, permafrost and karst are anticipated from the all-season road.

10.0 CLOSURE

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

Respectfully submitted,
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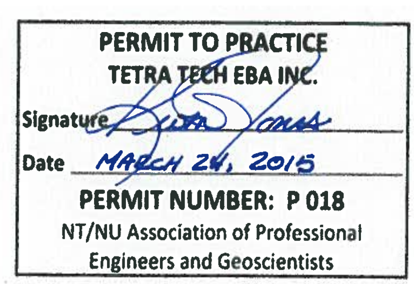

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APPENDIX A

TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

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

1.0 USE OF REPORT AND OWNERSHIP

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

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

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

2.0 ALTERNATE REPORT FORMAT

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

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

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

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

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

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

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

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

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

5.0 LOGS OF 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.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

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

7.0 PROTECTION OF EXPOSED GROUND

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

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

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

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

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

10.0 OBSERVATIONS DURING CONSTRUCTION

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

11.0 DRAINAGE SYSTEMS

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

12.0 BEARING CAPACITY

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

13.0 SAMPLES

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

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

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

APPENDIX B
TESTHOLE LOGS AND LABORATORY TEST RESULTS

TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075mm 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 0.3m)
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 51mm O.D. split spoon sampler of a 63.5kg weight falling 0.76m, required to drive the sampler a distance of 0.3m from 0.15m to 0.45m.

FINE GRAINED SOILS (major portion passing 0.075mm 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

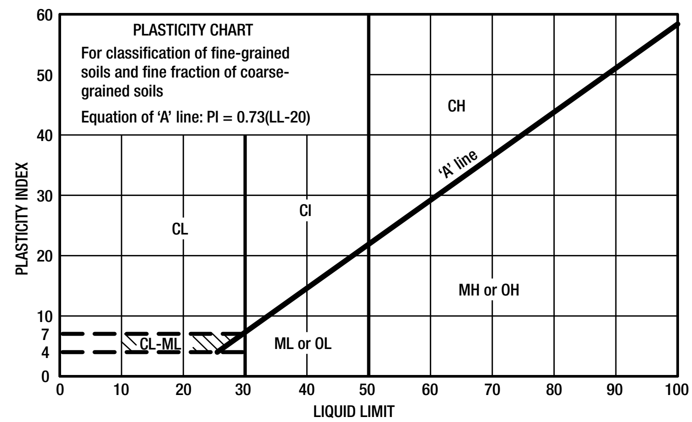
NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

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.

MODIFIED UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA		
COARSE - GRAINED SOILS More than 50% retained on No. 75 µm sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% pass 75 µm sieve: GW, GP, SW, SP More than 12% pass 75 µm sieve: GM, GC, SM, SC 5% to 12% pass 75 µm sieve: 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 and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60} / D_{10}$ 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 above 'A' line and 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 and 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			
		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			
		Liquid limit 30-50	CI	Inorganic clay of medium plasticity, silty clays			
		Liquid limit >50	CH	Inorganic clay of high plasticity, fat clays			
	ORGANIC SILTS AND CLAYS	Liquid limit <50	OL	Organic silts and organic silty clays of low plasticity			
		Liquid limit >50	OH	Organic clays of medium to high plasticity			
HIGHLY ORGANIC SOILS			PT	Peat, muck and other highly organic soils			

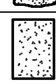


* Based on the material passing the 75 mm sieve

† ASTM Designation D 2487, for identification procedure see D 2488 USC as modified by PFRA

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	
N	Nf	Poorly-bonded or friable	
	Nbn	No excess ice, well-bonded	
	Nbe	Excess ice, well-bonded	

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	
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	

VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions	
	ICE	Ice without soil inclusions (greater than 25 mm thick)	

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.

LEGEND: Soil ☐ Ice ■

KP024.3 TO KP028.3

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP025.5 EAST SIDE OF TRIBUTARY	DRILL: PICK AND SHOVEL	Y14103320-01-TP08
NEAR NAHANNI BUTTE, NT	6828718N; 417869E; Zone 10	

SAMPLE TYPE	DISTURBED	NO RECOVERY	SPT	A-CASING	SHELBY TUBE	CORE
BACKFILL TYPE	BENTONITE	PEA GRAVEL	SLOUGH	GROUT	DRILL CUTTINGS	SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - silty, sandy, trace to some cobbles, trace of boulders at ground surface, (150 mm thick)						0
	GRAVEL (GLACIOFLUVIAL) - trace to some sand, trace to some cobbles, trace of boulders, trace of silt and clay, trace of organics - trace of organics, gravel to 38 mm diameter, sample 150 mm minus	Disturbed	S1				
	END OF TESTPIT (0.30 m) Note: East side tributary crossing, near top edge of proposed full bench cut.						
1							
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.3m
	REVIEWED BY: KJ	COMPLETE: 14/09/23
	DRAWING NO:	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Prarie Creek All Season Road

Project Number: Y14103320-01

Date Tested: November 10, 2014

Borehole Number: TP-08

Depth: 0.2-0.3 m

Soil Description: GRAVEL, some sand, trace fines (silt/clay)

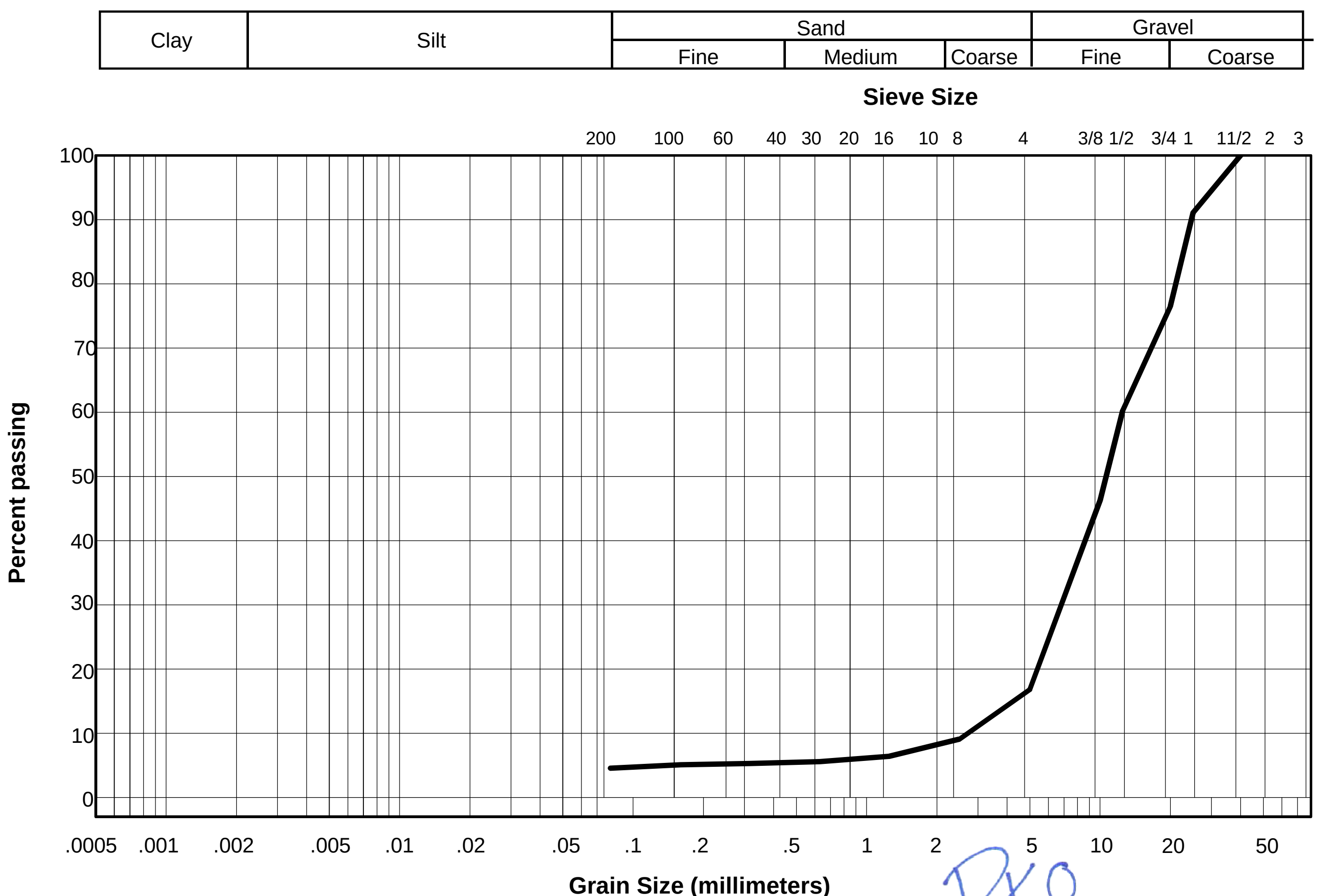
Cu: 4.6

Cc: 1.4

Natural Moisture Content: 3.2%

Remarks:

Sieve Size (mm)	Percent Passing
50	#N/A
40	100
25	91
20	76
12.5	60
10	46
5	17
2.5	9
1.25	6
0.63	6
0.315	5
0.160	5
0.080	4.6



Reviewed By: RKO P.Eng.

TETRA TECH

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP025.54 EAST SIDE OF TRIBUTARY	DRILL: PICK AND SHOVEL	Y14103320-01-TP08A
NEAR NAHANNI BUTTE, NT	6828714N; 417896E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000; SPT (N) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80; SILT (%) 20 40 60 80; SAND (%) 20 40 60 80; GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - (50 mm thick)					0
	SAND AND GRAVEL (GLACIOFLUVIAL) - cobbles to 120 mm diameter, coarse grained sand, gravel and cobbles are flat and elongated					
	END OF TESTPIT (0.30 m) Note: East side of tributary crossing, just above heli landing area.					
1						
						5
2						
3						10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.3m
	REVIEWED BY: KJ	COMPLETE: 14/09/23
	DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP025.3 WEST SIDE OF TRIBUTARY	DRILL: PICK AND SHOVEL	Y14103320-01-TP09
NEAR NAHANNI BUTTE, NT	6828766N; 417746E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - sandy, rootlets, (250 mm thick)						0
	GRAVEL AND COBBLES (GLACIOFLUVIAL) - some sand, trace of silt and clay, trace of organics, subangular cobbles to 150 mm diameter, samples 150 mm minus	DISTURBED	S1				
	END OF TESTPIT (0.45 m) Note: West side tributary crossing, road crest, est. ~4 m cut on top of bench.						
1							
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.45m
	REVIEWED BY: KJ	COMPLETE: 14/09/23
	DRAWING NO:	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Prarie Creek All Season Road

Project Number: Y14103320-01

Date Tested: November 10, 2014

Borehole Number: TP-09

Depth: 0.4-0.45 m

Soil Description: GRAVEL, some sand, trace fines (silt/clay)

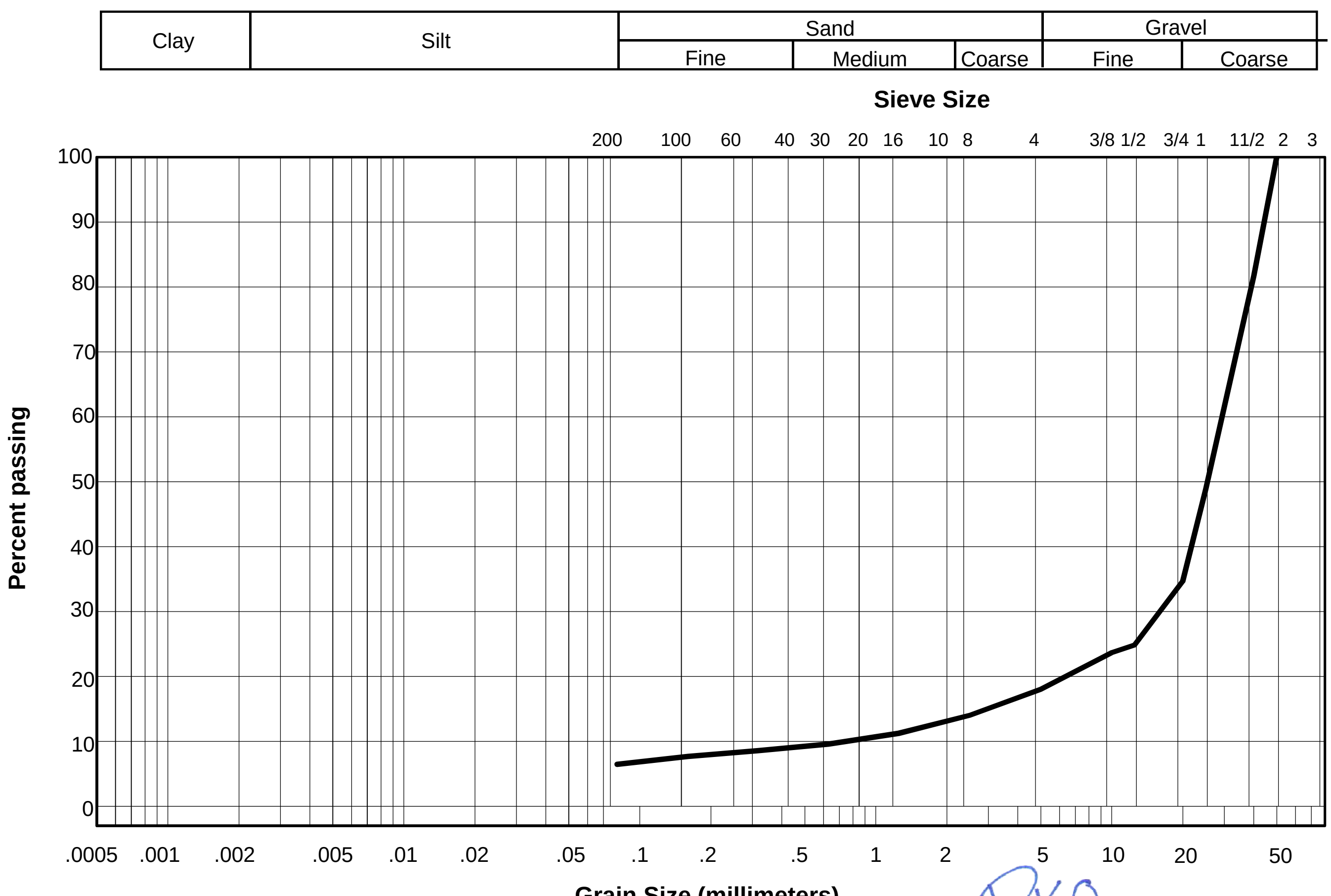
Cu: 39.0

Cc: 11.6

Natural Moisture Content: 6.6%

Remarks:

Sieve Size (mm)	Percent Passing
50	100
40	82
25	49
20	35
12.5	25
10	24
5	18
2.5	14
1.25	11
0.63	10
0.315	9
0.160	8
0.080	6.5



Reviewed By: RKO P.Eng.

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TETRA TECH

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP025.65 ON TREED TERRACE/LEDGE	DRILL: PICK AND SHOVEL	Y14103320-01-TP10
NEAR NAHANNI BUTTE, NT	6828645N; 418005E; Zone 10	

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - (50 mm thick)						0
	SILT (probable COLLUVIUM) - trace of sand, trace of clay, moist, light brown, organic pockets						
	- some sand, some gravel to 75 mm diameter, no visible organics, light yellowish brown						
	- brown	DISTURBED	S1		● (M.C.)		
	END OF TESTPIT (0.45 m) Note: Along forested bench east of tributary.						
1							
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.45m
	REVIEWED BY: KJ	COMPLETE: 14/09/23
	DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP025.6 ON TREED TERRACE/LEDGE	DRILL: PICK AND SHOVEL	Y14103320-01-TP11
NEAR NAHANNI BUTTE, NT	6828658N; 417973E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	SAND AND SILT (probable COLLUVIUM) - trace of clay, damp, light brown						0
	SILT (probable COLLUVIUM) - trace to some sand, trace of clay						
1	- trace to some gravel to 38 mm diameter - becoming gravelly	DISTURBED	S1		●		
	END OF TESTPIT (1.20 m) Note: Located in suspected suffosion hole near west end of treed bench.						
2							5
3							10

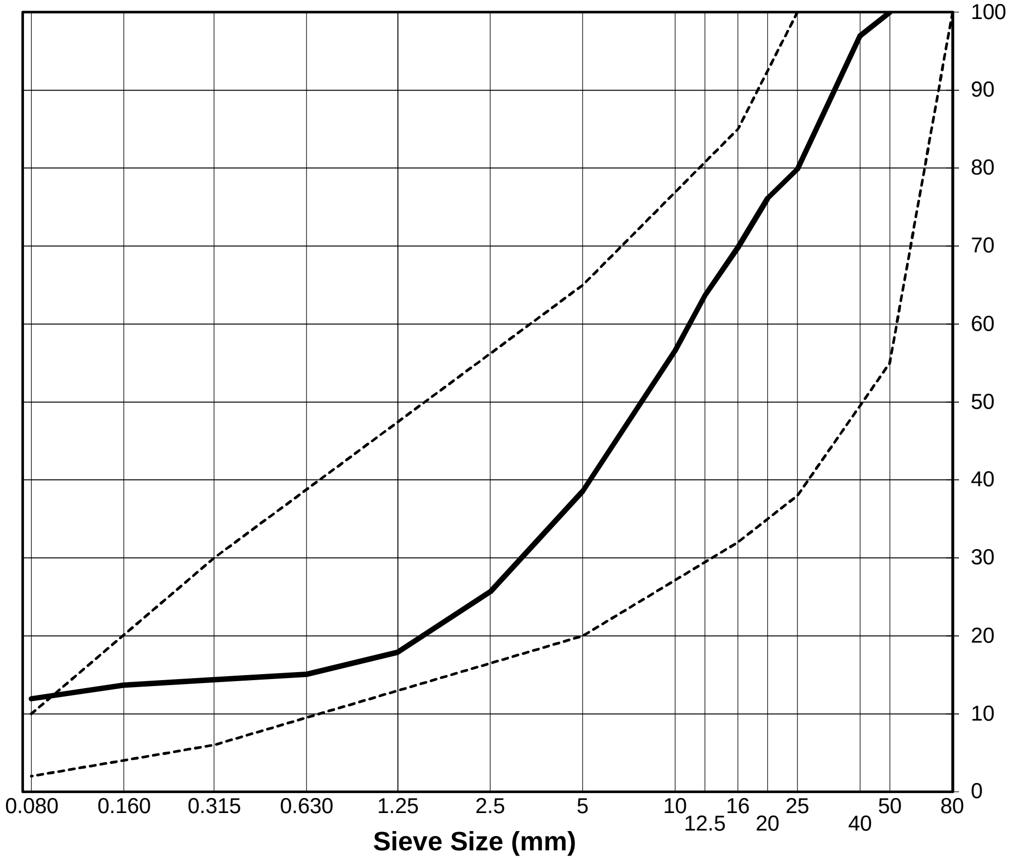
TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 1.2m
	REVIEWED BY: KJ	COMPLETE: 14/09/23
	DRAWING NO:	Page 1 of 1

SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.:	Y14103320-01	Sample No.:	6161 / Allnorth KP026
Project:	Prairie Creek All-Season Road	Date Received:	October 9, 2014
Client:	Canadian Zinc Corporation	Sampled by:	EK (Allnorth)
Attention:	David Harpley	Date Tested:	December 5, 2014
Email:	david@canadianzinc.com	Tested by: JD	Office: Yellowknife
Description:	GRAVEL, sandy, some silt/clay	Moisture Content (as received):	6.6%
		No. Crushed Faces:	Two (2) or Three (3)
Source:	BP 25	By Particle Mass:	
Supplier:	n/a		
Sample Location:	Proposed borrow area at about KP025.6		
Specification:	GNWT 80mm Gravel Fill		

Sieve Size	Percent Passing
50	100
40	97
25	80
20	76
16	70
12.5	64
10	57
5	39
2.5	26
1.25	18
0.630	15
0.315	14
0.160	14
0.080	11.9



Remarks: Sampled from alluvial mound at 61.583084°N, 124.546565°W.

Sampled 50 mm minus. Cobbles up to 120 mm present, gravel/cobbles are flat/elongated. Oversize on slope.

Reviewed By: RKO P.Eng.

KP048.8 TO KP058.6

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP049.7 UPPER CROSSING POLJE REROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH01
NEAR NAHANNI BUTTE, NT	6829758.7N; 436880E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	SILT - some fine grained sand, some clay, wet, brown grey, likely slough from scarp upslope						0
		Disturbed	S1				
	CLAY (possible TILL) - silty, some fine grained sand, free water, medium plastic, sand lenses						
		Disturbed	S2				
1							
		Disturbed	S3				
	END OF BOREHOLE (1.20 m) Note: Burn area. Slope failure on west side of creek near HP50, upper proposed crossing.						
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 1.2m
	REVIEWED BY: KJ	COMPLETE: 14/09/21
	DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP049.9 POLJE REROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH02
NEAR NAHANNI BUTTE, NT	6829694N; 437305E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m^3) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	TURF AND TOPSOIL - (100 mm thick)						0
	SAND - trace to some silt, fine to medium grained, damp, reddish brown, trace of oxides	DISTURBED	S1				
	- fine grained, brown	DISTURBED	S2				
1	- damp to moist	DISTURBED	S3		M.C. ●		
	END OF BOREHOLE (1.15 m) Note: Burn area.						5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1.15m
REVIEWED BY: KJ	COMPLETE: 14/09/21
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP049.95 POLJE REROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH03
NEAR NAHANNI BUTTE, NT	6829733N; 437383E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT AND DUFF - sandy, (80 mm thick)						0
	SAND - trace to some silt, fine to medium grained, damp, reddish brown						
1							
		DISTURBED	S1		●	■ ● ▲	
	END OF BOREHOLE (1.15 m) Note: Burn area.						
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1.15m
REVIEWED BY: KJ	COMPLETE: 14/09/21
DRAWING NO:	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM C136 & C117

Project: Prairie Creek All-Season Road

Project Number: Y14103320-01

Date Tested: December 5, 2014

Borehole Number: BH 3, S1

Depth: 1.05m - 1.15m

Soil Description: SAND, some silt, damp, brown

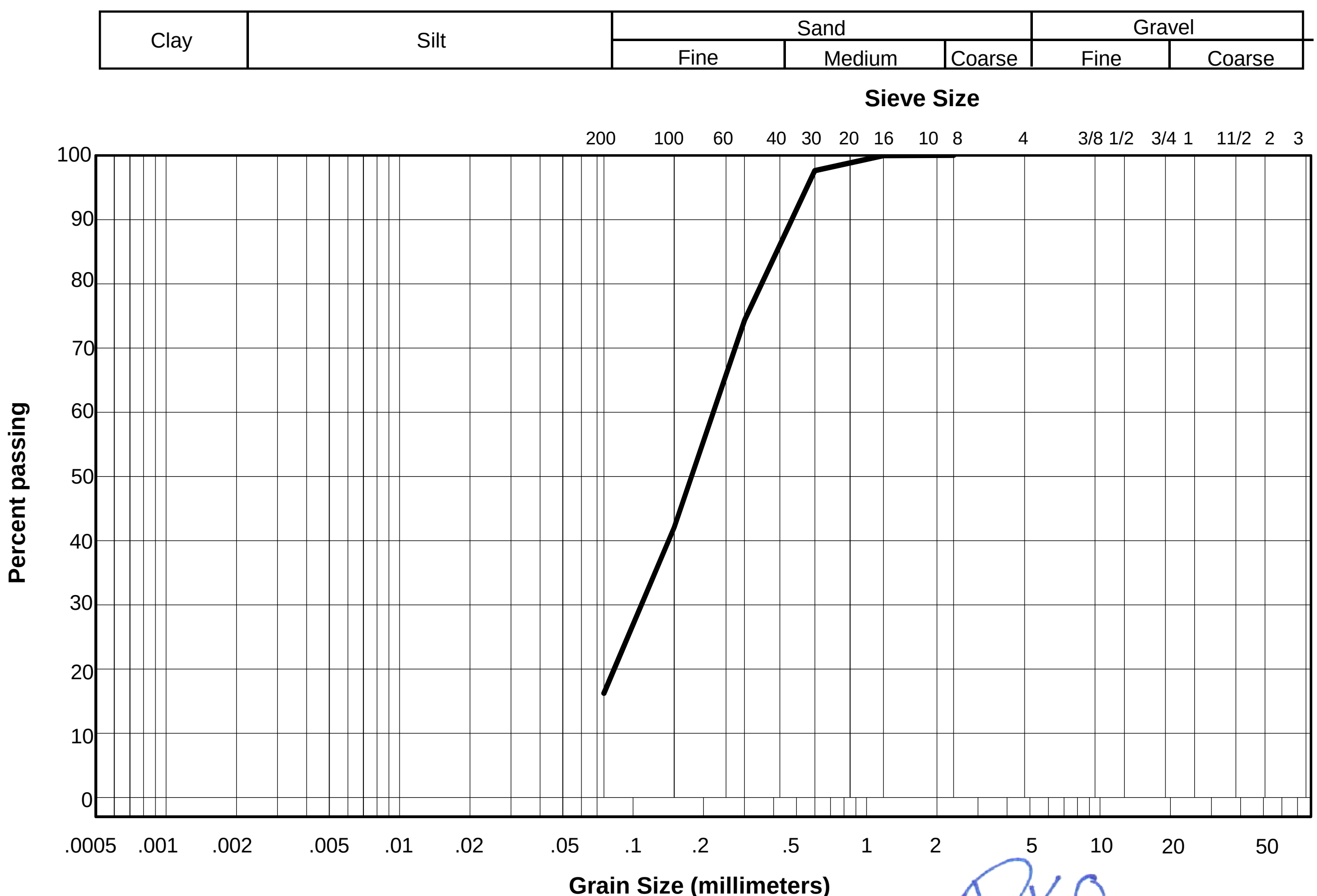
Cu:

Cc:

Natural Moisture Content: 5.0%

Remarks:

Sieve Size (mm)	Percent Passing
50.000	
37.500	
25.000	
19.000	
12.500	
9.500	
4.750	
2.360	
1.180	100
0.600	98
0.300	74
0.150	42
0.075	16.2



Reviewed By: RKO P.Eng.

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PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP050.5 POLJE REROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH04
NEAR NAHANNI BUTTE, NT	6829960N; 437825E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000; SPT (N) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80; SILT (%) 20 40 60 80; SAND (%) 20 40 60 80; GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT AND TURF - (100 mm thick)						0
	SAND - fine to medium grained, damp to moist, grey brown becoming reddish brown						
	- slightly coarser grained						
	- grey brown						
1	- trace of silt, damp to moist, clay lumps	DISTURBED	S1		● (M.C.)		
	END OF BOREHOLE (1.10 m) Note: Tributary valley slope.						
2							5
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1.1m
REVIEWED BY: KJ	COMPLETE: 14/09/21
DRAWING NO:	Page 1 of 1

MECHANICAL SIEVE ANALYSIS

Sample No. **N/A** Date Sampled **October 2012** By **M.L.** of **SNC Lavalin Group Inc.**

Location **Prairie Creek Mine** Sample Type **Bag** Natural Moisture **3.9** %

Description **Sand, trace clay, trace silt (Marked as "Km 52 Sand Pit")** Tech **G.S.**

Specifications

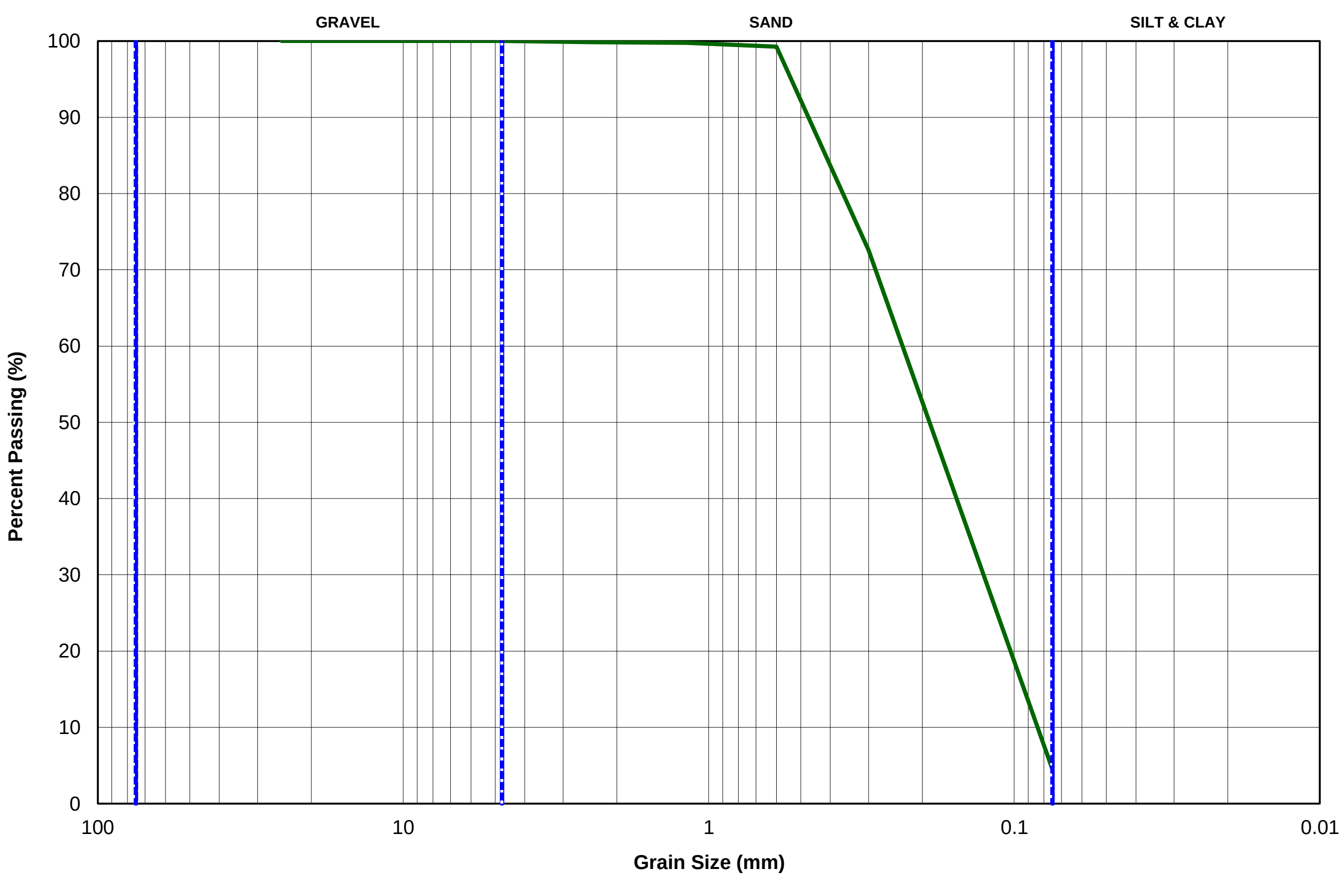
Comments Sample "Km 52 Sand Pit"

Fracture **N/A** Method **N/A**

Sieve Results

Sieve mm	25	19	9.5	4.75	2.36	1.18	0.60	0.30	0.075
% Passing	100.0	100.0	100.0	100.0	99.8	99.7	99.2	72.6	4.5

By Type Gravel = **0.0%** Sand = **95.5%** Silt & Clay = **4.5%**



Harder Associates engineering consulting inc.
Member of the SNC•LAVALIN Group

Client **SNC Lavalin Group Inc.** Date **20-Oct-12**

Project **2012 Materials Testing** File No. **FN364**

Location **Fort Nelson, British Colubmia** Sample No. **N/A**

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP053.95 ABOUT 30 m SOUTH OF ROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH05
NEAR NAHANNI BUTTE, NT	6830925N; 440985E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT - fibrous, (300 mm thick)						0
	SILT (possible GLACIAL OUTWASH) - sandy, trace of clay, damp, light brown	Disturbed	S1				
	- nuggetty, moist						
	SAND (POSSIBLE GLACIAL OUTWASH) - some silt, trace of clay, moist						
1	- silty, moist to wet						
	- wet, grey, cold	Disturbed	S2		●		
	END OF BOREHOLE (1.20 m) Note: Southwest of bedrock outcrops, about 90 m north of slump. Permafrost probably close to end of borehole.						
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1.2m
REVIEWED BY: KJ	COMPLETE: 14/09/22
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP049.75 POLJE REROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP01
NEAR NAHANNI BUTTE, NT	6829644N; 437158E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	TURF - (150 mm thick)						0
	SAND - silty, fine to medium grained, reddish grey brown, silt or clayey silt laminations	DISTURBED	S1				
	END OF TESTPIT (0.45 m) Note: Lower crossing below HP50, east sideslope in burn area.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.45m
REVIEWED BY: KJ	COMPLETE: 14/09/21
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP049.8 POLJE REROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP02
NEAR NAHANNI BUTTE, NT	6829656N; 437195E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m^3) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	TURF - (100 mm thick)						0
	SAND - silty, fine to medium grained, reddish grey brown	Disturbed	S1				
	END OF TESTPIT (0.35 m) Note: East side of swale ~KP50.5, burn area						
1							
							5
2							
3							10

LOGGED BY: RKO	COMPLETION DEPTH: 0.35m
REVIEWED BY: KJ	COMPLETE: 14/09/21
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP049.85 POLJE REROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP03
NEAR NAHANNI BUTTE, NT	6829701N; 437244E; Zone 10	

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	TURF - (100 mm thick)						0
	SAND - some silt, trace to some organics, trace of clay	DISTURBED	S1				
	- occasional gravel or cobble	DISTURBED	S2				
	END OF TESTPIT (0.55 m) Note: Burn area						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.55m
REVIEWED BY: KJ	COMPLETE: 14/09/21
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP053.8 ABOUT 100 m SOUTH OF ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP06
NEAR NAHANNI BUTTE, NT	6830777N; 440912E; Zone 10	

SAMPLE TYPE	DISTURBED	NO RECOVERY	SPT	A-CASING	SHELBY TUBE	CORE
BACKFILL TYPE	BENTONITE	PEA GRAVEL	SLOUGH	GROUT	DRILL CUTTINGS	SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m^3) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT AND TURF - (300 mm thick)						0
	SILT (possible GLACIAL OUTWASH) - clayey, low plastic						
		DISTURBED	S1				
1	CLAY (possible TILL) - silty, moist, firm, medium to high plastic	DISTURBED	S2				
							5
	- some sand, wet, dark grey, sliding surface	DISTURBED	S3				
2	END OF TESTPIT (2.00 m) Notes: Intermediate scarp in Polje permafrost thaw slump/flow in burn area, about 30 m upslope (east) of Polje Creek. Sliding surface, backscarp is bowl-shaped, debris flow type behaviour.						
3							10

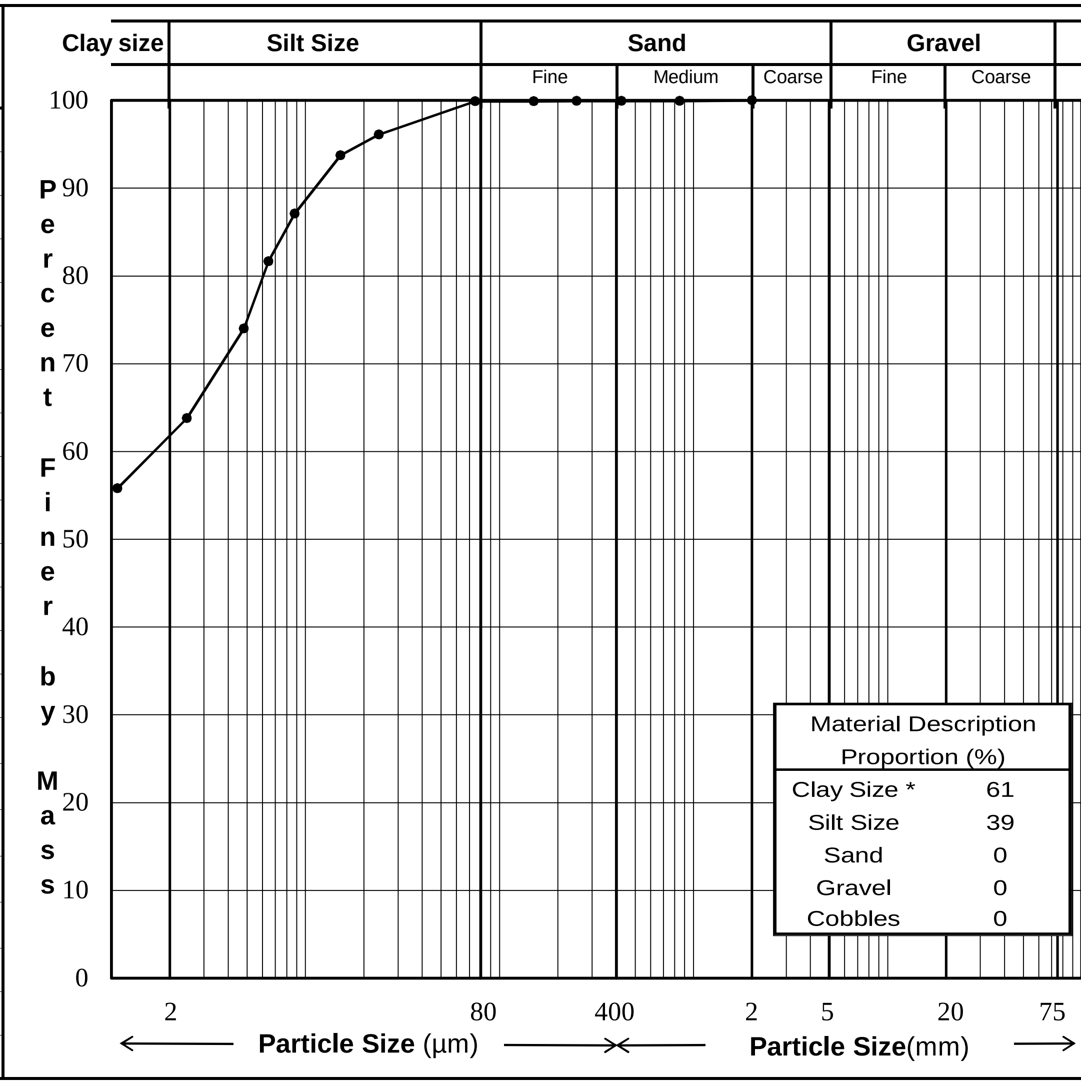
TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 2m
	REVIEWED BY: KJ	COMPLETE: 14/09/22
	DRAWING NO:	Page 1 of 1

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Prairie Creek All-Season Road	Sample No.:	
Client:	Canadian Zinc Corp.	Borehole/ TP:	TP06
Project No.:	Y14103320-01	Depth:	1.9m - 2.0m
Location:	~30 m above toe of thaw slump/flow at KP054	Date Tested	December 8, 2014
Description **:	CLAY, silty, brown	Tested By:	MC

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
19 mm	
13 mm	
10 mm	
5 mm	
2 mm	100
850 µm	100
425 µm	100
250 µm	100
150 µm	100
75 µm	100
34 µm	96
22 µm	94
13 µm	87
9 µm	82
6 µm	74
3 µm	64
1 µm	56



Material Description	Proportion (%)
Clay Size *	61
Silt Size	39
Sand	0
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Reviewed By: RKO P.Eng.

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP054.2 ABOUT 100 m WEST OF ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP07
NEAR NAHANNI BUTTE, NT	6830823N; 441132E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	USC	SOIL SYMBOL	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ / ● SILT (%) ● / ▲ SAND (%) ▲ / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT AND TURF- (300 mm thick)								0
	SILT (possible GLACIAL OUTWASH) - some sand to sandy, trace of angular, flat and elongated gravel to 120 mm diameter, trace of clay, dark brown to black, layers, lenses, varving, interspersed coarse particles oriented with layers	DISTURBED	S1						
1									
	SAND (GLACIOFLUVIAL or OUTWASH) - trace of gravel, medium to coarse grained, damp, brown, occasional grey brown layer	DISTURBED	S2						5
	SHALE (GLACIOFLUVIAL or OUTWASH) - boulders, discontinuous, thinly laminated, moist, black	DISTURBED	S3A						
2	CLAY (possible TILL) - silty, nuggetty, moist, firm, medium to high plastic - soft - soft to firm, apparent sliding surface now thawed - high plastic	DISTURBED	S3	CH			●(plotted with plastic-liquid range)	▲ ● ◆	
	END OF TESTPIT (2.50 m) Note: Headscarp of Polje permafrost thaw slump/flow. Stopped due to auger refusal on suspected permafrost. Upper 2.25 metres is mapped headscarp. Lower 0.25 metres is borehole.								
3									10

TETRA TECH EBA

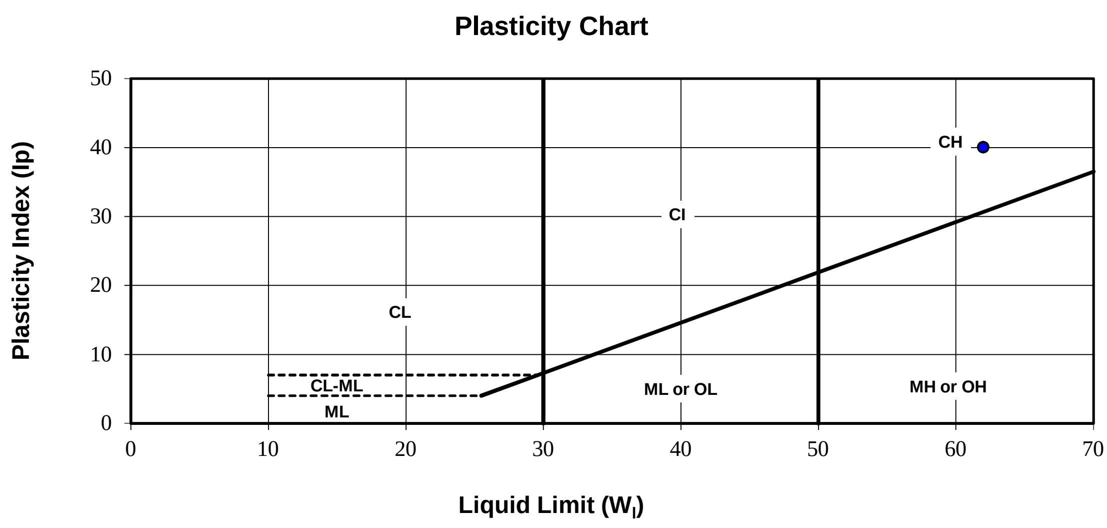
LOGGED BY: RKO	COMPLETION DEPTH: 2.5m
REVIEWED BY: KJ	COMPLETE: 14/09/22
DRAWING NO:	Page 1 of 1

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Prairie Creek All-Season Road	Sample Number:	S3
		Borehole Number:	TP 07
Project No:	Y14103320-01	Depth:	1.85 - 1.95 m
Client:	Canadian Zinc Corp.	Sampled By:	RKO Tested By: MC, KTP
Attention:	David Harpley	Date Sampled:	September 22, 2014
Email:	david@canadianzinc.com	Date Tested:	January 12, 2015

Sample Description: CLAY, silty, trace sand, brown.



Liquid Limit ($W_{1)}$:	62	Natural Moisture (%)	
Plastic Limit :	22	Soil Plasticity:	High
Plasticity Index (Ip) :	**40**	Mod.USCS Symbol:	CH

Remarks:

Reviewed By: RKO P.Eng.

Data presented hereon is for the sole use of the stipulated client. Tetra Tech EBA 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 EBA. 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 EBA will provide it upon written request.

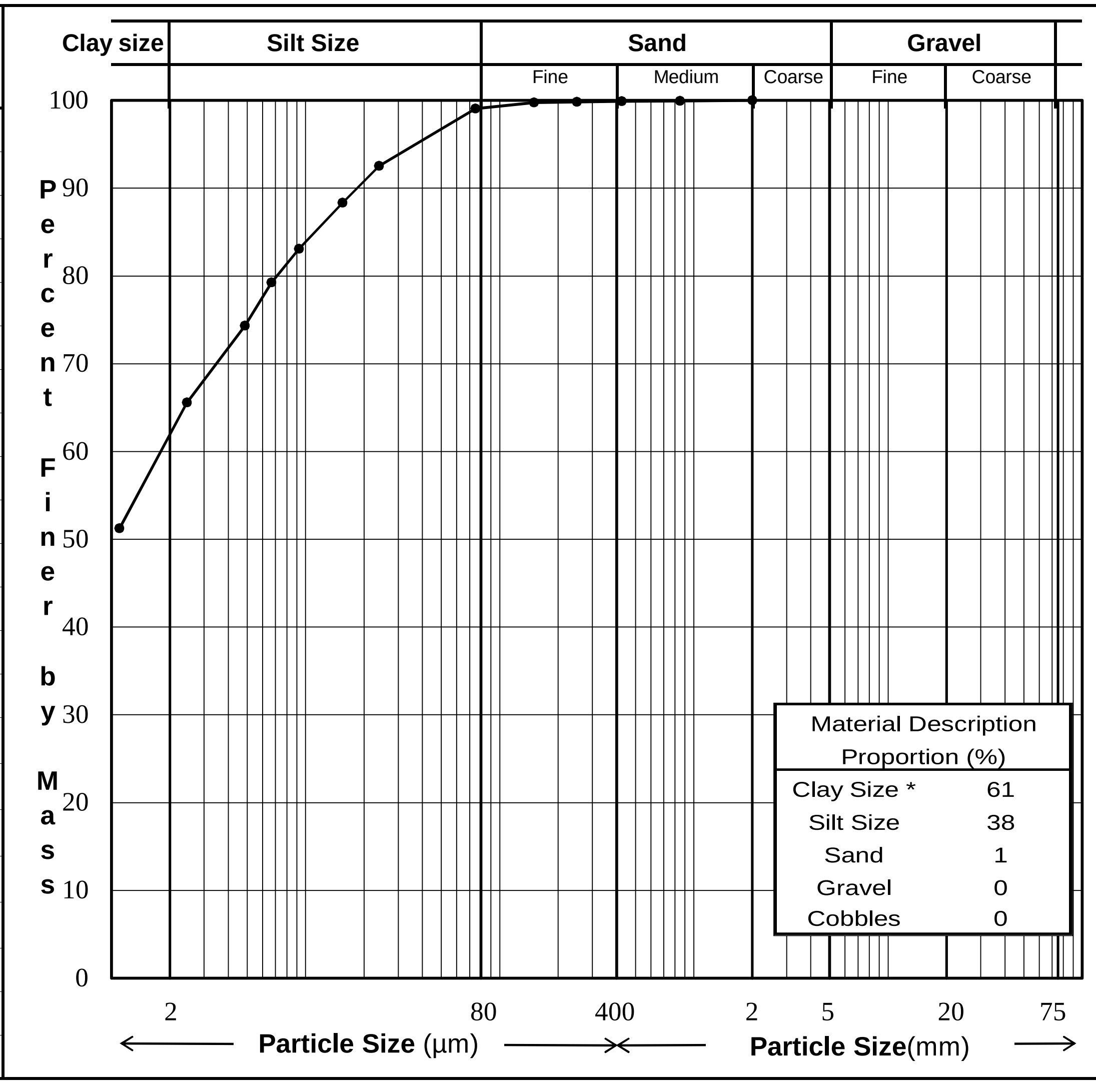
TETRA TECH

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Prairie Creek All-Season Road	Sample No.:	
Client:	Canadian Zinc Corp.	Borehole/ TP:	TP07
Project No.:	Y14103320-01	Depth:	1.85m - 1.95m
Location:	Headscarp of thaw slump/flow at KP054	Date Tested	December 8, 2014
Description **:	CLAY, silty, trace sand, brown	Tested By:	MC

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
19 mm	
13 mm	
10 mm	
5 mm	
2 mm	100
850 µm	100
425 µm	100
250 µm	100
150 µm	100
75 µm	99
34 µm	93
22 µm	88
13 µm	83
9 µm	79
6 µm	74
3 µm	66
1 µm	51



Material Description	Proportion (%)
Clay Size *	61
Silt Size	38
Sand	1
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Reviewed By: RKO P.Eng.

TETRA TECH

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-PJ-01**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Polje crossing**	Start Date (yyyy-mm-dd)	**2012-09-28**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-28**
Coordinates	6830794 N, 440704 E	Elevation (m)	**710 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Water Content (%)	Water Level	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	710.00	Ground Surface							
		TOPSOIL Black silty sandy organics, dry							
	709.5 / 0.5	**SAND** Very loose, light brown, fine SAND, poorly graded, moist	⊗	▼	0 0 3 6 5	3			8 83 9
1	709.1 / 0.9	Medium to coarse, trace gravel							
		GRAVEL Compact, light brown, coarse sandy GRAVEL			0 5 6 5 5	11			
2	707.9 / 2.1	END of BOREHOLE at 2.1 m			5 7 7 6	14			

SNC·LAVALIN

Borehole Log

Project **Prairie Creek, Northwest Territory**

Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-PJ-02**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Polje Crossing**	Start Date	**2012-09-28** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-28** (yyyy-mm-dd)
Coordinates	6830799 N, 440704 E	Elevation (m)	**710 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	710.00	Ground Surface									
	709.9 / 0.2	TOPSOIL Silty organics, moist									
		SAND Very loose, brown, coarse SAND, some gravel, moist					1 1 2 3 2	3			
1	709.0 / 1.0	Wet, trace silt, some cobbles		▼							
		GRAVEL Loose, dark grey, coarse, sandy GRAVEL, trace silt, some cobbles, wet					2 3 4 9 11	7			
2	707.9 / 2.1	Compact at 1.9 m					12 11 7 5 8	18			
		END of BOREHOLE at 2.1 m									

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-PJ-03**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**Polje Crossing**	Start Date	**2012-09-28** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-28** (yyyy-mm-dd)
Coordinates	6830795 N, 440704 E	Elevation (m)	**710 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100 200 300 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Elevation (m) / Depth (m)	Description	Water Content (%)	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
710.00	Ground Surface								
709.9 / 0.1	TOPSOIL Black, organics								
	SAND Loose, brown, fine SAND, poorly graded, moist to wet								
708.7 / 1.3	HOLE COLLAPSED	⊗							57 40 3
708.1 / 1.9	END of BOREHOLE at 1.9 m								

Depth (m): 1

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Borehole Log

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-PJW-01**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Polje Crossing**	Start Date	**2012-09-28** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-28** (yyyy-mm-dd)
Coordinates	6830788 N, 440673 E	Elevation (m)	**710 m**

Project **Prairie Creek, Northwest Territory**

Contract **610984**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Water Content (%)	SPT Blow Counts	N-value (# blows/0.3m)	Gr Sa Si/Cl
	710.00	Ground Surface				
	709.9 / 0.2	TOPSOIL Soft, grey, organic, silt, moist				
1		SAND Very loose, light brown, fine SAND, trace silt, moist		0 0 0 1 2	1	
	708.5 / 1.5			2 2 3 3 3	5	
	708.3 / 1.7	SILT Loose, light brown SILT, wet				
2		GRAVEL Very loose, dark grey, coarse, sandy GRAVEL, trace shale, wet	~37	1 1 3 13 13	4	1 29 70
		Compact at 2.65 m		9 9 9 6 3	18	
3	707.0 / 3.0	END of BOREHOLE at 3.0 m				

Water level ▼ at approx. 1.5 m.

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-PJW-02**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Polje Crossing**	Start Date (yyyy-mm-dd)	**2012-09-28**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-28**
Coordinates	6830790 N, 440673 E	Elevation (m)	**710 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	710.00	Ground Surface									
	709.8 / 0.3	TOPSOIL Brown, silt, trace organics, moist									
1		SAND Very loose, light brown, fine SAND, moist					0 0 1 1 2	1			
	708.6 / 1.4	Loose at 1.15 m Trace silt					7 5 5 12 13	10			
2		GRAVEL Compact, dark grey, coarse, sandy GRAVEL, wet		▼			11 10 9 10 9	19			
	707.7 / 2.3	END of BOREHOLE at 2.3 m									

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-PJW-03**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**Polje Crossing**	Start Date (yyyy-mm-dd)	**2012-09-28**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012/09028**
Coordinates	6830792 N, 440673 E	Elevation (m)	**710 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS, Q Test, P.P. (US); Field Vane: Intact, Remold; Lab. Vane: Intact, Remoulded; 100, 200, 300, 400 kPa
Water Content (%), Plastic Limit (%), Liquid Limit (%): 20, 40, 60, 80

Samples/Field Tests: Sample Condition, Type & Number, SPT Blow Counts, N-value (# blows/0.3m), Recovery %, RQD %, Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Water Content (%)	Gr Sa Si/Cl
	710.00	Ground Surface		
		TOPSOIL Light brown, organic sandy silt, moist	~40	0 33 67
	709.6 / 0.5	**SAND** Light brown, fine SAND, some silt, moist	~17	0 77 23
1				
	708.7 / 1.3	**SILT** Loose, light brown, SILT, wet		
	708.5 / 708.4 / 708.3 / 1.7	**SAND** Light brown, SAND, wet	~10	60 37 3
2	708.0 / 2.0	**GRAVEL** Loose, dark grey, coarse, sandy GRAVEL, wet		
		SAND Light brown, medium to fine, SAND, trace shale, wet		
		END of BOREHOLE at 2.0 , Blocked on a 76 mm shale fragment		

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky mountain**	Borehole ID	**BH-M-01**
Method	**2 inch Pionjar**	Page	**1 of 1**
Location	**M Switchbacks**	Start Date	**2012-09-24** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-24** (yyyy-mm-dd)
Coordinates	6829038 N, 442339 E	Elevation (m)	**456 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m^3)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100 200 300 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Depth (m)	Elevation (m) / Depth (m)	Stratigraphy – Description	Stratigraphic Plot	Piezometer Installation and Water Level	Field Undrained Shear C_u/Lab Tests	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	456.00	Ground Surface										
	455.9 / 0.2	SILT Loose, grey and light brown, SILT, slightly moist										
	455.3 / 0.7	CLAY Silty CLAY, trace shale, organic, slightly moist										
1		SAND Brown, coarse, gravelly SAND, trace silt and shale, organic, moist Some silt and shale										
	454.0 / 2.0	Some gravel										
		END of BOREHOLE at 1.98 m 2 inch and 3 inch Pionjar refusal at 1.98 m										

SNC·LAVALIN

Borehole Log

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-M-02**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**M Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-24**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-24**
Coordinates	6829110 N, 442365 E	Elevation (m)	**455 m**

Project **Prairie Creek, Northwest Territory**

Contract **610984**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa

Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description
	455.00	Ground Surface
	454.7 / 0.3	TOPSOIL Black and brown, organics and gravelly organic clay, trace shale, moist, cold
1		SAND Brown, coarse SAND, trace shale, moist, cold
2		Frozen at 1.96 m
3		
	451.2 / 3.8	END of BOREHOLE at 3.8 m

PRAIRIE CREEK 610984 PRAIRIE CREEK.GPJ GEOTECH.GDT 11/14/12

SNC·LAVALIN

Borehole Log

Project	Prairie Creek, Northwest Territory
Contract	610984
Drilling Company	Rocky Mountain
Method	3 inch pionjar
Location	M Switchbacks
Logged/Reviewed by	MP Lachance
Coordinates	6829298 N, 442400 E
Borehole ID	BH-M-03
Page	1 of 1
Start Date (yyyy-mm-dd)	2012/23/09
End Date (yyyy-mm-dd)	2012-09-23
Elevation (m)	455 m

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level
	455.00	Ground Surface		
0 – 1.3		TOPSOIL Black, TOPSOIL, some clay, some gravel, moist		
	453.7 / 1.3	GRAVEL Dark grey, GRAVEL, some coarse sand, trace silt, moist		
	452.4 / 2.6	END of BOREHOLE at 2.57 m 3 inch Pionjar Refusal		

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-M-04**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**M Switchbacks**	Start Date	**2012-09-24** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-24** (yyyy-mm-dd)
Coordinates	6829475 N, 442352 E	Elevation (m)	**827 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); Field Vane: Intact, Remold; Lab. Vane: Intact, Remoulded; 100 200 300 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description
	827.00	Ground Surface
	826.8 / 0.2	TOPSOIL Soft, black and light brown, organics and organic silt, trace shale, moist
1	826.1 / 0.9	SILT Very loose, light brown, grey, SILT Some shale
2		SAND Loose, black, coarse silty SAND, some shale, moist Dark grey and brown Cold Some gravel and shale
3	823.5 / 3.5	Large gravel
		END of BOREHOLE at 3.35 m

KP080.3 TO KP086

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP083.5 AT HELIPAD HP85	DRILL: PICK AND SHOVEL	Y14103320-01-TP12A
NEAR NAHANNI BUTTE, NT	6815639N; 457583E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT - black					0
	SILT (possible COLLUVIUM or TILL veneer) - some organics, trace of clay, trace of sand, wet					
	END OF TESTPIT (0.60 m)					
1						
						5
2						
3						10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.6m
REVIEWED BY: KJ	COMPLETE: 14/09/23
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP083.65 NEAR STREAM NORTH OF ROUTE	DRILL: PICK, SHOVEL AND HAND AUGER	Y14103320-01-TP12/BH06
NEAR NAHANNI BUTTE, NT	6815646N; 457692E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m^3) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT - (50 mm thick)						0
	SILT (possible COLLUVIUM or TILL veneer) - trace to some sand, trace of clay, dry, light brown						
	- some clay, dry, poor sample recovery						
	- trace to some clay, trace of sand, nuggetty, damp, stiff to hard, trace of oxides	Disturbed	S1				
		Disturbed	S2				
	- trace of angular gravel, damp	Disturbed	S3				
1							
	- some clay, very stiff, trace of sand pockets, trace of rootlets	Disturbed	S4		●		
	END OF TESTPIT (1.10 m) Note: KP080.3 to KP086.6 reroute north, typical mound with aspen, paper birch and white spruce. About 100 m north of route along stream parallel to crest of valley slope above Upper Tetcela River.						
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1.1m
REVIEWED BY: KJ	COMPLETE: 14/09/23
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP084 NEAR STREAM NORTH OF ROUTE	DRILL: PICK, SHOVEL AND HAND AUGER	Y14103320-01-TP13/BH07
NEAR NAHANNI BUTTE, NT	6815665N; 458117E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	USC	SOIL SYMBOL	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - roots and rootlets, (150 mm thick)								0
	SILT (COLLUVIUM) - trace of clay, trace of sand, dry, light brown								
		DISTURBED	S1						
	- clayey, stiff to hard, low plastic	DISTURBED	S2						
1									
	CLAY - silty, stiff to hard, low plastic	DISTURBED	S3	CI					
	END OF TESTPIT (1.10 m) Note: About 90 m northeast of reroute along stream parallel to crest of valley slope above Upper Tetcela River.								
									5
2									
3									10

TETRA TECH EBA

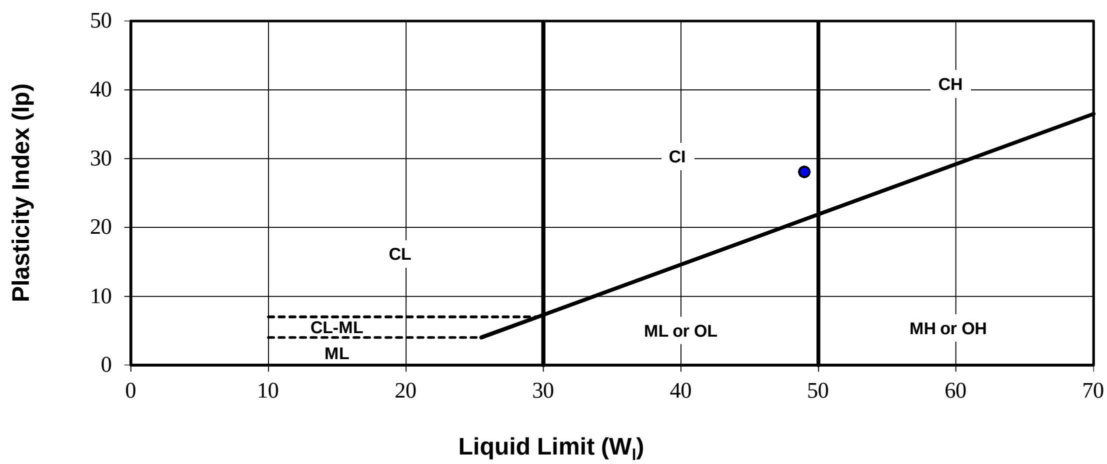
LOGGED BY: RKO	COMPLETION DEPTH: 1.1m
REVIEWED BY: KJ	COMPLETE: 14/09/23
DRAWING NO:	Page 1 of 1

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Prairie Creek All-Season Road	Sample Number:	6161
	Near KP084	Borehole Number:	TP-13/BH-07, S-3
Project No:	Y14103320-01	Depth:	1.05-1.10m
Client:	Canadian Zinc Corporation	Sampled By:	RKO Tested By: NR
Attention:	David Harpley	Date Sampled:	September 23, 2014
Email:	david@canadianzinc.com	Date Tested:	November 14-17, 2014

Sample Description: CLAY, silty, stiff to hard, medium plastic



Liquid Limit ($W_{1)}$:	49	Natural Moisture (%)	22.6
Plastic Limit :	21	Soil Plasticity:	Medium to High
Plasticity Index (Ip) :	**28**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: RKO P.Eng.

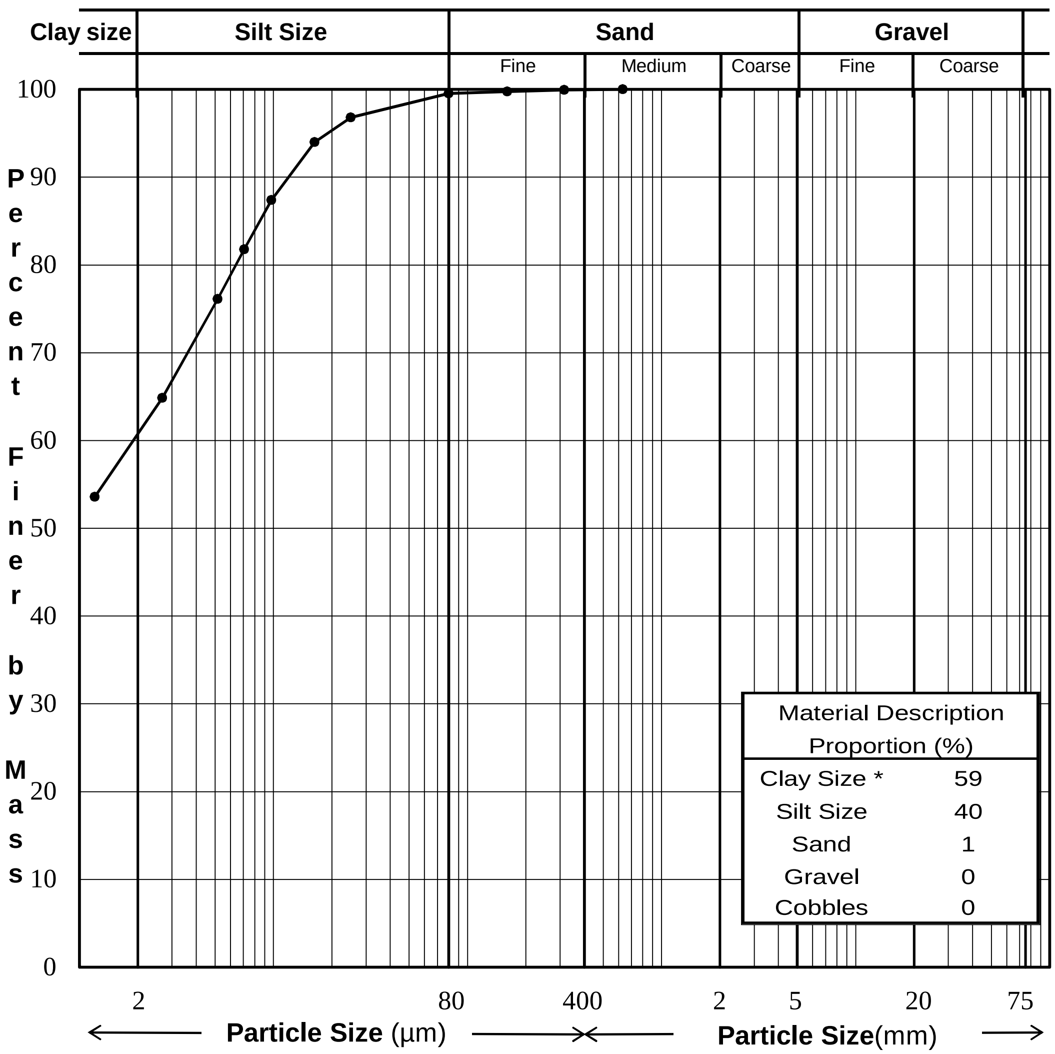
TETRA TECH

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Prairie Creek All-Season Road	Sample No.:	6161
Client:	Canadian Zinc Corporation	Borehole/ TP:	TP-13/BH-07, S3
Project No.:	Y14103320-01	Depth:	1.05-1.10m
Location:	Near KP084	Date Tested	Nov 18-20, 2014
Description **:	CLAY, silty, trace sand, with organic material	Tested By:	NR

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
16 mm	
13 mm	
10 mm	
5 mm	
2 mm	
1.3 mm	
630 µm	100
315 µm	100
160 µm	100
80 µm	100
25 µm	97
16 µm	94
10 µm	87
7 µm	82
5 µm	76
3 µm	65
1 µm	54



Material Description	Proportion (%)
Clay Size *	59
Silt Size	40
Sand	1
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Reviewed By: RKO P.Eng.

SNC·LAVALIN
Borehole Log

Project	Prairie Creek, Northwest Territory	Drilling Company	Rocky Mountain
Contract	610984	Method	SPT Tripod
		Location	Tetcela facility footprint, west
		Logged/Reviewed by	MP Lachance
		Coordinates	6814581 N, 457739 E

Borehole ID	BH-TTF-01
Page	1 of 1
Start Date (yyyy-mm-dd)	2012-09-22
End Date (yyyy-mm-dd)	2012-09-22
Elevation (m)	835 m

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

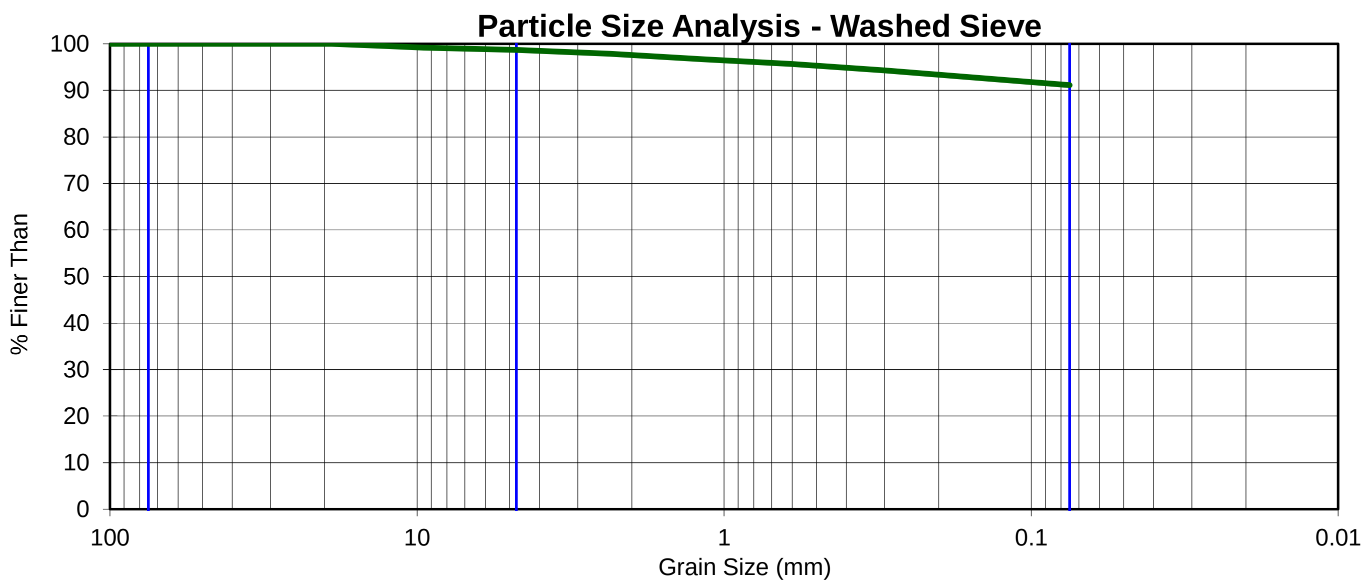
Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa. Water Content (%), Plastic Limit (%), Liquid Limit (%): 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Field Undrained Shear / Lab Tests	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	835.00	Ground Surface										
		CLAY Soft, grey, CLAY, trace sand, high plasticity, moist, very cold						0 0 0 2 3				
1		Frozen at 1.07 m Firm at 1.15 m						3 3 5 8 8	8			1 8 91
2		Very stiff at 1.90 m						9 9 14 17 18	23			
3	832.0 3.0							9 10 12 15 16 30	22			
	831.8 3.2	GRAVEL Loose rocks										
		END of BOREHOLE at 3.16 m Refusal at 3.16 m										

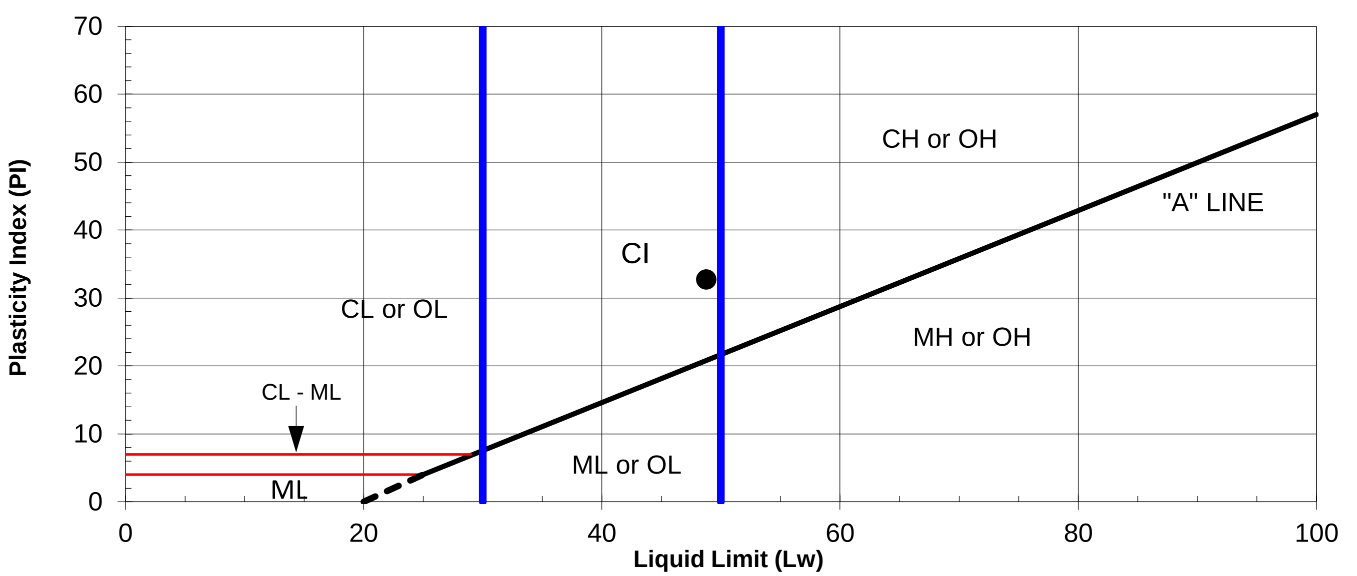
PRAIRIE CREEK 610984 PRAIRIE CREEK.GPJ GEOTECH.GDT 11/14/12

UNIFIED SOILS CLASSIFICATION

Sample: BH-TTF-01	Date Sampled	**Oct. 2012**	By **M.L.**	of	**SNC Lavalin Group Inc.**
Borehole No. **N/A**	Depth	**0" to 90"**		Specification	**ASTM D 2487**
Description	**Clay, silty, trace gravel, trace sand.**			Tech./ Eng.	**G.S./M.L.**



Gravel = **1.3%** Sand = **7.6%** Silt and Clay = **91.1%**



Pw =	**16.06%**	Group Index:	**18**
Lw =	**48.79%**	Soil type:	**Inorganic**
PI =	**32.72%**	Fines type:	**Cl**

Unified Soils Classification: **Cl - Medium clay**

Harder Associates engineering consulting inc. Member of the SNC•LAVALIN Group	Client **SNC Lavalin Group Inc.**	Date	**26-Oct-12**
	Project **Geotechnical Investigation**	File No.	**FN364**
	Location **Prairie Creek Mine, NWT.**	Sample No.	**BH-TTF-01**

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-TTF-02**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Tetcela facility footprint, east**	Start Date	**2012-09-22** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-22** (yyyy-mm-dd)
Coordinates	6814557 N, 457806 E	Elevation (m)	**836 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100 200 300 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	836.00	Ground Surface									
		CLAY Soft, grey CLAY, medium plasticity, moist					0 0 2 3 4	2			
1		Light brown, silty CLAY									
		Trace shale fragments Firm at 1.15 m		▼			2 2 6 6 6	8			
		Frozen at 1.5 m									
2		Very stiff at 1.9 m					7 9 10 12 14	19			
3							13 13 14 16 18	27			
		Not frozen at 3.5 m					17 16 18 19 23	34			
4							20 24 24 26 28	48			
	831.4 4.6	END of BOREHOLE at 4.6 m									

KP086 TO KP095.7

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
NEAR WEST END OF SOUTH TETCELA REROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH08
NEAR NAHANNI BUTTE, NT	6812485N; 460364E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	USC	SOIL SYMBOL	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80 / SILT (%) 20 40 60 80 / SAND (%) 20 40 60 80 / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - (180 mm thick)								0
	CLAY (possible GLACIOLACUSTRINE) - silty								
	SILT (probable TILL) - sandy, trace to some clay, trace of gravel	Disturbed	S1						
1	CLAY (probable TILL) - silty, trace of gravel, moist, firm to stiff, medium plastic, sandy lenses, cold								
	- stiff to very stiff	Disturbed	S2						
	- sandy, low plastic	Disturbed	S3	CI					
	END OF BOREHOLE (1.20 m) Note: KP86 reroute south, east of Tetcela River tributary, on gentle slope. Stopped due to refusal on probable frozen soil. (Route not used).								
2									5
3									10

TETRA TECH EBA

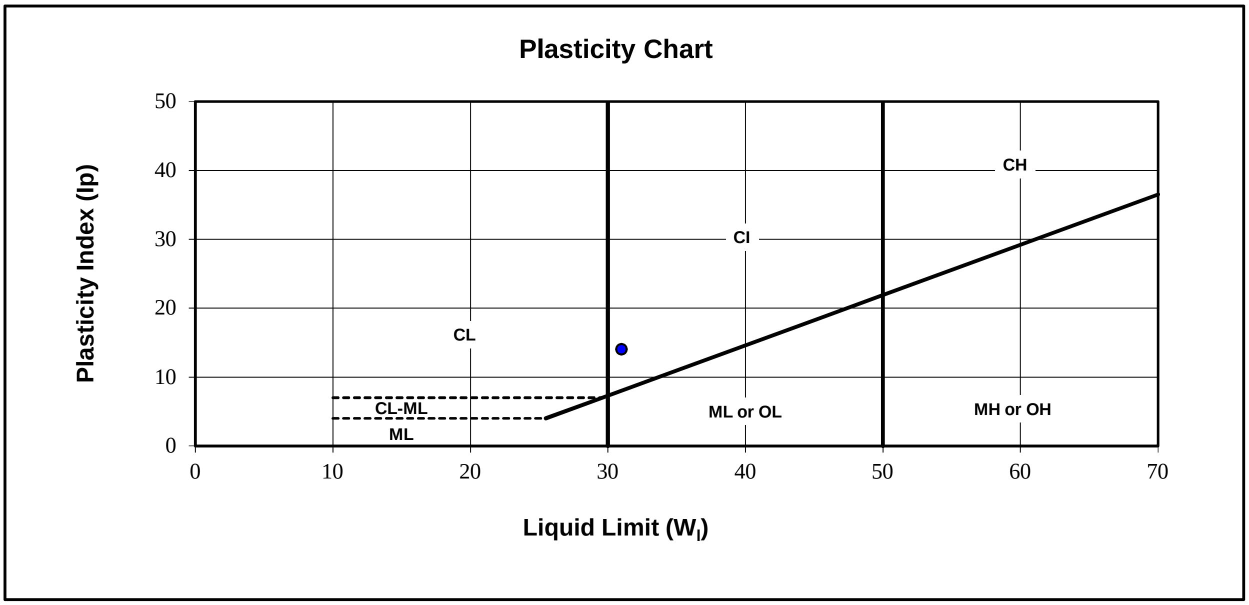
LOGGED BY: RKO	COMPLETION DEPTH: 1.2m
REVIEWED BY: KJ	COMPLETE: 14/09/23
DRAWING NO:	Page 1 of 1

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Prairie Creek All-Season Road	Sample Number:	6161
	Northwest of Nahanni Butte, NT	Borehole Number:	BH-08, S-1
Project No:	Y14103320-01	Depth:	1.05-1.10m
Client:	Canadian Zinc Corporation	Sampled By:	RKO Tested By: NR
Attention:	David Harpley	Date Sampled:	September 23, 2014
Email:	david@canadianzinc.com	Date Tested:	November 14-17, 2014

Sample Description: CLAY, silty, sandy, trace gravel, stiff to very stiff, moist



Liquid Limit ($W_{1)}$:	31	Natural Moisture (%)	22.0
Plastic Limit :	17	Soil Plasticity:	Low to Medium
Plasticity Index (Ip) :	**14**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: RKO P.Eng.

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TETRA TECH

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
1.35 km SOUTH OF KP092	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH10
NEAR NAHANNI BUTTE, NT	6813784N; 462962E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000; SPT (N) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80; SILT (%) 20 40 60 80; SAND (%) 20 40 60 80; GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT					0
	SAND (GLACIOLACUSTRINE) - silty, trace of sand, fine to medium grained, dry					
	- trace of fine gravel					
	- dense, hard drilling, poor return					
	END OF BOREHOLE (0.75 m) Note: Sidehill 60% at edge of mound. Spruce, occasional pine, birch. Proposed South Tetcela reroute on uplands section. (Route not used).					
1						
						5
2						
3						10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.75m
REVIEWED BY: KJ	COMPLETE: 14/09/24
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
1.35 km SOUTH OF KP092	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH11
NEAR NAHANNI BUTTE, NT	6813766N; 462980E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - fibrous, moist, brown						0
	- fibrous to decayed, black						
	SILT (GLACIOLACUSTRINE) - some sand, trace of clay, moist, brown						
	CLAY (possible TILL) - silty, trace of sand, wet	DISTURBED	S1				
	- very cold						
1	- frozen, probable permafrost sandy, trace of fine gravel	DISTURBED	S2	Frozen, laminated ice Nf to Nbe, est. 10% excess ice	●		
	END OF BOREHOLE (1.10 m) Note: "inter-mound" flat lands. Proposed South Tetcela reroute on uplands section (Route not used).						
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 1.1m
	REVIEWED BY: KJ	COMPLETE: 14/09/24
	DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP094.4 SOUTHEAST OF C-LAKE ON REROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH12
NEAR NAHANNI BUTTE, NT	6813670N; 464512E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - fibrous, moist, brown						0
	- partly decomposed, black						
	SILT (GLACIOLACUSTRINE) - clayey, dilatant, wet, soft, low plastic, grey brown	DISTURBED	S1				
	CLAY (possible TILL) - silty, sandy, trace of oxides	DISTURBED	S2	Ice rich, 10-20% excess ice (est.), Nf becoming Nbe	●	■ ▲ ◆ ●	
	END OF BOREHOLE (0.85 m) Note: Proposed alignment south of C-shaped lake, in thermokarst terrain of Fishtrap Creek drainage.						
1							
2							5
3							10

TETRA TECH EBA

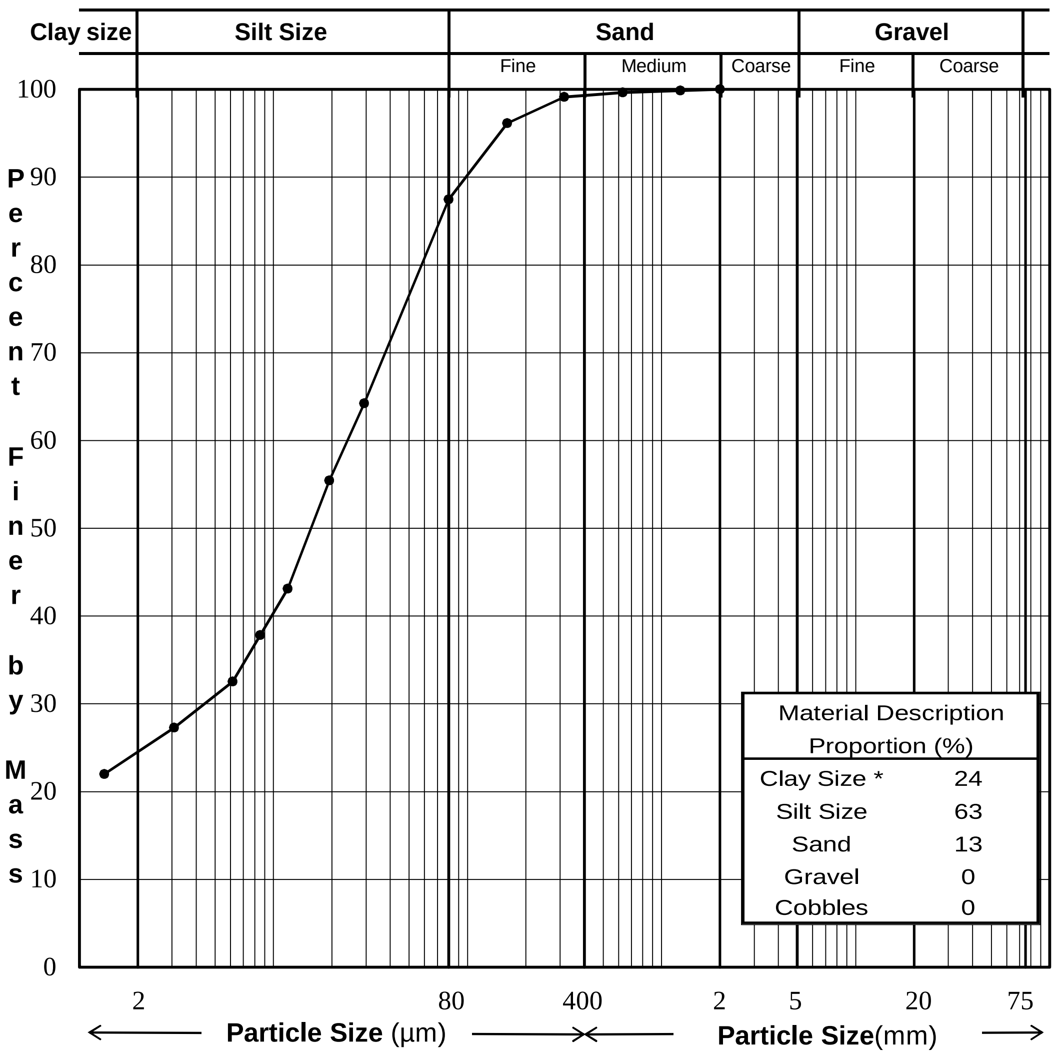
LOGGED BY: RKO	COMPLETION DEPTH: 0.85m
REVIEWED BY: KJ	COMPLETE: 14/09/24
DRAWING NO:	Page 1 of 1

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Prairie Creek All-Season Road	Sample No.:	6161
Client:	Canadian Zinc Corporation	Borehole/ TP:	BH-12, S2
Project No.:	Y14103320-01	Depth:	0.80-0.85m
Location:	~KP094.3	Date Tested	Nov 18-20, 2014
Description **:	CLAY, silty, some sand, with organic material	Tested By:	NR

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
16 mm	
13 mm	
10 mm	
5 mm	
2 mm	100
1.3 mm	100
630 µm	100
315 µm	99
160 µm	96
80 µm	87
29 µm	64
19 µm	55
12 µm	43
9 µm	38
6 µm	33
3 µm	27
1 µm	22



Material Description	Proportion (%)
Clay Size *	24
Silt Size	63
Sand	13
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Reviewed By: RKO P.Eng.

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
WEST END OF SOUTH TETCELA REROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP14
NEAR NAHANNI BUTTE, NT	6812367N; 460281E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000; SPT (N) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80; SILT (%) 20 40 60 80; SAND (%) 20 40 60 80; GRAVEL (%) 20 40 60 80	GTC515	Depth (ft)
0	PEAT - weathered, friable, occasional woody inclusions							0
	- frozen, 5-10% visible ice, probably permafrost	DISTURBED	S1	Vx & Vx = 5-10%, Nf to Nbn, becoming Nbe by end of hole GTC515 = 16.32 kohm	298			
	END OF TESTPIT (0.60 m) Note: KP86.3 to KP94 proposed reroute south, across Tetcela River tributary, on northwest facing slope above floodplain. (Route not used).							
1								
								5
2								
3								10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.6m
REVIEWED BY: KJ	COMPLETE: 14/09/23
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
1.35 km SOUTH OF KP092	DRILL: PICK, SHOVEL AND HAND AUGER	Y14103320-01-TP18/BH09
NEAR NAHANNI BUTTE, NT	6813823N; 462940E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - fibrous, (100 mm thick)						0
	SILT (GLACIOLACUSTRINE) - trace of sand, damp, light brown						
	- 200 mm thick clay lens - silty, trace of sand, moist, low plastic						
	- trace of clay, moist	DISTURBED	S1				
	SAND (GLACIOLACUSTRINE) - trace to some silt, trace of clay, fine grained, moist, grey brown						
		DISTURBED	S2				
	- few fines, fine to medium grained, damp, grey brown						
1	- clean, medium grained						
	SILT (GLACIOLACUSTRINE) - trace to some clay, trace of sand, moist, grey brown	DISTURBED	S3		●		
		DISTURBED	S4		●		
	END OF TESTPIT (1.25 m) Note: On aspen mound above swampy helipad. Proposed South Tetcela reroute on uplands section. (Route not used).						
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 1.25m
	REVIEWED BY: KJ	COMPLETE: 14/09/24
	DRAWING NO:	Page 1 of 1

KP095.7 TO KP101.7

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
WEST OF POND AT HELIPAD HP99	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH13
NEAR NAHANNI BUTTE, NT	6812729N; 466855E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	☐ BULK DENSITY (kg/m³) ☐ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT - fibrous, dry to damp, brown, (250 mm thick)					0
	SILT (probable TILL) - trace of sand, trace of clay, trace of gravel to 10 mm diameter, dry to damp, light brown					
	- increasing gravel					
	- more gravel					
	END OF BOREHOLE (0.60 m) Note: Just west of outlet of pond at HP99. Refusal on gravel.					
1						
						5
2						
3						10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.6m
REVIEWED BY: KJ	COMPLETE: 14/09/24
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
WEST OF POND AT HELIPAD HP99	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH14
NEAR NAHANNI BUTTE, NT	6812785N; 466810E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	PEAT AND DUFF - fibrous, dry to damp, brown, (150 mm thick)						0
	SILT (probable TILL) - some sand, trace of clay, trace of flat and elongated gravel to 100 mm diameter, hard	DISTURBED	S1		●		
	END OF BOREHOLE (0.60 m) Note: On ridge at switchback west of pond. Refusal on gravel.						
1							
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.6m
	REVIEWED BY: KJ	COMPLETE: 14/09/24
	DRAWING NO:	Page 1 of 1

SNC·LAVALIN

Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company **Rocky Mountain**
Method **SPT Tripod**
Location **Sillent Hills Switchbacks**
Logged/Reviewed by **MP Lachance**
Coordinates 6812075 N, 467292 E

Borehole ID **BH-SWI-01**

Start Date **2012-09-22** (yyyy-mm-dd)
End Date **2012/09/252** (yyyy-mm-dd)
Elevation (m) **481 m**

Sample Condition	Sample Types			Abbreviations		
▨ Disturbed ▨ Undisturbed ■ Lost	SS - Split Spoon	ST - Thin Walled Open (Shelby)	RC - Rock Core	PP - Pocket Penetrometer	RQD - Rock Quality Designation	SPT - Standard Penetration Test
	CS - Core Sample	WS - Wash Sample	BU - Bulk	PT - Standard Proctor Test	DS - Direct Shear	Q test - Triaxial Compression Test (UU)
	AU - Auger			K - Hydraulic Conductivity (cm/s)	GS - Grain Size Analysis	U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: ■ Lab UCS; □ Q Test; ● P.P. (US); *Field Vane* ▲ Intact ◆ Remold; *Lab. Vane* △ Intact ◇ Remoulded; 100 200 300 400 kPa

Water Content (%) ⊗; Plastic Limit (%) ⊢; Liquid Limit (%) ⊣; 20 40 60 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Field Undrained Shear / Water Content	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	481.00	Ground Surface										
	481.0 / 0.1	TOPSOIL Black organics										
1	480.0 / 1.0	SILT and CLAY Grey and light brown SILT and CLAY, some gravel, dry			⊗ ⊢—⊣							16 13 71
		END of BOREHOLE at 1.0 m Refusal on possible cobble at 1.0 m										

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Borehole Log

Project	Prairie Creek, Northwest Territory	Drilling Company	Rocky Mountain
Contract	610984	Method	Pionjar
Borehole ID	BH-SWI-01-02	Location	Sillent Hills Switchbacks
Page	1 of 1	Logged/Reviewed by	MP Lachance
Start Date (yyyy-mm-dd)	2012-09-22	Coordinates	6812075 N, 467292 E
End Date (yyyy-mm-dd)	2012-09-22	Elevation (m)	481 m

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m^3)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Field Undrained Shear / Lab Tests	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	481.00	Ground Surface										
	480.9 / 0.1	TOPSOIL Black organics										
1		CLAY Hard, grey and light brown, silty CLAY, some fractured shale and gravel, some sand, dry										
		Moist			Water content plotted with plastic–liquid limit range							22 14 64
	479.2 / 1.8	END of BOREHOLE at 1.8 m Refusal on possible cobble at 1.8 m										

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-01-03**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date	**2012-09-23** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-23** (yyyy-mm-dd)
Coordinates	6812075 N, 467292 E	Elevation (m)	**481 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100 200 300 400 kPa
Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level
	481.00	Ground Surface		
	481.0 / 0.1	TOPSOIL Black organics		
1	479.9 / 1.1	SILT Soft, light brown, SILT, some organics, dry		
		END of BOREHOLE at 1.1 m		

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-01-04**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-23**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-23**
Coordinates	6812075 N, 467292 E	Elevation (m)	**481 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	481.00	Ground Surface							
	481.0 / 0.1	TOPSOIL Black organics							
		SILT Loose, light brown and grey, SILT, some fractured shale and gravel, trace organics, dry			3 6 8 11	9			
1		Dense at 1.15 m			7 18 24 24 22	42			
	479.1 / 1.9	END of BOREHOLE at 1.9 m Refusal on shale fragment at 1.9 m			20 17 23 23	37			
					21 30				

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-02**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-22**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-22**
Coordinates	6812292 N, 467146 E	Elevation (m)	**306 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa

Water Content (%); Plastic Limit (%); Liquid Limit (%): 20, 40, 60, 80

Elevation (m) / Depth (m)	Description	SPT Blow Counts	N-value (# blows/0.3m)	Gr Sa Si/Cl
306.00	Ground Surface			
305.9 / 0.1	TOPSOIL Black, organics			5 16 79
	SILT Firm, light brown, clayey SILT, some sand, dry Trace shale	0 2 3 5 6	5	
				28 35 37
	Very stiff at 1.15 m			
	Cold	8 10 12 8 8	22	
		8 8 8	16	
	Moist	12 17 9 9 13	22	
		10 9 8	19	
301.4 / 4.6		7 9 9 11 8	18	
	END of BOREHOLE at 4.6 m			

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-03-03**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-24**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-24**
Coordinates	6812569 N, 466788 E	Elevation (m)	**391 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; PT - Standard Proctor Test; K - Hydraulic Conductivity (cm/s); RQD - Rock Quality Designation; DS - Direct Shear; GS - Grain Size Analysis; SPT - Standard Penetration Test; Q test - Triaxial Compression Test (UU); U - Wet Unit Weight (kN/m^3)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane* Intact, Remold; *Lab. Vane* Intact, Remoulded; 100, 200, 300, 400 kPa
Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Elevation (m) / Depth (m)	Description	SPT Blow Counts	N-value (# blows/0.3m)
391.00	Ground Surface		
390.9 / 0.2	TOPSOIL Black, organics, dry		
	CLAY Very soft to soft, grey, silty CLAY, some gravel, moist	0 0 0 4 1	
		1 1 1 1.5 1.5	2
388.7 / 2.3		2 2 2 3 5	4
	SILT Soft, grey, SILT, some gravel, low plasticity, dry		
388.0 / 3.0		4 2 2 2 5	4
	CLAY Stiff, grey, CLAY, wet	5 5 6 5 4	11
	Sandy, some fractured rocks and some gravel		
386.4 / 4.6		4 6 6 5 7	12
	END of BOREHOLE at 4.6		

Columns also present: Depth (m) 1–4; Stratigraphic Plot; Piezometer Installation and Water Level (water level ▼ at approx. 3.6 m); Sample Condition; Type & Number; Recovery %; RQD %; Gr Sa Si/Cl.

PRAIRIE CREEK 610984 PRAIRIE CREEK.GPJ GEOTECH.GDT 11/14/12

SNC·LAVALIN

Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-04**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date	**2012-09-24** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-24** (yyyy-mm-dd)
Coordinates	6812310 N, 466776 E	Elevation (m)	**383 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane* Intact, Remold; *Lab. Vane* Intact, Remoulded; 100 200 300 400 kPa

Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Depth (m)	Elevation (m) / Depth (m)	Description	SPT Blow Counts	N-value (# blows/0.3m)	Gr Sa Si/Cl
	383.00	Ground Surface			
0		TOPSOIL Very soft, black organics Silty, moist	0 0 4 5 6	4	
	382.2 / 0.8	SILT Stiff, grey, SILT, trace clay, trace fractured rock, moist, cold Firm at 1.15 m	5 5 6 5 6	11	
2	381.0 / 2.0	GRAVEL Sandy GRAVEL, some silt, some clay	2 4 3 4 3	7	40 34 26
	380.7 / 2.3	LOST SAMPLE			
3	380.0 / 3.0	END of BOREHOLE at 3.0 m	4 3 5 5 5	8	

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-04-02**
Method	**SPT Tripod**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-24**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-24**
Coordinates	6812310 N, 466776 E	Elevation (m)	**383 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane* Intact, Remold; *Lab. Vane* Intact, Remoulded; 100 200 300 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20 40 60 80

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	383.00	Ground Surface									
		TOPSOIL Very loose, black, organics Silty, moist					0 11 3 3 4	6			
1	382.2 0.8	SILT Loose, grey SILT, some fractured rock, moist					3 3 4 3 3	7			
2	381.5 1.5	LOST SAMPLE					3 4 4 5 6	8			
							0 4 5 4 4	9			
3	380.0 3.0	END of BOREHOLE at 3.0 m									

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-04-03**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-24**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-24**
Coordinates	6812310 N, 466776 E	Elevation (m)	**383 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; PT - Standard Proctor Test; K - Hydraulic Conductivity (cm/s); RQD - Rock Quality Designation; DS - Direct Shear; GS - Grain Size Analysis; SPT - Standard Penetration Test; Q test - Triaxial Compression Test (UU); U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); Field Vane: Intact, Remold; Lab. Vane: Intact, Remoulded; 100, 200, 300, 400 kPa. Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Stratigraphy Description	Stratigraphic Plot	Piezometer Installation and Water Level	Field Undrained Shear / Lab Tests	Sample Condition	Type & Number	SPT Blow Counts	N-value (# blows/0.3m)	Recovery %	RQD %	Gr Sa Si/Cl
	383.00	Ground Surface										
0	382.8 / 0.3	TOPSOIL Loose, black, silty organics										
1	381.7 / 1.3	SILT Loose, grey SILT, some fractured rock, moist, cold										
2		CLAY Soft, grey, silty CLAY, some gravel, moist, cold										
		Some fractured rock										
3		Becoming firm and wet										
4												26 35 39
				▼								
	378.2 / 4.8	END of BOREHOLE at 4.8 m										

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Borehole Log

Project	**Prairie Creek, Northwest Territory**
Contract	**610984**
Drilling Company	**Rocky Mountain**
Method	**SPT Tripod**
Location	**Silent Hills Switchbacks**
Logged/Reviewed by	**MP Lachance**
Coordinates	6812426 N, 466789 E
Borehole ID	**BH-SWI-05**
Page	**1 of 1**
Start Date (yyyy-mm-dd)	**2012-09-24**
End Date (yyyy-mm-dd)	**2012-09-24**
Elevation (m)	**398 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa. Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Depth (m)	Elevation (m) / Depth (m)	Description	SPT Blow Counts	N-value (# blows/0.3m)	Gr Sa Si/Cl
	398.00	Ground Surface			
	397.9 / 0.1	TOPSOIL Loose, black organics			
		CLAY Firm, grey silty CLAY, some gravel, trace fractured rock, slightly moist, cold	0 2 3 10 15	5	
1					16 23 61
		Hard at 1.15 m	15 19 19 22 23	38	
2	396.0 / 2.0	END of BOREHOLE at 2.0 m	20 22 30	52	

Other columns: Stratigraphic Plot; Piezometer Installation and Water Level; Sample Condition; Type & Number; Recovery %; RQD %

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Borehole Log

Project **Prairie Creek, Northwest Territory**

Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-96-500**
Method	**3 inch Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-24**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-24**
Coordinates	6812007 N, 466417 E	Elevation (m)	**480 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; PT - Standard Proctor Test; K - Hydraulic Conductivity (cm/s); RQD - Rock Quality Designation; DS - Direct Shear; GS - Grain Size Analysis; SPT - Standard Penetration Test; Q test - Triaxial Compression Test (UU); U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa. Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description
	480.00	Ground Surface
		SILT Light brown, SILT, some clay, trace organics, dry Grey, SILT, some gravel, some clay, medium plasticity, dry
1		
2		Moist and cold
	477.3 / 2.7	CLAY Firm, grey, silty CLAY, some gravel, medium plasticity, moist, cold
3		
	476.6 / 3.4	GRAVEL GRAVEL, some silty clay
	476.3 / 3.7	END of BOREHOLE at 3.7 m Auger Refusal at 3.7 m

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Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-99-100**
Method	**Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date	**2012-09-23** (yyyy-mm-dd)
Logged/Reviewed by	**MP Lachance**	End Date	**2012-09-23** (yyyy-mm-dd)
Coordinates	6811818 N, 467442 E	Elevation (m)	**-77 m**

Sample Condition: Disturbed; Undisturbed; Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; PT - Standard Proctor Test; K - Hydraulic Conductivity (cm/s); RQD - Rock Quality Designation; DS - Direct Shear; GS - Grain Size Analysis; SPT - Standard Penetration Test; Q test - Triaxial Compression Test (UU); U - Wet Unit Weight (kN/m^3)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level
	-77.00	Ground Surface		
	-77.1 / 0.1	TOPSOIL Loose, black organics		
		SILT Grey and light brown, SILT, trace gravel, dry		
1		Becoming compact, moist		
2				
3				
4		Trace gravel, cold		
	-81.6 / 4.6	END of BOREHOLE at 4.6 m		

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-CUT-A**
Method	**Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-23**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-23**
Coordinates	6812015 N, 467313 E	Elevation (m)	**471 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; PT - Standard Proctor Test; K - Hydraulic Conductivity (cm/s); RQD - Rock Quality Designation; DS - Direct Shear; GS - Grain Size Analysis; SPT - Standard Penetration Test; Q test - Triaxial Compression Test (UU); U - Wet Unit Weight (kN/m^3)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level
	471.00	Ground Surface		
	470.9 / 0.2	TOPSOIL Black and grey, orgranic clay, moist		
		SILT Loose, grey, SILT, some fractured shale, dry		
1				
2				
3				
4				▼
	466.4 / 4.6	END of BOREHOLE at 4.6 m		

SNC·LAVALIN
Borehole Log

Project **Prairie Creek, Northwest Territory**
Contract **610984**

Drilling Company	**Rocky Mountain**	Borehole ID	**BH-SWI-CUT-E**
Method	**Pionjar**	Page	**1 of 1**
Location	**Sillent Hills Switchbacks**	Start Date (yyyy-mm-dd)	**2012-09-23**
Logged/Reviewed by	**MP Lachance**	End Date (yyyy-mm-dd)	**2012-09-23**
Coordinates	6811660 N, 467885 E	Elevation (m)	**505 m**

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; RQD - Rock Quality Designation; SPT - Standard Penetration Test; PT - Standard Proctor Test; DS - Direct Shear; Q test - Triaxial Compression Test (UU); K - Hydraulic Conductivity (cm/s); GS - Grain Size Analysis; U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa; Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level
	505.00	Ground Surface		
0	504.9 / 0.1	TOPSOIL Soft, black organics		
		SILT Loose, brown, SILT, trace gravel, moist		
1				
2				
	502.7 / 2.3	END of BOREHOLE at 2.3 m Blocked by possible cobble at 2.3 m		

SNC·LAVALIN

Borehole Log

Project	Prairie Creek, Northwest Territory	Drilling Company	Rocky Mountain
Contract	610984	Method	2 inch Pionjar
		Location	Sillent Hills Switchbacks
		Logged/Reviewed by	MP Lachance
		Coordinates	6811660 N, 467885 E
Borehole ID	BH-SWI-CUT-E-02	Page	1 of 1
Start Date (yyyy-mm-dd)	2012-09-24	End Date (yyyy-mm-dd)	2012-09-24
Elevation (m)	505 m		

Sample Condition: Disturbed, Undisturbed, Lost

Sample Types: SS - Split Spoon; ST - Thin Walled Open (Shelby); RC - Rock Core; CS - Core Sample; WS - Wash Sample; BU - Bulk; AU - Auger

Abbreviations: PP - Pocket Penetrometer; PT - Standard Proctor Test; K - Hydraulic Conductivity (cm/s); RQD - Rock Quality Designation; DS - Direct Shear; GS - Grain Size Analysis; SPT - Standard Penetration Test; Q test - Triaxial Compression Test (UU); U - Wet Unit Weight (kN/m³)

Field Undrained Shear C_u/Lab Tests: Lab UCS; Q Test; P.P. (US); *Field Vane*: Intact, Remold; *Lab. Vane*: Intact, Remoulded; 100, 200, 300, 400 kPa. Water Content (%); Plastic Limit (%); Liquid Limit (%); 20, 40, 60, 80

Samples/Field Tests: Sample Condition; Type & Number; SPT Blow Counts; N-value (# blows/0.3m); Recovery %; RQD %; Gr Sa Si/Cl

Depth (m)	Elevation (m) / Depth (m)	Description	Stratigraphic Plot	Piezometer Installation and Water Level
	505.00	Ground Surface		
	504.9 / 0.1	TOPSOIL Soft, black organics		
		SILT Loose, brown, SILT, trace gravel, moist		
	502.7 / 2.3	SILT Firm, grey, SILT, some gravel, moist, cold Some fractured shale		
	500.7 / 4.3	END of BOREHOLE at 4.3 m		

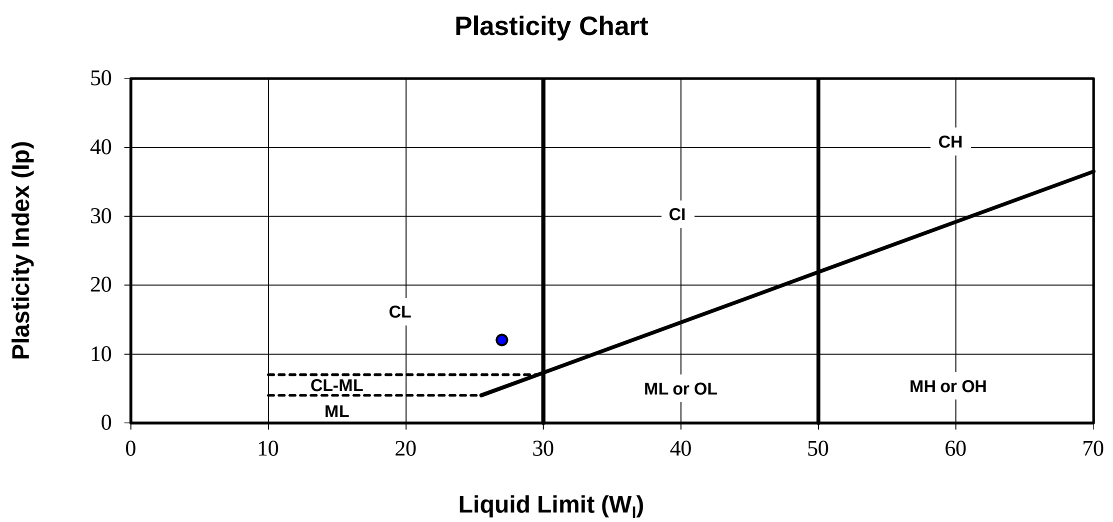
KP101.7 TO KP118

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Prairie Creek All-Season Road	Sample Number:	EK-3, S1
	Northwest of Nahanni Butte, NT	Sample Location:	471430m E, 6800254m N
Project No:	Y14103320-01	Depth:	0.4 m
Client:	Canadian Zinc Corporation	Sampled By:	Allnorth Tested By: MC
Attention:	David Harpley	Date Sampled:	September 28, 2014
Email:	david@canadianzinc.com	Date Tested:	January 8, 2015

Sample Description: CLAY, silty, sandy, trace gravel, brown



Liquid Limit ($W_{1)}$:	27	Natural Moisture (%)	18.4
Plastic Limit :	15	Soil Plasticity:	Low
Plasticity Index (Ip) :	**12**	Mod.USCS Symbol:	CL

Remarks:

Reviewed By: RKO P.Eng.

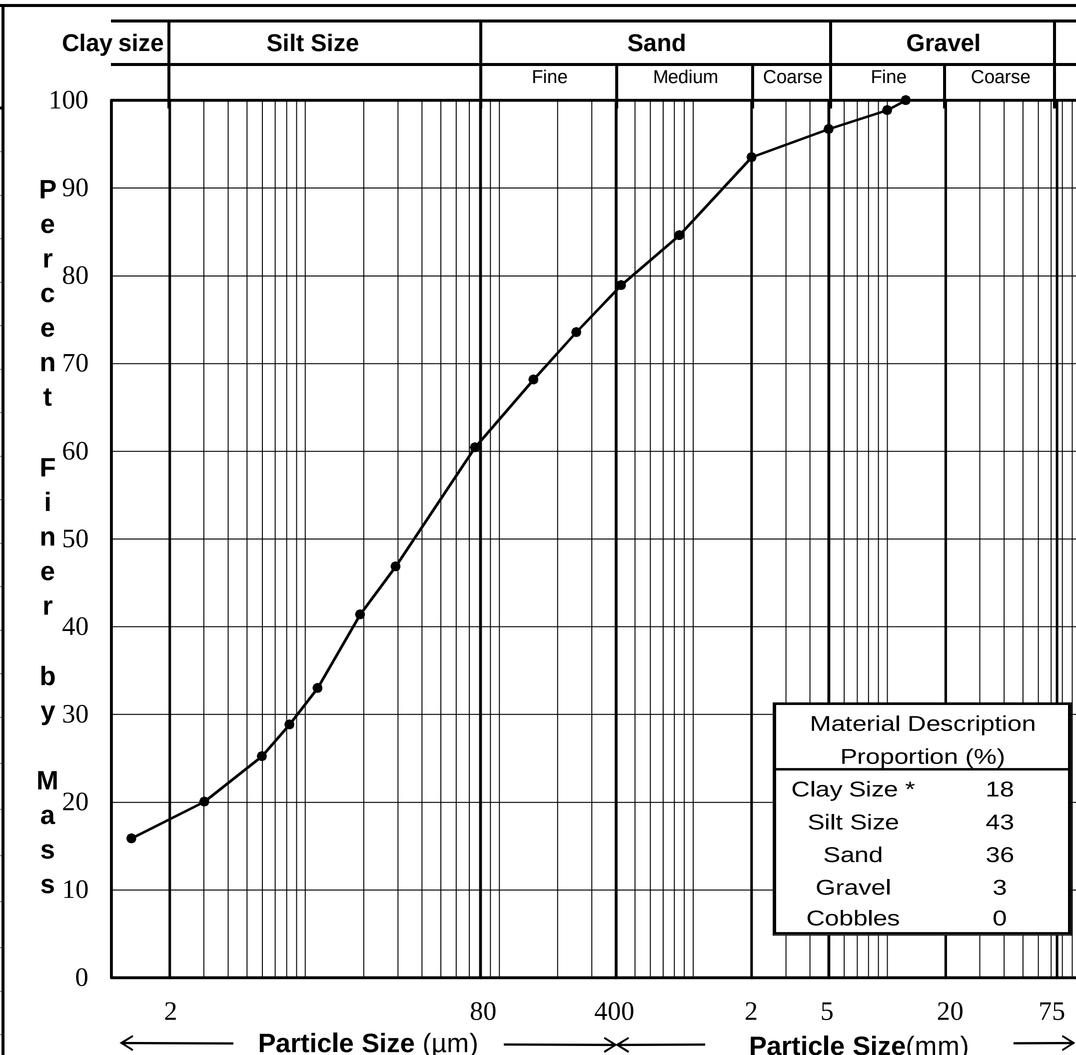
TETRA TECH

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Prairie Creek All-Season Road	Sample No.:	S1
Client:	Canadian Zinc Corp.	Borehole/ TP:	EK-3
Project No.:	Y14103320-01	Depth:	0.4m
Location:	471430m E, 6800254m N	Date Tested	January 8, 2015
Description **:	CLAY, silty, sandy, trace gravel, brown**	Tested By:	MC

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
19 mm	
13 mm	100
10 mm	99
5 mm	97
2 mm	94
850 µm	85
425 µm	79
250 µm	74
150 µm	68
75 µm	60
34 µm	47
22 µm	41
13 µm	33
9 µm	29
6 µm	25
3 µm	20
1 µm	16



Material Description	Proportion (%)
Clay Size *	18
Silt Size	43
Sand	36
Gravel	3
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Reviewed By: RKO P.Eng.

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	Prairie Creek All-Season Road	Sample No.:	EK (Allnorth)
Project No.:	Y14103320-01	Date Tested:	January 8, 2015
Client:	Canadian Zinc Corp.	Tested By:	MC
Address:	david@canadianzinc.com	Location:	KP116, upslope gullies

B.H. Number	Sample Number	Moisture Content (%)	Visual Description of Soil
EK-1	0.39	6.8	SAND
EK-2	0.4	15.1	CLAY, silty, sandy, trace gravel, mottled brown and black
EK-3	0.4	18.4	CLAY, silty, sandy, trace gravel, brown
EK-4	0.3	25.7	CLAY, silty, sandy, trace gravel, brown and grey, trace rootlets

Reviewed By: RKO P.Eng.

TETRA TECH

KP121.5 TO KP159.4

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP126.9 ABOUT 200 m ABOVE ROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH15
NEAR NAHANNI BUTTE, NT	6798302N; 480769E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	TOPSOIL - organic, (300 mm thick)						0
	SILT (probable TILL) - some clay to clayey, trace to some sand and gravel, damp, light brown, (150 mm thick)						
	CLAY (probable TILL) - silty, sandy, some gravel, moist, low plastic, light olive brown	Disturbed	S1				
	- 50 mm thick clay (till-like) lens - higher silt and medium to coarse grained sand content, stiff	Disturbed	S2		●		
	SAND (GLACIOFLUVIAL, or sand pocket in till), some gravel, medium to coarse grained	Disturbed	S3				
1	END OF BOREHOLE (1.00 m) Note: Burn area. Refusal on gravel.						
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - BOREHOLE NO.
KP126.8 AOUBT 400 m ABOVE ROUTE	DRILL: EDELMAN-TYPE HAND AUGER	Y14103320-01-BH16
NEAR NAHANNI BUTTE, NT	6798207N; 480521E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000; SPT (N) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80; SILT (%) 20 40 60 80; SAND (%) 20 40 60 80; GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT AND TOPSOIL - decomposed, black, rootlets, (200 mm thick)						0
	CLAY (probable TILL) - silty, trace to some sand, trace of fine gravel, moist, stiff, light olive brown, trace of oxides						
	- more gravel	DISTURBED	S1				
	- some gravel	DISTURBED	S2		●		
	END OF BOREHOLE (0.70 m) Note: Low shrubby patch to northwest of ridge top heli landing site. Grinding on gravel at end of borehole.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.7m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP123.35 STEEP SLOPE ABOVE STREAM	DRILL: PICK AND SHOVEL	Y14103320-01-TP04
NEAR NAHANNI BUTTE, NT	6798920N; 477942E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80 / SILT (%) 20 40 60 80 / SAND (%) 20 40 60 80 / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - (300 mm thick)						0
	SAND (probable COLLUVIUM) - silty, gravelly, some cobbles to 125 mm diameter, gap graded, dry to damp - some organics, moist, reddish brown, rootlets	DISTURBED	S1		●		
	END OF TESTPIT (0.45 m) Note: On rocky knoll south of stream at Grainger Gap.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.45m
REVIEWED BY: KJ	COMPLETE: 14/09/22
DRAWING NO:	Page 1 of 1

WHITEHORSE Y14103320-01.GPJ EBA.GDT 15/02/04

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP123.3 ON BLUFF ABOVE STREAM	DRILL: PICK AND SHOVEL	Y14103320-01-TP05
NEAR NAHANNI BUTTE, NT	6798868N; 477947E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	TURF AND DUFF - (50 mm thick)						0
	SILT (probable COLLUVIUM) - trace to some subangular gravel to 35 mm diameter, trace of sand increasing with depth, trace of clay, dry, light reddish brown	DISTURBED	S1				
	END OF TESTPIT (0.40 m) Note: West end of bluff, Grainger Gap.						
1							
							5
2							
3							10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.4m
	REVIEWED BY: KJ	COMPLETE: 14/09/22
	DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP124.8 AT EAST END OF GRAINGER GAP	DRILL: PICK AND SHOVEL	Y14103320-01-TP15
NEAR NAHANNI BUTTE, NT	6799534N; 479230E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT AND TURF - mat overhanging 5-6 m high, 12 m wide slope failure below to Grainger River floodplain						0
	SAND (possible GLACIOFLUVIAL remnant) - some gravel to gravelly to 75 mm diameter, some cobbles and boulders under overhand, fine to medium grained, damp to moist, brown, trace to some silt lenses	DISTURBED	S1				
1	- more gravel to east, less gravel to west on soil surface, little fines	DISTURBED	S2		●		
	END OF TESTPIT (1.20 m) Note: South side of Grainger Gap, east end at slope failure. Mapped headscarp of failed slope.						5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 1.2m
REVIEWED BY: KJ	COMPLETE: 14/09/23
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP126.6 ABOUT 950 m UPSLOPE	DRILL: PICK AND SHOVEL	Y14103320-01-TP16
NEAR NAHANNI BUTTE, NT	6797870N; 480057E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000; ■ SPT (N) ■ 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80; ● SILT (%) ● 20 40 60 80; ▲ SAND (%) ▲ 20 40 60 80; ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	GRAVEL AND SAND (COLLUVIUM) - few fines, appearance of crushed gravel to 10 mm diameter, gravel to 75 mm diameter, cobbles and boulders at ground surface					0
	END OF TESTPIT (0.30 m) Note: ~KP126.6 on rock glacier mapped by J.D. Mollard. Toe of small gully within upper end feature.					
1						
2						5
3						10

TETRA TECH EBA	LOGGED BY: RKO	COMPLETION DEPTH: 0.3m
	REVIEWED BY: KJ	COMPLETE: 14/09/24
	DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP126.5 ABOUT 550 m UPSLOPE	DRILL: PICK AND SHOVEL	Y14103320-01-TP17
NEAR NAHANNI BUTTE, NT	6798255N; 480195E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m^3) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	ROCK FRAGMENTS (TALUS) - sandy, silty, some organics in interstices, coarse grained (est.)					0
	END OF TESTPIT (0.30 m) Note: ~KP126.5 on rock glacier at proposed borrow site (debris/rubble ridge)., near lower end.					
1						
						5
2						
3						10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.3m
REVIEWED BY: KJ	COMPLETE: 14/09/24
DRAWING NO:	Page 1 of 1

WHITEHORSE Y14103320-01.GPJ EBA.GDT 15/02/04

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP159.4 ABOUT 500 m ABOVE ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP19
NEAR NAHANNI BUTTE, NT	6770946N; 483685E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	GRAVEL (COLLUVIUM) - cobbly, bouldery, occasional talus block at ground surface, (200 mm thick)						0
	CLAY (probably COLLUVIUM/ALLUVIUM over TILL) - silty, sandy, gravelly, cobbly, moist	DISTURBED	S1				
	- very hard						
	END OF TESTPIT (0.45 m) Note: Broad flat deposition area at ~KP159.4, upslope of debris flow prongs, proposed borrow near Liard crossing.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.45m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP159.5 ABOUT 450 m ABOVE ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP20
NEAR NAHANNI BUTTE, NT	6770856N; 483705E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	□ BULK DENSITY (kg/m³) □ 1400 1600 1800 2000 / ■ SPT (N) ■ 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	◆ CLAY (%) ◆ 20 40 60 80 / ● SILT (%) ● 20 40 60 80 / ▲ SAND (%) ▲ 20 40 60 80 / ■ GRAVEL (%) ■ 20 40 60 80	Depth (ft)
0	GRAVEL (COLLUVIUM) - sandy to some sand, trace of silt (est. <5% near surface)					0
	END OF TESTPIT (0.30 m) Note: Broad flat deposition area at ~KP159.5 near Liard crossing, close to heli landing area.					
1						
						5
2						
3						10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.3m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP159.5 ABOUT 470 m ABOVE ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP21
NEAR NAHANNI BUTTE, NT	6770852N; 483688E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	GRAVEL (COLLUVIUM) - sandy, trace to some silt (<5% near surface), fine to coarse grained, angular to subangular						0
		DISTURBED	S1				
	END OF TESTPIT (0.45 m) Note: Broad flat deposition area at ~KP159.5 near Liard crossing, 10 m north of small stream.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.45m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

WHITEHORSE Y14103320-01.GPJ EBA.GDT 15/02/04

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP154.8 ABOUT 900 m BELOW ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP22
NEAR NAHANNI BUTTE, NT	6774948N; 486705E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	USC	SOIL SYMBOL	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - (200 mm thick)								0
	SILT (TILL veneer or COLLUVIUM) - some sand, trace of clay, trace of organics, wet, soft, dark grey to black								
	CLAY (probably TILL) - silty, sandy, trace of gravel, wet, high plastic, light grey brown	DISTURBED	S1	CI					
	END OF TESTPIT (0.55 m) Note: Next to HP154, in low black spruce unit, near lower proposed route.								
1									
									5
2									
3									10

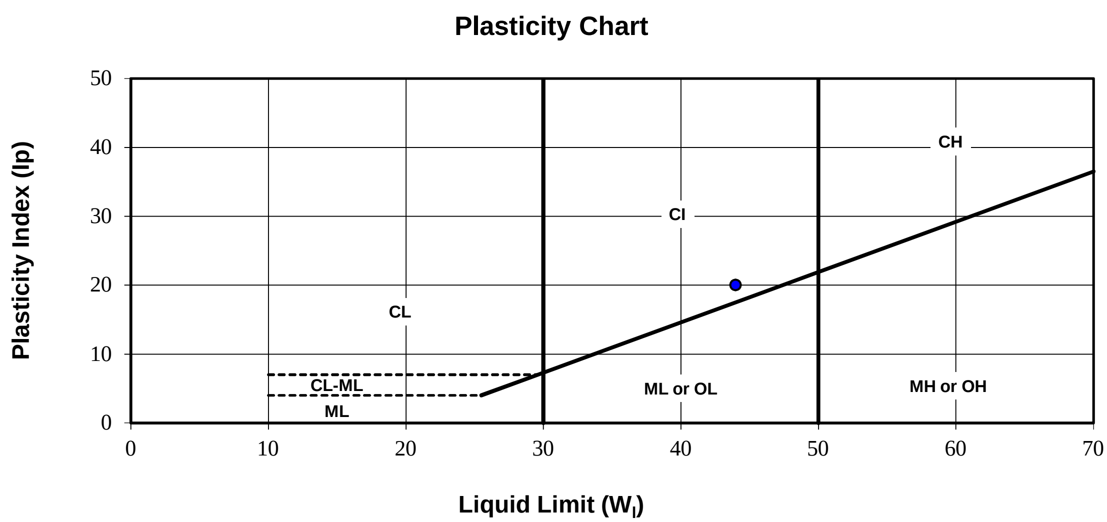
	LOGGED BY: RKO	COMPLETION DEPTH: 0.55m
TETRA TECH EBA	REVIEWED BY: KJ	COMPLETE: 14/09/26
	DRAWING NO:	Page 1 of 1

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Prairie Creek All-Season Road	Sample Number:	6161
	Northwest of Nahanni Butte, NT	Borehole Number:	TP-22, S-1
Project No:	Y14103320-01	Depth:	0.50-0.55m
Client:	Canadian Zinc Corporation	Sampled By:	RKO Tested By: NR
Attention:	David Harpley	Date Sampled:	September 26, 2014
Email:	david@canadianzinc.com	Date Tested:	November 13-15, 2014

Sample Description: CLAY, silty, sandy, trace gravel



Liquid Limit ($W_{1)}$:	44	Natural Moisture (%)	34.1
Plastic Limit :	24	Soil Plasticity:	Medium
Plasticity Index (Ip) :	**20**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: RKO P.Eng.

TETRA TECH

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP154.9 ABOUT 900 m BELOW ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP23
NEAR NAHANNI BUTTE, NT	6774878N; 486660E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - fibrous to partly decomposed, brown to dark brown, (300 mm thick)						0
	SILT (probably TILL veneer) - sandy, trace of gravel to 10 mm diameter, trace of clay forming 1 mm diameter peds, moist, low plastic						
		Disturbed	S1				
	- increasing oxides						
	- trace of subangular grained to 60 mm diameter	Disturbed	S2				
	END OF TESTPIT (0.55 m) Note: South of stream on south side of HP154, in tall black spruce unit, near lower proposed route.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.55m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP154.9 ABOUT 900 m BELOW ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP24
NEAR NAHANNI BUTTE, NT	6774850N; 486660E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000; SPT (N) 20 40 60 80; PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) 20 40 60 80; SILT (%) 20 40 60 80; SAND (%) 20 40 60 80; GRAVEL (%) 20 40 60 80	Depth (ft)
0	PEAT - partly decomposed, damp to moist, brown to black, (200 mm thick)						0
	SILT (TILL veneer or COLLUVIUM) - trace of clay, dry, light brown - brown - sandy, some fine gravel	DISTURBED	S1				
	END OF TESTPIT (0.50 m) Note: South of stream on south side of HP154, in aspen unit, near lower proposed route.						
1							
							5
2							
3							10

TETRA TECH EBA

LOGGED BY: RKO	COMPLETION DEPTH: 0.5m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

WHITEHORSE Y14103320-01.GPJ EBA.GDT 15/02/04

PRAIRIE CREEK ALL-SEASON ROAD	CANADIAN ZINC	PROJECT NO. - TESTPIT NO.
KP127 ON RIDGE 350 m ABOVE ROUTE	DRILL: PICK AND SHOVEL	Y14103320-01-TP25
NEAR NAHANNI BUTTE, NT	6798209N; 480722E; Zone 10	

SAMPLE TYPE: DISTURBED, NO RECOVERY, SPT, A-CASING, SHELBY TUBE, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	GROUND ICE DESCRIPTION AND COMMENTS	BULK DENSITY (kg/m³) 1400 1600 1800 2000 / SPT (N) 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	CLAY (%) / SILT (%) / SAND (%) / GRAVEL (%) 20 40 60 80	Depth (ft)
0	SAND (possible TILL) - some silt to silty, trace of clay (not sampled)					0
	END OF TESTPIT (0.30 m) Note: Ridge top at heli landing ~KP127.					
1						
						5
2						
3						10

TETRA TECH EBA

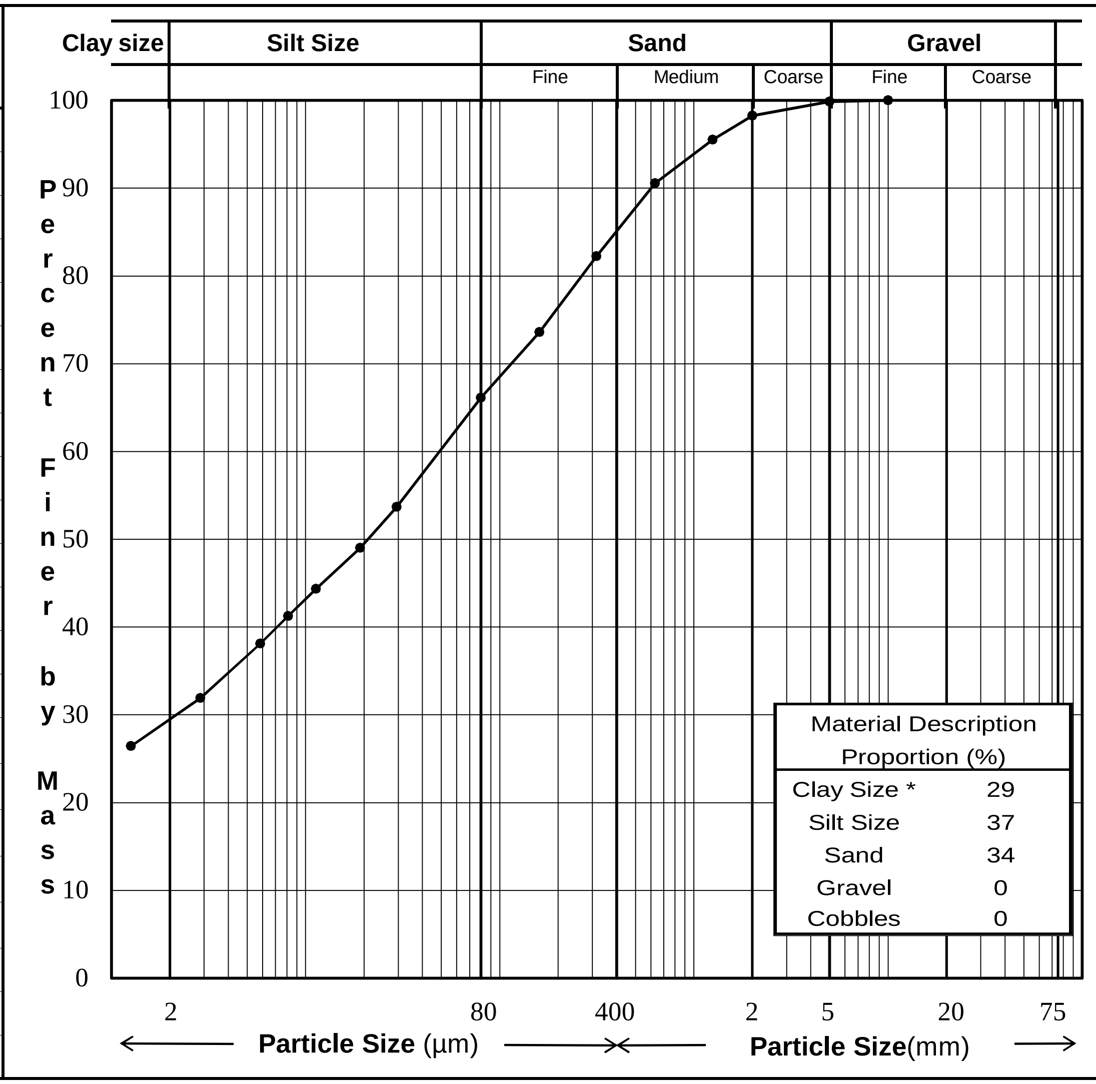
LOGGED BY: RKO	COMPLETION DEPTH: 0.3m
REVIEWED BY: KJ	COMPLETE: 14/09/26
DRAWING NO:	Page 1 of 1

PARTICLE SIZE ANALYSIS (Hydrometer) TEST REPORT

ASTM D422

Project:	Prairie Creek All-Season Road	Sample No.:	6161/Allnorth KP144.7
Client:	Canadian Zinc Corporation	Borehole/ TP:	KP144.7, S-1
Project No.:	Y14103320-01	Depth:	0.20-0.30 m
Location:	Outlet of Triangle Lake, NT	Date Tested	December 9-10, 2014
Description **:	CLAY, silty, sandy, with organic material	Tested By:	NR

Particle Size	Percent Passing
100 mm	
75 mm	
50 mm	
38 mm	
25 mm	
16 mm	
13 mm	
10 mm	100
5 mm	100
2 mm	98
1.3 mm	96
630 µm	91
315 µm	82
160 µm	74
80 µm	66
30 µm	54
19 µm	49
11 µm	44
8 µm	41
6 µm	38
3 µm	32
1 µm	26



Material Description	Proportion (%)
Clay Size *	29
Silt Size	37
Sand	34
Gravel	0
Cobbles	0

Remarks: * The upper clay size of 2 µm is as per the Canadian Foundation Manual.
** The description is behaviour based & subject to EBA description protocols.

Reviewed By: RKO P.Eng.

TETRA TECH

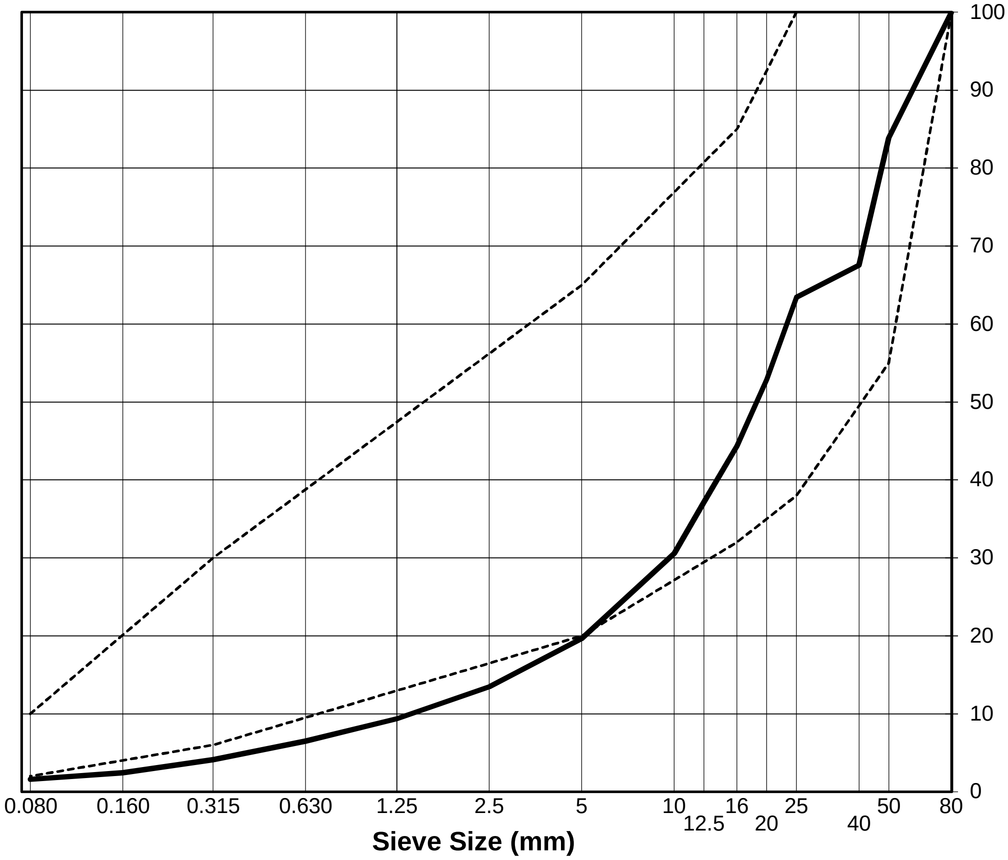
SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: Y14103320-01
Project: Prairie Creek All-Season Road
Client: Canadian Zinc Corporation
Attention: David Harpley
Email: david@canadianzinc.com
Description: GRAVEL, some sand, trace silt/clay
Source: BP 151A / 151B
Supplier: n/a
Sample Location: Proposed borrow area
Specification: GNWT 80mm Gravel Fill

Sample No.: 6161 / Allnorth KP151
Date Received: October 9, 2014
Sampled by: EK (Allnorth)
Date Tested: December 5, 2014
Tested by: JD Office: Yellowknife
Moisture Content (as received): 2.6%
No. Crushed Faces: Two (2) or Three (3)
By Particle Mass:

Sieve Size	Percent Passing
	100
80	100
50	84
40	68
25	63
20	53
16	44
12.5	37
10	31
5	20
2.5	13
1.25	9
0.630	7
0.315	4
0.160	2
0.080	1.6



Remarks: Sampled from alluvial fan at 61.134787°N, 123.239557°W.
Described as cobbles and gravel. Sampled 75 mm minus.

Reviewed By: RKO P.Eng.

APPENDIX C

STATION-BY-STATION SUMMARY OF FIELD OBSERVATIONS

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
0	0.4	-	First 400 m of road route adjacent to Prairie Creek Mine and Camp, just south of southeast end of water retention pond. Steep high slopes, mostly treed in the first 100 m along road, then few trees in prominent area of slope ravelling next 200 m, then essentially untreed. Streams marked on orthophotography are likely ephemeral as a result of surficial erosion in shallow ridge-gully features. Air photos A28099- 137-138.	 Looking north at first 600 m of road from just southeast of Admininistration building (blue building mid-photo) to BP 1 (top left of photo). (Photo credit: CZN)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
0.40	2.60	-	Last station of Mollard's route is partly marked on A28099 - 137; probably km 185. If so, km 185.4 would be about the SE end of the pond, just before Prairie Creek Mine/Camp. This means Mollard's km 185.4 = our KP000.4 and KP001 is approx. NW end of pond. Road skirts toe of steeper slope, and berm of pond is immediately downslope south between KP000.4 and KP001. Upslope of ~KP000.55 to KP000.7 is proposed borrow BP 1. From KP000.7 to corner at ~KP001.1, is steep cutslope above road. From KP001.1 to KP001.4, road skirts steep toe of slope to south end of airstrip, some ravelling apparent on slope. Prairie Creek is tight on road toe to the south, then west as road rounds the corner heading north. From KP001.4 to KP002.6 is airstrip, with Prairie Creek along west edge. More room, slopes above less steep. Stream at about KP002 has the potential to carry debris flows, but no recent deposits are obvious on the air photos or imagery. Air photos A28099- 137-139.	 Looking south from north end of airstrip at about KP002.6. Steep slope above road in background is at about KP001.1 to KP001.4. Some ravelling talus/scree at corner. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
2.60	4.20	-	North end of airstrip is where valley becomes tight upstream. Small borrow proposed upslope east from ~KP002.7 to KP002.8 at existing borrow area. Creek crossing at ~KP002.9. Stream has potential to carry debris flows, but no recent deposits noted on air photos or imagery. Road is tight along toe, with wide and highly braided Prairie Creek to the west. Especially tight between creek and slope between KP003.4 and KP004.2, with very steep gradients upslope. Air photos indicate ravelling of slope above road in this section. Slope failure KP004.1 to KP004.2 likely due to toe erosion from Prairie Creek before the road was there; overflow channel still visible on air photos. Outside bend of creek means adequate erosion protection needed along road. Strip borrow proposed upslope of road understood to be as a result of cutslope for road widening; however, consider potential for exacerbating slope ravelling by adding to rock cut. This area is also mapped as avalanche terrain. Air photos A28099- 137-139.	 Looking south from KP003.8 at possible bedrock outcrop, plus talus/scree along road. (Photo credit: Allnorth)  Looking south at KP004.1 slope (Photo credit: Allnorth)

4.20	4.80	-	Route on floodplain to about KP004.8, where road tucks in along toe of slope again. Proposed borrows ~KP004.2 to KP004.35 and ~KP004.4 to KP004.7 (BP 4A and 4B). Long steep unvegetated slope on north side of KP004.4 stream indicates likelihood of periodic debris flow deposits that may impact road. Small debris flow deposit seen on air photos between toe of slope and road embankment, less obvious on imagery. Long unvegetated slope above BP 4B. Slope gradients 55% for about 150 m (horizontal), then steeper to 85% plus in long concave configuration to ridge crest above. Based on slope gradients in starting zones and lack of trees, this could be avalanche terrain but is not mapped as such. Gentler gradients in borrow area (mound at toe) might serve as deposition zone (and is itself the deposition zone of old slope failure), but doesn't show obvious effects. Lack of snow? Sinking streams on slope suggest freezing seepage as possible contributor to slope failures. These also correlate with narrow gully-ridge features in upper half of slope that suggest ravelling, surface erosion and possible debris flows on slope. No obvious recent events on air photos or imagery. Deposits from older events would likely have been obscured or obliterated by Prairie Creek at high water. Treed on steeper slopes above road again north of ~KP004.7, and slopes not as steep as untreed section immediately south. Air photos A28099- 138-140.	 Looking upstream at KP004.4 alluvial fan; note material to cobble/boulder size. (Photo credit: Allnorth)  From KP004.85, looking south. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
4.80	6.20	-	Sloughing on road just south of KP005 suggests possible toe erosion due to Prairie Creek braided channel. Erosion protection required. From KP005 to KP005.4, route is tight against toe of talus cone, with steep cut slope. North of KP005.4, route shortcuts pre-1994 detour around mound, staying on higher ground near toe of steeper slope. North of mound, route stays above pre-1994 winter road, skirting toe of slope from KP005.7 to KP006.1 where crossing of Casket Creek begins. Casket Creek is braided, with main channel currently on south side of floodplain. Locations and numbers of channels should be expected to vary in this stream, as the 1994 air photos indicate 4 streams of about equal width in middle of channel at that time. Casket Creek carries significant coarse-grained material which is deposited in the Prairie Creek drainage as an alluvial fan, and which on the 1994 air photos over-ran the road. Prairie Creek is wide and highly braided from ~KP005.4 to KP006.2. Route rejoins winter road on north side of crossing, about KP006.2. Air photos A28099- 138-140.	 At KP005, ravelling cut slope, tension cracks on fill slope. (Photo credit: Allnorth)  Looking north at KP006.1 Casket Creek (Photo credit: CZN)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
6.20	6.75	-	Road closely follows toe of steep slope in narrow section of Prairie Creek, which remains braided in this section. Slope at corner just before turn into Fast Creek drainage is treed but steep. Air photos A28099- 138-140.	 Looking south from KP006.75. (Photo credit: Allnorth)
6.75	7.60	-	Starts at confluence of Prairie Creek from NW and Fast Creek from NE. Fast Creek has a wide braided streambed. Scalloped appearance of slope above Fast Creek suggests past erosion from creek has triggered occasional slope failures. Anticipate some talus block and scree shedding to continue, but there is also significant tree growth on this section. Turns up the Funeral Creek drainage at about KP007.4, and stream bed is still braided and relatively wide (est. >50 m) until about KP007.6. Road closely follows toe of slope along southeast side of Fast Creek floodplain, then southwest side of Funeral Creek floodplain. Air photos A28099- 138-140 (missing 141).	 Looking south from KP007.25, Fast Creek on right. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

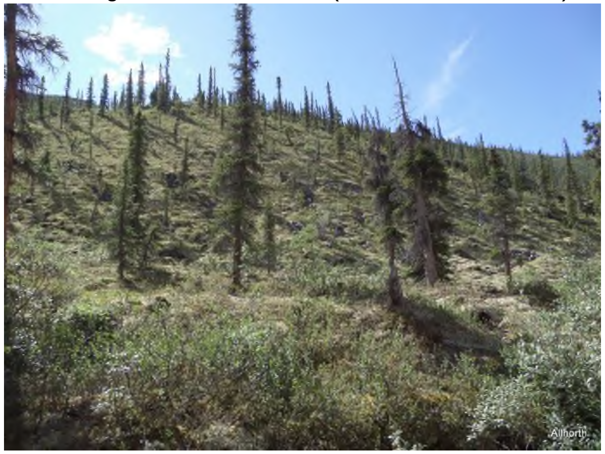
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
7.60	9.95	-	Road continues along south side of Funeral Creek along toe of slope. Very tight V-shaped valley. Talus/scree with some tributary streams between slope sections. Stream is braided from about KP008.6 to KP009.3., then occasional braids continuing eastbound. Several talus cones above road ~KP008.6 to KP010, less active than next road section. Possible slope failures above KP008 to KP008.25 and KP008.5 to KP008.65 (ragged configuration suggests possible headscarps in sloughing talus). Some treed areas, esp. gullies. Cones that reach road with few trees include ~KP009.15 to KP009.3, ~KP009.5 to KP009.6, and ~KP009.85 to KP009.95. Air photos A28099- 138-140 (missing 141, stereo coverage on edge of photo), A28099 - 106, 108 (missing 107, 109-112, no stereo coverage).	 Looking east from KP007.6 (Photo credit: Allnorth)  Looking upslope from KP009.25 at talus cone. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
9.95	12.75	-	Route continues on south side of Funeral Creek along toe of slope. Funeral Creek very narrow in tight V-shaped valley to about KP012, where valley bottom begins to widen eastbound. Road curves around prominent talus cone from ~KP009.95 to KP010.23. Small borrow at toe of slope above road at KP10.1 in talus. Talus slope above road ~KP010.23 to KP010.6. Immediately upslope of KP011, there is a series of small parallel trails up to 250 m long and up to 150 m (horizontal) above the road. Talus above road KP011.1 to KP012 appears more recent than sections immediately west and east. Another more recent section appears ~KP012.34 to KP012.5. Air photos A28099 - 106, 108 (missing 107, 109-112).	 Looking west from KP010.5, talus cone in background. (Photo credit: Allnorth)  Looking west from KP012. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
12.75	13.85	-	Route enters tributary drainage at start of hairpin. Skirts below talus for about 100 m, then treed 50 m, then skirts toe of talus to W tributary at about KP13.3, tight hairpin curve at KP013.36, then crosses E tributary ~KP013.4. Hairpin a little tighter and lower in E tributary valley than it is on existing winter road, but more rounded at switchback. Then route climbs out of tributary valley along treed slope below winter road, rejoining winter road again at main Funeral Creek valley slope at ~KP013.7. Three narrow slides below winter road at ~KP013.54, KP013.57, KP013.59, possibly due to fillslope failures in sidecast fill. Slope much steeper below route than above. Some trees on main valley sideslope until about KP013.85. No stereo coverage. Air photos A28099 - 106, 108 (missing 107, 109-112).	 Looking downstream north from existing hairpin at ~KP013.4. Two streams at crossing. (Photo credit: Allnorth)  Looking west from ~KP013.57. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

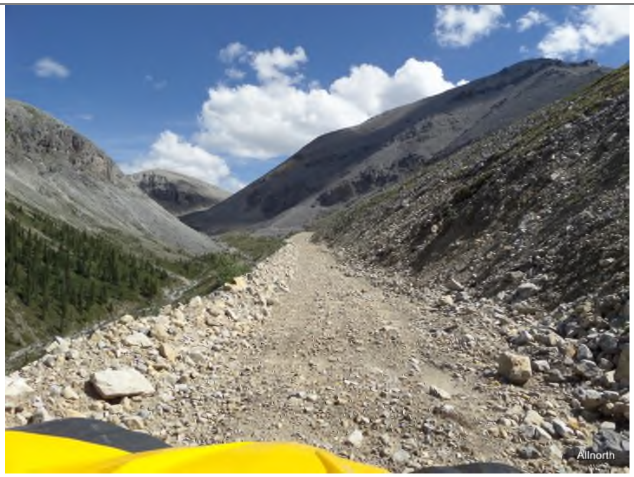
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
13.85	15.75	-	Now route cuts through apparently active talus slope (very light coloured and linear fall lines seen) from ~KP013.85 to ~KP014.2, then ~50 m treed, and back into talus. Air photos indicate possible fillslope failure below about KP014, about 30 m wide and 40 m long. Steep challenging terrain along climb to the pass. From about KP014 to KP020, Duk-Rodkin et al (2007) map the valleys as having been glaciated by a cordilleran glacier. Since the Funeral Creek valley at this location still appears more V-shaped than U-shaped, there may not have been much movement of the glacier. No stereo coverage. Air photos A28099 - 106, 108 (missing 107, 109-112), A28099 - 87-88 (missing 86).	 Looking east from KP014.1. (Photo credit: Allnorth)  Looking upslope from just west of KP014.8, at terrain seen in background from KP014.1. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
15.75	16.90	-	From crossing of Funeral Creek at ~KP015.75, hairpin up to tributary creek into Funeral Creek from the northeast at ~KP016.1, and eastbound to KP016.9 along cut in steep talus slope. Route bypasses existing switchback and continues west to skirt around knoll just east of tributary creek (using part of that acccess trail), then switches back east to rejoin winter road at ~KP016.3. The knoll appears to have two cuts in it, roughly on contour (borrow? exploration?). Mollard noted a small slide in the vicinity, which may be the slope feature seen below proposed route ~KP016, but that also appears more like a man-made cut on both air photos and imagery, particularly as it is not a fall-line feature. More likely, Mollard noted the largest of a series of apparent fillslope failures (or merely bladed fill from pushing the road) that has deposited near the Funeral Creek crossing. This particular feature may have in some form also predated the road, as there is also a narrow slough from the ridge upslope of the road at this location. The fillslope failures are prevalent on the steeper sideslopes from ~KP016.25 at the top of the existing switchback to ~KP016.75. No obvious changes on the imagery. Air photos A28099 - 87-88 (missing 86).	 Looking northeast from KP014.8. Note cuts in and below knoll near KP016.1 (pale orange). (Photo credit: Allnorth)  Looking east at existing switchback east of knoll inside proposed switchback at ~KP016.1. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

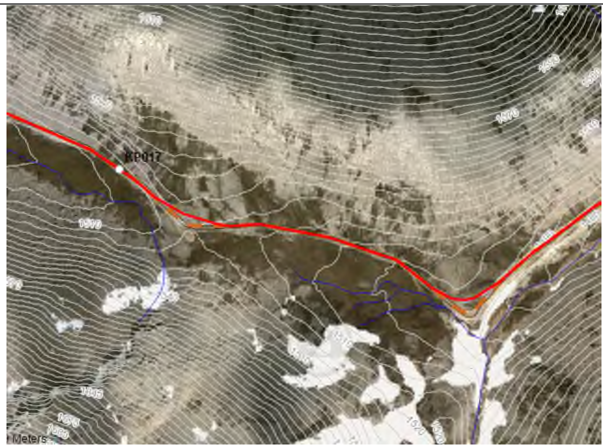
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
16.90	17.50	-	Route skirts toe of active talus slope on north side of Funeral Creek and Sundog Creek watersheds. Height of land between Funeral Creek and Sundog Creek drainages is at about KP017.1 (understood also to be the NNPR boundary). Duk-Rodkin et al (2007) map a Cordilleran ice cap along the height of land in this location, with approximate extents to KP014 to the west and KP020 to the east. It is not known if glaciofluvial deposits noted downstream at KP025.4 may originate from this glaciated area, or from a previous glaciation. Air photos A28099 - 87-88 (missing 86).	 Talus lobes and rock bluffs north of road. (Allnorth website)
17.50	19.10	-	Route follows winter road on north side of Sundog Creek, along toe of talus or cutting into toe on steady downgrade. Cuts across alluvial cones. Valley tight until ~KP018, where it gradually begins to widen, until ~KP018.4 where valley is wide enough for terraces. Route continues to skirt toe of talus until ~KP019.1. Air photos A28099 - 66, 68 (missing 67, no stereo coverage).	 Looking west from ~KP018.4 towards the pass. Sharp bend right ~KP017.4 (top of photo). (Photo credit: Golder 2010)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
19.10	20.60	-	Route continues on northeast side of Sundog Creek on gravelly terraces between stream and toe of talus slopes, crossing alluvial fans at ~KP019.9, ~KP020.1, and ~KP020.5 at proposed crossing of Sundog Creek, ~90 m upstream of winter road crossing. Road climbs onto terrace on southwest side of Sundog at ~KP020.6, about 200 m west of winter road crossing (due to crossing with less skew than winter road) southwest. Rock glaciers from ~KP019.7 to KP020.1, most prominent of which is at ~KP019.9 on upper slope south of stream. Air photos A28099 - 66, 68 (missing 67, no stereo coverage).	 View northwest from ~KP020.8. (Photo credit: Golder 2010)  Looking upstream at Sundog Creek crossing ~KP020.5 (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
20.60	21.70	-	Route on narrow terrace with large eroded talus cones just upslope, and cutting through a series of smaller cones at ~KP021.2 to KP021.5. Terrace is a little wider at ~KP021.5 to KP021.7, narrowing again so that road is again tight along toe by KP021.8. Air photos A28099 - 66, 68 (missing 67, no stereo coverage).	 View northwest from ~KP021.1. (Photo credit: Golder 2010)
21.70	23.15	-	Sundog Creek forms steep-sided V-shaped gully in this section, where route closely follows toe of talus, with some cuts (~KP021.8 to KP021.9, ~KP022.2 to KP022.6). Valley bottom widens out again at about KP022.6, where road also descends away from the steeper talus. Air photos A28099 - 66, 68 (missing A28099-67, A28099 - 46-48).	 View southwest from ~KP023 at knoll left to KP022.65 right.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
23.15	23.65	-	KP023.15 (old KP022.9) is start of existing hairpin on north approach to Sundog Canyon crossing. Two more hairpin approaches at floodplain, one per side. Ice plug builds at Sundog Canyon, blows out with spring flows. Old KP023.5 is south edge of braided floodplain, just before climb east up out of drainage. Talus most prevalent on NW side of stream and upstream. Proposed reroute removes hairpins and is further from talus, but closer to confluence with stream from northwest. Re-route KP023.05 to KP023.65 (old KP22.8 km to KP24.1). Reroute skirts around large debris slide in gravel north of ~KP023.6. Air photos for this section are missing (A28099 - 46-48).	 KP23.4 Crossing, looking southwest at Sundog Canyon
23.65	24.65	-	Possibly glaciofluvial on high-level terraces, fluvial on low-level terraces below road. Bedrock exposed in channel bottom. Talus mounds above road; road cuts through some of these.	 KP023.7 Looking south at southeast side of Sundog Canyon stream crossing.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
24.65	25.6	-	Mollard's description follows existing winter road to north side of Sundog Creek Tributary. KP024.2 (old KP24.6) is approximate start of proposed reroute on south side of Sundog Creek Tributary. Avoids one crossing of Sundog Creek Tributary, but adds a crossing of a tributary at ~KP025.4 (old KP25.8). Until that crossing, route stays in the trees which grow in densely-vegetated elongated depressions winding between older talus (light areas with trees) and recent alluvial mounds. These look older than more-active talus further upslope, which is also further from reroute than active talus is on existing route. Anticipate evidence of creep on steeper sections. Upper terraces are probably glaciofluvial, lower terraces may be fluvial, west and east of KP025.4 tributary crossing.	 Looking west from KP025.4 crossing, glaciofluvial terraces and U-shaped valley upstream. (Photo credit: Allnorth)  Looking west to KP025.4 from ~KP025.8. Route on treed bench top left. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
25.6	26.65	-	Terrain unit becomes glaciofluvial veneer and colluvial veneer where bedrock is near-surface. Anticipate talus forming aprons, cones, blankets and veneers on top of terraces. A cluster of shallow depressions (up to 0.6 m deep and up to 1.5 m in diameter) possibly formed by piping, i.e. tunnel erosion (suffosion) were observed in the field at KP25.6. Two well-defined round depressions of ~5 m diameter, indicative of such piping, were interpreted from the hi-res imagery between KP026 and the creek channel. Reroute looks more favourable after KP026. Air photos for this section are missing (A28099 – 46-48).	 Suspected suffosion feature at about KP025.6  KP26 at mid-left, looking upstream. Transition of glaciofluvial terrace to veneer (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

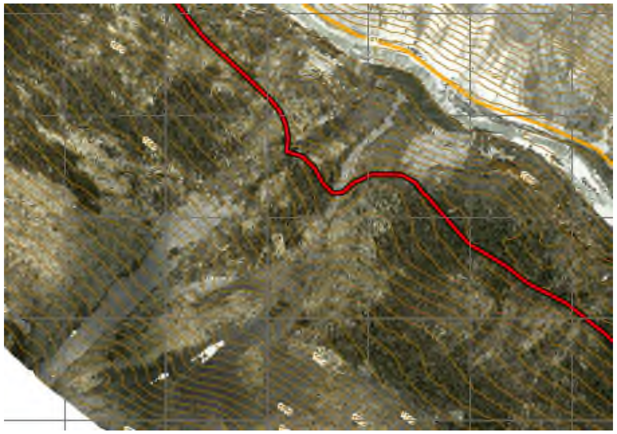
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
26.65	28.25	-	At KP026.6, route avoids another crossing of Sundog Ck Trib (still on S side), but at KP026.7 must cross another tributary. Route stays high, out of the creek bottom continuing ESE. Large debris flow with three crossings within about 120 m beginning at ~KP027.2. Bedrock exposed as cliffs on lower slopes at debris flows and in creek area; should be fairly stable. The first two (NW) debris flow channels look less recent (avulsion) and/or grown in with trees (main channel), but new debris toe is only about 100 m upslope. The next (SE) debris channel is recently active. Two more streams marked at about KP027.55 km and KP027.65 that appear to be intermittent debris flows, with two smaller adjacent features that could be avulsions. Debris flows in these channels are possible at any time due to exposed talus above, and avulsions should also be expected. Creep probable but no obvious evidence of permafrost. Big rocky bluff below road begins ~KP027.45 and peters out ~KP027.8 at HP28. Air photos for this section are missing (A28099 - 46-48; A28094 - 200-202 est.).	 Debris flow channels from KP027.2 to KP027.65

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
28.25	33.55	-	Route descends at ~KP028.25 to coarse gravelly floodplain of Sundog Creek Tributary, crossing the creek and rejoining the winter route on the north side at about KP028.35. The winter route crosses along the toes of some large talus/scree slopes and alluvial cones/fans. Route crosses main creek again at ~KP028.85, continuing on winter route on floodplain. Crosses tributary stream at ~KP029.13 and skirts toe of alluvial fan to about KP029.23, following winter route to ~KP030.6, closer to stream than to slope toe, then upslope near slope toe, rejoining winter route at ~KP031.4. Route is subject to debris flows or rock slides between ~KP029.6 and KP029.8. Alluvial fans between ~KP030.6 and KP031.8 may be subject to debris flows, and location of creek crossings may not stay the same. Route skirts just below toes of fans, except at KP031.3 where it crosses mid-fan. Route then skirts toe of tributary fan at ~KP032.4. New route stays on S side of Sundog at ~KP032.9. From here to ~KP039, rock fill section proposed in creek. Air photo and imagery east of KP032 shows series of steep bluffs above ridge/gully features within large concave bowl or scalloped feature which could be post-glacial failure, almost top to bottom of slope. Air photos for this section are missing (A28099 - 46-48; A28094 - 201-204 est.).	 Looking south (downstream) along winter road at ~KP028.9. Rock bluff east and alluvial fan at ~KP029.13 from southwest in middle ground. (Photo credit: Allnorth)  At KP032.4 looking downstream. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

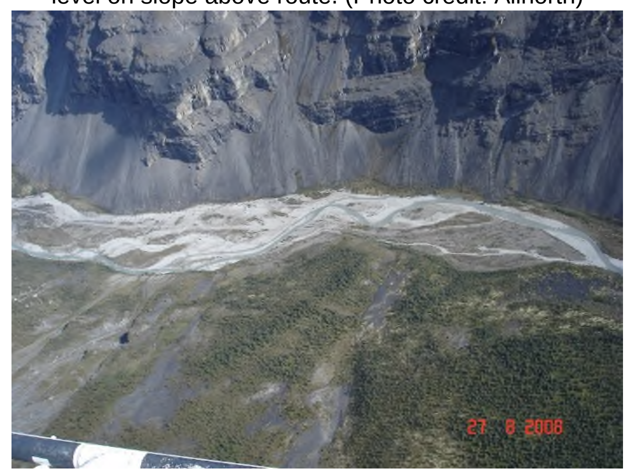
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
33.55	35.0	-	Mollard's description is for winter route crossing stream from KP033 on south side to KP033.5 on north side, back again to south side at KP034, and back again to the north by KP034.7. All-season route stays on southeast side, skirting toe of slope in left side of photo. Talus/scree is prevalent in this section, as are large bedrock bluffs. At ~KP034.6, there is a large bedrock bluff about 150 m wide and about 90 m (horizontal) above the toe of slope, which appears to have bedding or jointing different from the nearby outcrops south and north, but similar to the outcrops north of KP035. Air photos A28094 - 209; other air photos missing for this section.	 Looking southwest upstream from KP34.3 towards KP032. Bedrock bluffs on southeast side above road appear nearly level on slope above route. (Photo credit: Allnorth)  Looking east at outcrops between KP033.3 (RHS) and KP034.1 (LHS). (Photo credit: CZN)

Table C-1: Summary of Mapping and Field Observations

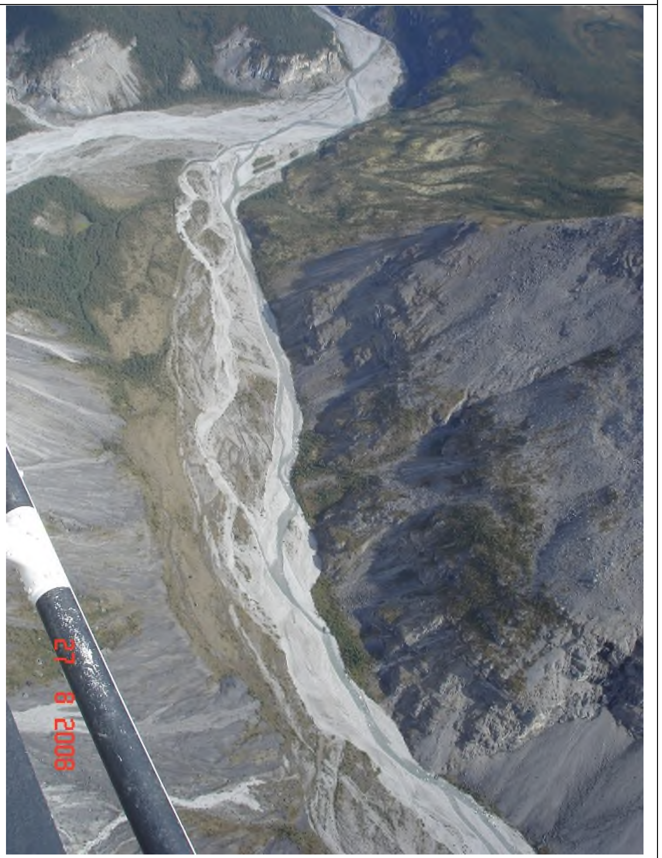
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
35.0	36.5	-	Mollard's description is for winter route on floodplain on north side of Sundog. All-season route stays on south side of Sundog throughout this section, skirting toe of steep slope. Bedrock or rocky bluffs prevalent northeast of ~KP035 along southeast shore of Sundog Creek, which are parallel to the stream direction in this section. There are some smaller scree/talus sections between outcrops and upslope of outcrops. Small borrow proposed at about KP035.4 between road and toe of slope (BP 35). A few debris flows features along this section, with a sizeable alluvial fan at KP035.7 where the road skirts around the toe of the fan. Northeast of ~KP036.3 appears to be older talus mounds. Bend in creek at top middle of photo is at about KP037.5. Air photo A28094 - 209; other air photos missing for this section.	 Looking downstream east-northeast from ~KP034.9. Bend in creek at ~KP036.5. (Photo credit: CZN)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
36.5	39.7	-	At ~KP036.5, at approx. bend in stream heading east-southeast, winter route crosses eastbound from north side of Sundog to south side. All-season route skirts along toe of steep slope on south side of Sundog floodplain, except at borrow BP 37 (~KP037.4 to KP037.7) where it follows edge of floodplain. Apparent talus mounds to ~KP037.2. Steep scarp upslope of road from ~KP037.2 to KP037.8, probably in bedrock. Bedrock bluffs above route ~KP038 and KP038.9. Proposed borrow between route and toe of bluffs, KP038-KP038.45 (BP 38). Air photos A28094 - 272-278 for KP038-KP049, A28094 - 209, 211. No stereo coverage south of ~KP038. See also photo in previous section for KP036.5 to KP037.8 view.	 Looking south at KP039.4 tributary into Sundog Creek. Bluff on right is above ~KP038.8. (Photo credit: Allnorth)
39.7	40.1	-	Edge of Sundog floodplain just before climb east out of valley bottom. Proposed borrow on vegetated terrace on upslope side of route (BP 40). Remnants of Cat Camp to be disposed of. Air photos A28094 - 277-278.	 Looking northeast along route. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
40.1	41.5		Route climbs out of Sundog drainage just south of apparent rocky headland jutting into river. Road crosses a series of swales and gullies along the climb east. Three small borrow areas enroute, which Allnorth hopes to be glaciofluvial sand but hasn't yet confirmed. Terrain looks quite different here than further east, and is well west of granular terrace beginning KP041.5. Mollard's suggestion of old mass-wasted till seems more likely. No obvious distress, but patchy trees on this irregular north-facing slope suggest possibly wet seeping areas in mid-slope and slopewash colluvium in areas of "mottled" looking terrain (patchy trees and areas of open-slope drainage). Air photos A28094 - 276-278.	 Just northeast of KP041, looking east at transition between slopewash colluvium and terrace. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
41.5	45.5		Route climbs onto flat granular terrace ~KP41.5, descending again at ~KP042.7. Borrow at KP043 (BP 43A) appears to be within the east-facing sideslope of the granular terrace. Determined by Allnorth to be fine glaciofluvial sand. Road continues east descending from borrow, down to stream crossing at about KP043.2. Possible flooding to 70 m from 5 m wide stream, but only 1 m deep at 1:100 year flood. Stream bed and overflow is gravel to cobbles, with areas of sand-silt. Slight reroute west of winter road on east side of stream for slightly wider corner at bend east at ~KP043.4. Granular terraces continue eastbound, with more of this terrain north of the road than south. Ground surface is more rugged than the KP041.5 to KP043 terrace, as a result of dune ridges prevalent north of road, but also present though more subdued south of road. Some sections of soil are exposed along this part of the route; probably similar to the borrow anticipated by Allnorth (glaciofluvial fine sand). Road descends off the main terrace at about KP045.5, leaving the granular terraces/dunes altogether at about KP45.7. In the section between KP045.5 and KP045.7, there may be little or no granular thickness beneath the road, which follows along the south side of a small stream here. There are still terraces beside the road, north and south. Air photos A28094 - 275-277.	 West of KP043, view southeast across route just below edge of terrace and stream below. (Photo credit: Allnorth)  KP045: view northeast, exposed soil (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
45.5	46.3		"Mottled" slope appearance due to patchy trees and open-slope drainage features in area of slopewash colluvium. Mollard notes moderate slope with slopewash colluvium possibly over old till. Exposed soil at HP47, at about KP046.1. No obvious reason for it, may just be a borrow area in small knoll just north of route. Creek crossing immediately east looks washed out on air photos, but there likely was little or no fill there anyway, so this may just be stream incised into original grade (0.5 m wide by 0.5 m deep on vegetated floodplain). No exposed soil at stream. No apparent distress on imagery. Stream crossing study suggests potential for 1:100 year flood to 806.5 m elevation and width of 24 m. Air photos A28094 - 273-275.	 Looking northeast across route, exposed soil at HP47. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
46.3	48.8	-	On winter road route. ~KP046.5 is Mollard's ~km 140. Terrain eastbound is now steeper, road winds its way around steep toes of knolls, especially between ~KP047 and KP048, where there are some areas of exposed soils on the air photos at each cut location on knolls, and on a steep slope section above an outside bend of the creek between ~KP047.4 and KP047.6. From KP047.6 to KP047.65, a very tight outside bend of the creek has resulted in erosion at the slope toe and a slope failure below the road. The sloughing has not retrogressed to the road yet, even in the 2012 imagery, but some consideration should be made to protecting this slope from further erosion. A similar situation is present at ~KP048.5, at KP49b, where another outside bend of the creek comes very close to the road. There is little vertical difference between road and creek here though, so it may be easier to protect. Air photos A28094 - 273-275.	 On southeast side of creek by KP047.5, looking northwest.  From KP048.35 looking northeast, road close to creek bends here and at KP048.5. (Photo credits: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
48.8	49.1	-	The 2014 all-season route begins at ~KP048.8 (old KP49.3, and Mollard's km 137.5), heading NE to avoid karst area to east, and staying northwest, then north, of creek (referred to in Golder 2010 as a tributary of Polje Creek). Almost the entire reroute is within an area burned by a forest fire in 1996, within only some short lengths of valley bottom and gullies typically preserved, as well as the western ~0.5 km of the reroute. Soils appear to be slopewash colluvium, possibly over old till, resulting in mottled appearance of terrain where knolls and ridges are dark (typically treed) and drainage paths around and between the knolls and ridges are light (fewer or smaller trees, brush or other groundcover, sometimes bare ground). Much of this terrain appears relatively benign, with only the difference in vegetation to indicate slope processes; however, when pursuing such drainage paths to the crest of slope, there are typically identifiable headscarps. Though most of these appear to be inactive, they can reactivate under the right conditions. For example, about 2.2 km due north of HP46, there is a readily identifiable example of a reactivated debris slide, with two headscarps of 300 m and 130 m in width resulting in exposed soil along a 400 m length of drainage. Air photos A28094 - 272-274, and 217-218-219 (missing 219). No stereo coverage north of ~KP049. All-season route is at edge of photos, thus some distortion.	 Looking northeast from KP048.8 along reroute north of Poljes. KP050.5 failure top right. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

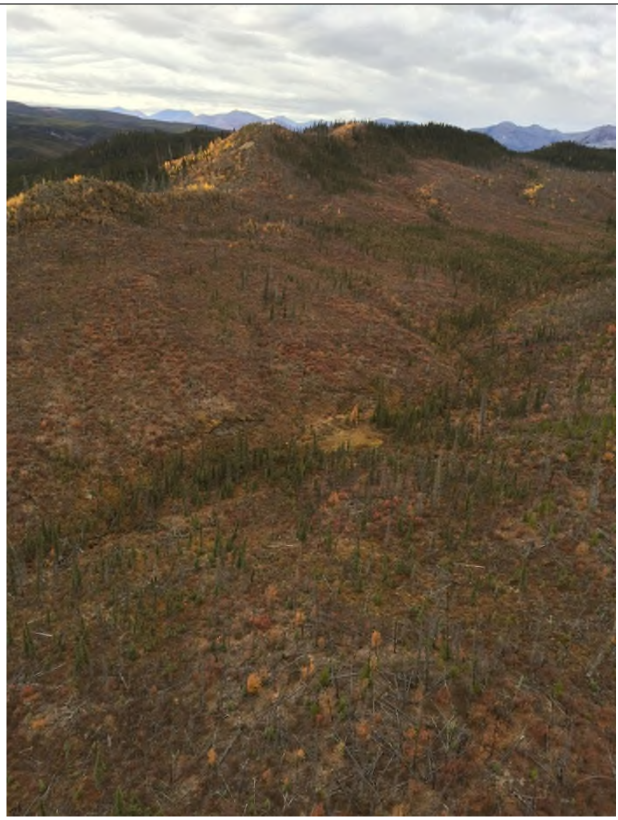
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
49.1	49.8	-	BH-01 west of creek at upper HP50 indicates till-like textures in sloughed soils (silt with some sand and clay) and underlying apparently-intact soils (silty clay with some sand and sand lenses). In contrast, shallow TPs and BHs east of the creek at HP50 to 1.2 m maximum depth indicate 0.1 - 0.15 m peat/organics over SAND, trace to some silt to silty on the main portion of the reroute. Comparing upper and lower tributary creek crossings at HP50, the better crossing is the lower one at ~KP049.7. The upper one entails crossing tributary sideslopes which are already failing - shallow slips in active layer, with heavy seepage throughout this slope. At ~KP049.8 (old KP50.5), terrain no longer mottled upslope of route, suggesting slopewash processes are not as prevalent, but slope instabilities are more prevalent downslope of realignment, extending to creek floodplain. For the most part, these instabilities appear to be related to undercutting of slope toe at outside bends of stream, but a contributing factor is probably the 1996 forest fire damaging the organic layer, subjecting the underlying fine-grained soils to additional infiltration and erosion, and possibly thaw of permafrost if present. Since this is a warm south-facing slope, permafrost may or may not be present, but was not encountered in the shallow testholes. Also a factor in near-surface soils, due to the forest fire, is the loss of integrity of roots of mature trees, as well as the loss of tree trunks in reducing avalanche activity on local steep gradients, both of which can result in increased susceptibility to soil disturbance.	 Looking west at slope failure along gully bottom near proposed upper crossing at KP049.7 (BH-01).

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
49.8	50.8	-	Crossing sidehill above creek, but climbing early onto successive benchy areas. Slope instabilities noted downslope of realignment - especially beginning at KP050, where there is a slope failure at the outside bend of the creek below due to undercutting, and at KP050.1 (old KP51 area) where the available 1994 air photo (#218) shows series of small slides that seem to have grown over in the 2012 LiDAR. On the ground, these narrow features proved to be ridge/gully features, sliding in linear fashion downslope, with depths of about 1 to 1.5 m. Same soil constituents as encountered upslope - essentially sand. The road has been routed a little further upslope to stay further back from the steeper slopes above the creek. A slope failure at ~KP050.5 (old KP51.5) as seen on 2012 LiDAR has grown larger since the 1994 air photos. A revegetated slope failure is also noted immediately west and upstream of this large open slope, along with an abandoned stream channel at the toe, indicating the close correlation between slope stability and stream channel behaviour. Two routes were considered upslope of the KP050.5 slide area, with an alternative further northeast to avoid possible road failure due to progressive slope headscarp retrogression. However, the headscarp is near local height of land now, along what turns out to be a ridge with a swale behind it, and away from the road. Shallow soils are identified as sand throughout this rerouted section to at least as far as heli pad at creek (HP52), at about KP50.8 along route. Presence or absence of permafrost could not be determined on the basis of the 2014 testholes, but based on slope aspect, the slope should be locally warmer than adjacent terrain.	 Left side is ridge-gully features at KP050.1 (within area of yellow vegetation), right side is large slope failure at KP050.5, treed area immediately left of large failure is revegetated old failure. Looking northwest.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
50.8	53.6	-	Crossing tributary floodplain from just west of ~KP050.8 to ~KP50.9 (about 80 m), short climb northeast out of floodplain, then on contour on sideslopes of 10-15% above the apexes of several apparent alluvial/colluvial fans. Road grade situated on fine sand, with proposed borrow sites between floodplain and KP051, and at ~KP051.7 (Allnorth data). Then, from ~KP51.8 to ~KP052.2, the route crosses a large alluvial/colluvial fan about halfway down from the apex and, depending on location, about 380 to 500 m from the floodplain of the main creek (referred to as a tributary of Polje Creek in Golder 2010). Slope gradient below the road at KP052 is about 3%. At ~KP052.2, the edge of another newer fan appears to overrun the upper part of the large fan. Different events can be discerned from the colour variation in the streaking of the fan materials. Small streams are running on the fans to the south and east, and then northeast; all joining and running towards Polje Creek, where the creek downslope meets the stream flowing from the Poljes, becoming a larger meandering S-N stream at ~KP053.6 (old KP54.5). The road crosses a couple of tributaries just west of Polje Creek, including one consisting of the streams from the fans, just as the road enters the main floodplain of Polje Creek at ~KP053.4. Need air photos A28094 - 218-223. (Missing 219-222)	 Looking west-southwest from KP051.7, in proposed borrow area along route. Ridge on horizon just right of centre is ridge west of KP049.7, upslope of BH-01. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
53.6	54.6	-	A recent slope failure is marked on the LiDAR south of the proposed route (beside route between ~KP053.8 and KP054.1, and below the route at KP054.2) as the route climbs east-northeast and then turns south-southeast. Slump/flow is ~300 m long and ~80 m wide, and may be associated with a small stream draining west to Polje Creek, as well as effects of 1996 forest fire on permafrost. Site visit September 22, 2014: Retrogressive thaw slump/flow has potential to spread; diagonal feature in photo top right may limit retrogression. Seepage, water flow and standing water are confirmed in the slide area. Apparent bedrock control north side may help limit lateral progression to the north, where the road is presently proposed. Similar terrain continues outside the perimeter of the bedrock outcrop / near-surface bedrock. Trees associated with bedrock / higher ground appear to be mostly straight, whereas trees outside this area are leaning in towards the main slide or leaning upslope, and there are a few "drunken forest" trees. Below (west-southwest of) bedrock area, slopes are gentler (~8%), and Allnorth is proposing embankment fill only (overlanding) through this area. Soils exposed on headscarp and sliding surface are peat, silt, sand, and clay (till-like). Head scarp 2.25 m high. Refusal on suspected permafrost at 2.5 m. The soil is ~60% clay and ~40% silt, with <1% sand.	 Looking downslope and southwest at upper end of thaw slump/flow, possibly limited by bedrock control.  Headscarp logged in TP-07.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
54.6	57.7	-	From ~KP054.6 to KP057.7, the reroute skirts around bedrock bluffs and drainages flowing to the Third Polje and to Polje Creek. Carbonates identified in the bluffs at ~KP054.6 (Allnorth's BP54), and shale at ~KP055.3 and ~KP055.9 (BP55 and BP56). Sinkhole noted about 80 m SSE and downslope of route at ~KP056, well below shale borrow at BP56 which is along a bluff along the proposed road route. Anticipate residual and colluvial veneer over near-surface bedrock, including some slopewash features downslope (west and south) of the road. SLI noted an historical landslide between about KP056.8 and KP057.4 (current stations), in the vicinity of their boreholes BH-M-01 through BH-M-04. At least some of the boreholes were within their identified slide area. There are several possible scarps along the route in this section, all of which appear relatively well-vegetated on the 2012 imagery. No 1994 air photos to compare to. There is an obvious slope failure downslope of the route between about KP057.4 and KP057.7, above the east end of the Third Polje (probably the same site reported by Dillon in Sept 2009). See Figure 6 for slope failures.	 Sinkhole Near KP056, note apparent subsidence cracking  Looking north at KP056 shale bluff, note slope issues.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
57.7	58.6 meets winter road	-	All-season reroute towards mine heads NW from ~KP058.6 (old KP59.6) to avoid karst, skirting north and east of swales and drainages at top of slope, specifically to avoid the Poljes southwest of ~KP055.5 to KP058.5, as well as avoiding some but not all potentially unstable ground (Figure 6). Between KP057.7 and KP058.6, the road skirts around the crest of slope above Second Polje. The sand and gravel terrace noted by Mollard in the next road section appears to continue to the north and east of the route, at least as far north along the road as ~KP057.7, based on slope gradients and similarities in surface texture as it appears in the 2012 imagery. Winter road heads south from KP058.6 towards mine. Heading east, all-season alignment is on winter road. Need air photos A29094 - 218-223 (missing 219-222).	 At KP059.3, looking west, light low area at KP059. Route bends north with edge of terrace. (Photo credit: Allnorth)
58.6	59.9	-	Route is on winter road alignment. Mollard's description extends east from first switchback where all-season route leaves the winter road heading northwest. This terrain is much flatter than the terrain immediately east and west, with gradients of 0-2%. Some steep and unstable slopes south (Figure 6). Proposed gravel borrow pit BP59 at ~KP059.4, with constituents noted as subrounded shale and sand. Swale along toe of ridge at about KP059.9 resembles a small meltwater channel. No stereo coverage west of ~KP060, no coverage at all west of ~KP058. Need air photos A29094 - 218-223 (missing 219-222).	 Looking north from ~KP059.6 at sand and gravel terrace; proposed borrow in foreground.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
59.9	61.3	-	Route is on winter road alignment. Crossing near head of steep-sided gully between ~KP059.9 and KP060.7; section from ~KP060.5 to KP060.7 has some poorly-vegetated and oversteepened slope sections due to seepage and/or sloughing (Mollard's KP123 to 123.2). Main stream at ~KP060.5, but road descends from ~KP061.1 along a tributary swale until ~KP060.6, where the tributary stream turns downslope to meet main stream. Caution required in design and construction so as not to direct water where it would not naturally run. Air photos A28094 - 196-197, 223-224. No stereo coverage west of ~KP060. Missing photos 219 to 222.	 From downslope side of road at about KP060.4, looking at cutslopes both sides of KP060.5 stream crossing.  From KP060.6 looking east along route, road in swale with stream, road bend at ~KP60.7. (Photo credits: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
61.3	62.6	-	Steep-sided gully crossing at ~KP061.6 (Mollard's ~km 122.1). Bare ground seen upstream along both forks of this gully; potential for debris flows but the most prominent features in the north fork appear to be bedrock-related. North approach appears to be a full bench cut. North end of Mosquito Lake at ~KP062.2. Air photos A28094 - 196-197, 223-224.	 Looking south across gully from KP061.3, cutslope with revegetation on road grade. (Photo credit: Allnorth)
62.6	64.3	Sh, Si, L GC-GP H 1,2,3, d (following Mollard)	Route is on winter road alignment. Terrain less rugged and gently sloping along route between ~KP63.3 and KP64.3. South end of Mosquito Lake is due west of ~KP064. Drainage across road from ponds on east side at ~KP063.7. Northwest approach (Mine side) is moderately steep ~KP063.5 to KP063.6. Air photos A28094 - 195-196.	 Wet swale across road at KP063.7. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
64.3	65.0	Sh, Si, L GC-GP H 1,2,3, d (following Mollard)	Route is on winter road alignment. Ponds alongside road are in deep wide bowls. GSC mapping suggests lacustrine, but west of this section are some sharp-edged angular ridges surrounding some very deep unvegetated bowls that appear as though they are sometimes water-filled. These may be like the Poljes, which can fill or drain. More inclined to follow Mollard on terrain type in this section, unless there is also some lacustrine modification in the history. South of ~KP064, in approximate area of old burn (sometime 1940-1950). Considerable revegetation in road, some areas of exposed soil. Air photos A28094 - 195-196.	 From KP064.8, looking south. (Photo credit: Allnorth)
65.0	66.3	Sh, Si, L GC-GP H 1,2,3, d	Route is on winter road alignment. Between ~KP065 and KP066.3, the route follows crests of slopes/ridges generally staying out of drainages except to cross them, and usually crossing them high on slope. Detour around east side of a knoll and at about KP065.15 to KP065.4. From KP065.3, detour bends west and south again to follow ridge well above adjacent ponds west and east. Ponds alongside road are in deep wide bowls. Air photos A28094 - 195-196.	 Looking south from KP065.3. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
66.3	67.6	Sh, Si, L GC-GP H 1,2,3, d	Route is on winter road alignment. Between ~KP066.3 and KP067, the route follows crests of slopes/ridges generally staying out of drainages except to cross them, and usually crossing them high on slope. From ~KP067 to ~KP068, route skirts northeast toe of ridge, which has either bedrock or near-surface bedrock. Steeper faces appear marginally or unvegetated and may be ravelling. Road grade looks stable. Patchy old burn area ~KP066.5 to KP069.5. Air photos A28094 - 193-195.	 Looking east from ~KP067. (Photo credit: Allnorth)
67.6	70.2	Sh, Si, L GC-GP H 1,2,3, d	Route is on winter road alignment. Generally following ridge tops and skirting around drainage features. From ~KP067 to ~KP068, route skirts north toe of ridge. Just south of ridge crest from ~KP068.5 to KP069. Possible old slough in drainage west below ridge ~KP068.5-P069.3? Road appears to be cut into slope. Ridge may be bedrock or near-surface bedrock and parts of cut may also be into rock. No obvious influence of road on stability, aside from possible fill slope disturbance ~KP068.7 that seems well-vegetated. This is also in area of more recent burn (date unknown), up to ~KP069.5. Air photos A28094 - 192-194.	 Looking south, bend left ~KP068.7. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
70.2	71.7	Sh, Si, L GC-GP H 1,2,3, d	Route is on winter road alignment. Route skirts around steeper slope below from ~KP070.2 to ~KP071, with steeper ground upslope at KP070.6 to KP070.8. Air photos A28094 - 264-265.	 Looking south from KP070. (Photo credit: Allnorth)
71.7	75.6	Sh, Si, L GC-GP H 1,2,3, d	Route is on winter road alignment. Peaty wetland at about KP072.8. Allnorth identified fine sand at adjacent borrow site, at soil exposure along road. Air photos A28094 - 189-192, 263-265.	 Looking southeast from KP072.6. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
75.6	80.0	Sh, Si, L GC-GP H 1,2,3, d and (Cx1/tMv1)/ (Sh, Si, L)	All-season road is on winter road, following ridge top. Scattered bare patches seen on cleared ROW on 1994 airphotos. No apparent distress on or immediately adjacent to road on 2012 imagery. Transition from bedrock with residual/colluvial veneer to colluvial/till veneer over bedrock occurs at about KP078.6 according to transition marked on GSC mapping. Visually, on the 2012 imagery, the transition is at about KP079, where terrain has greyish undertone west and brownish undertone east. From ~KP079 to KP080 is also where route traverses along the crest of a broad bowl with streaky terrain (overland runoff channels or seeps, inactive or ephemeral). Narrow ridge between lower bowls about 250 m downslope ~KP079.8 to KP079.9. Air photos A28094 - 261-264.	 Looking northeast near KP079. (Photo credits: Allnorth)
80.0	80.3	(Cx1/tMv1)/ (Sh, Si, L)	Traversing along crest of steeper slope south, gentle slopes north. From ~KP080 to KP080.5 (old KP81.0 to about 81.5), the winter road alignment crosses within 140 m of a bowl-shaped feature downslope that appears to be an overgrown slope failure, streaky terrain. All-season route stays upslope of winter route east of KP080.3. Air photos A28094 - 260-261.	 Looking east from KP080.1, winter route visible southwest of KP081 at light-coloured strip, upper right of photo.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
80.3	83.0	(Cx1/tMv1)/ (Sh, Si, L)	At ~KP080.3 (old KP81.3) on the winter road, the route begins descent into, then across gully, descending east sidewall of gully, then bending east to follow just above valley bottom. Gully appears to be a shallow earth slide, with smaller old slope instabilities within gully, and at old KP83. Apparent headscarps are more obvious on 1994 air photos than on 2012 imagery. Mottled slope appearance between old KP82.7-82.9 on winter road. Short bare patches noted by Mollard seem to be related to cutslope disturbances. Clearly visible on the 1994 air photos, but not on the 2012 imagery. Streaky, subparallel runoff channels in valley south of road. All-season reroute departs from the winter road at ~KP080.3 (old KP81.3), staying north of the winter road and avoiding these features by staying above the crests of steeper gullies/drainages (locally to 40%), and on ridges (20% or less). From about KP080.8, the route descends a ridgeline south, switching back at about KP081.7, heading northeast and skirting above the steeper ground on the descent towards KP083, where the slope gradient lessens. Openings at ~KP082.4, KP082.5 and KP082.8 below the route along low northeast-running ridge suggest seepage areas and possibility of instabilities at heads of swales. First two of these are seen on 1994 air photos and 2012 imagery, the latter is on less-steep ground and is visible only on 1994 air photos. Care is required to optimize drainage across road. Air photos A28094 - 260-261.	 Looking south-southwest from about KP083.5. Note winter route in upper mid-photo. All-season route stays high along upper right, along and/or just within upper edge of aspen.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
83.0	83.9	(Cx1/tMv1)/ (Sh, Si, L)	Slope gradients between ~7-13% in streaky terrain. Slopes becoming gentler eastbound. All-season route is roughly parallel to and south of small stream. Decadent forest in this area; jackstrawed trees across stream, lots of old and new deadfall, old deadfall is moss-covered. Soils include silts with trace clay to clayey, to silty clays. Trace sand and sand pockets, trace oxides, trace gravel; till-like. (TP-12/BH-06, north of ~KP083.6; TP-13/BH-07, northeast of ~KP084.) Since this area is mapped colluvial or till moraine veneer, anticipate similar soil textures in either terrain type. See Figure 8. Air photos A28094 - 259-261.	 Jackstrawed trees and decadent forest along stream between TP-12 and TP-13. Trees straighter away from stream in open aspen/birch/spruce stands.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
83.9	85.9	Cx1	Slope gradients between ~4-7% in streaky terrain. Ends at about HP 86 (just south of winter road) and about KP085.9 along the all-season route (east edge of area). Anticipate similar soil types as upslope. Potential slope issues near the crest of a north-facing slope above upper Tetcela River, which is mapped entirely as colluvium by GSC. Most of this slope is off the 2012 imagery, but numerous slide paths are visible on the 1994 air photos. Recent ("fresh") slide path is clearly visible near KP084 on the 1994 air photos (A28094-259-260). From the air it appears that there may be tension cracks above crest of slope, areas of seepage and apparently slumping soil. Numerous scarps and slide paths along Tetcela River. Tension cracks have been interpreted along the crest of the slope on the 1994 air photos (A28094-259-260) - see Figure 8. Route proposed to stay well south of Tetcela River crest of slope, south of small stream noted in field and mapped by Allnorth. Care needed with drainage across road (drainage path interpreted on the 1994 air photos between KP085.2 and KP085.5. Slope instabilities on 2012 imagery seen in field in KP085 area. Active slope erosion of the Tetcela River slope was interpreted between KP085.5 and 086.5 - patches of the slope are devoid of trees. There is evidence of downslope block movement. Air photos A28094 - 259-261.	 Looking southwest from KP084.5. Route skirts upslope edge of aspen patches, then far side of streams near crest.  Looking southwest at instabilities downslope of KP085.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
85.9	86.3	Cx	Within colluvial soils, downslope and east of streaky terrain. Gentle slope, road route descends south towards winter road. All-season route stays on the higher ground, avoiding unstable areas downslope that appear wetter, with fewer trees. See Figure 8.	 From north of KP086.9, looking upstream along Tetcela River; route avoids lower slopes. (Photo credit: Allnorth)
86.3	87.3	Cx	Bare patches on road between ~KP086.6 and KP087.3 seem to be related to descent along sidehill above stream bank - could be sediment from cutslope. GSC mapping indicates colluvium on this slope and transition into gully with scarped edges, so it could also be that this slope is more easily disturbed. All-season route descends from broad gentle slope at ~KP086.3 and crosses winter road at ~KP086.4, rejoining it again at KP086.6 heading east. Gully just south mapped with stream. See Figure 8. Air photos A28094 - 258-260.	 Looking southwest from north of KP086.7. All-season route rejoins winter road at bend.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
87.3	88.0	g,sAp/ s,siCx	Crossing the upper Tetcela River floodplain and turning the corner north into lower Tetcela River floodplain. Terrain is well-treed in this road section. Confluence with tributary is further south, and not encountered on the winter route or all-season route. See Figure 8. Air photos A28094 - 258-260.	 Looking north, KP087.6 to KP088.0. (Photo credit: Allnorth)
88.0	88.6	s, siS	On same route as winter road, and N of the upper Tetcela River, KP088 is just N of knife-edge ridge along N crest of river. At valley bottom, existing winter road heads N along lower Tetcela River over toe of debris from slump upslope W. Tetcela River northbound has cut into toe of debris east of road. GSC anticipated sands and silts. Well-vegetated floodplain, which shows some scrolling and the occasional oxbow. This section of road appears generally well-behaved with two short bare sections at KP088.1 and KP088.3 possibly related to short steep rolling grades on essentially disturbed and possibly looser soils due to slump (these are likely the same bare patches noted by Mollard). Adjacent stream and stream crossings show lots of movement/deposition of bed material. See Figure 8. Air photos A29094 - 235-236.	 Looking southeast along existing winter road between about KP088.5 and KP088. Slump mapped right (west).

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
88.6	90.2	g,sAp/ s,siCx and/or s, siS	On winter road route, skirting lower edge of large slump and outside edge of floodplain up to crossing of lower Tetcela River. At ~KP088.8 to KP089.2 is possible incursion from slump into floodplain, although there is little change in elevation suggesting subsequent modification by river. At about KP089.4, the road bends east towards river, crosses the floodplain, and crosses the river at about KP089.9. All-season route threads between apparent old approaches and what looks like abandoned channels on east side of river. The road leaves the floodplain at about KP090.2. See Figure 8. Air photos A28094 - 235-236 and 273-275.	 Looking south from KP089.2, slump right, Tetcela River left  Looking south at river crossing at KP089.8.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
90.2	90.6	s, siAp	GSC maps as alluvial plain. Thermokarst ponds within peatland terrain continuing SE on the winter road. No thermokarst in immediate vicinity of this road section; well-treed. Photos A28094 - 235-239 (missing 238).	 Looking west from KP090.2, existing route is revegetating very well, no sign of thermokarst. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
90.6	94.2	s, siLrh	All-season route leaves the winter road at about KP090.6, heading upslope and southeast into higher, drier terrain. Route is directed to run primarily along ridges, knolls and hummocks along the periphery of this upland area, skirting around the crests of suspected old slope failures and local steep slope sections. Drainage is to the north and northeast, with crossings of streams or swales generally made near the crests of steeper slope sections. Terrain is similar to that characterized further south. Possible thermokarst for about 100 m along winter road downslope of route at about KP091.8, mapped as distributary stream on 2012 imagery, originating south of stream crossing at KP091.3 on all-season route. Not obvious on 1994 air photos. More significant thermokarst ponds noted within the peatland terrain downslope of the proposed all-season route from KP092.8 on. At ~KP093.9, just N of the N end of C-Lake, the route gradually descends and bends to the E around the S end of C-Lake, crossing into the alluvial plain and thermokarst terrain at about KP094.2. Air photos A28094 - 256-259 (E-W) and N side A28094 - 235-239 (missing 238) (W-E).	 Looking west from winter road below KP092.5, all-season route stays high left.  Thermokarst at KP092.8 avoided by upslope reroute.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
94.2	97.0	s, siAp	The all-season route crosses the thermokarst terrain / alluvial plain between ~KP094.2 and KP095.8, rejoining the winter road just W of the crossing of Fishtrap Creek and KP095. Could be thermokarst associated with small stream through area draining into C-Lake, from ~KP094.2 to ~KP094.5. Stream is very steep-sided but narrow. There don't seem to be any particularly actively-thawing or distressed-looking reaches, but the geometry of the stream bends is suspicious, suggesting patterned ground (Photos #2862-2863). Another small stream comes in from the wetland to the west, just before the main stream widens outs into what looks like a delta at the lake. It looks as though the area of lake and stream sometimes has significantly higher water level than at time of work. Outlets of lake appear to be immediately east of inlet in lower leg of C, and also possibly at upper leg of C. This lake may once have been a much larger body of water, maybe during glacial retreat. Photos A28094 - 235-239 (missing 238). From KP095.8, the route skirts the outside edge of the floodplain, climbing a little higher than the winter road beginning at about KP096.6, and maintaining a distance of about 40 m upslope in this section. See further discussion in next section. Beaver dams at ~KP096.2 and ~KP096.8, flooding the stream north of the dams. More dams and remnants of dams are visible further downstream, indicating a natural system that is likely always in flux. Fishtrap Creek drainage flows south. Thermokarst continues in valley bottom, see comments below.	 Route re-enters potential thermokarst terrain at KP094.2.  Looking east-northeast across Fishtrap Creek drainage. Route rejoins winter road at bend heading east.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
97.0	98.0	Sh, L GC-GP H 3,2,4	GSC mapping shows the Silent Hills as having shale and limestone bedrock, overlain by a discontinuous residual or colluvial veneer of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels. Mollard describes this material as till, and soil descriptions by SLI in 2012 and observations by Tetra Tech EBA in 2014 suggest a till-like material. Soils encountered included various silt and clay mixtures, with varying proportions of sand and gravel, gravel increasing with depth, and fractured shale rocks also found in the samples. The presence of these fractured rocks suggests possible shallow bedrock, but bedrock has thus far not been proved in any testholes. Downslope of the route in the valley bottom, there is evidence of thermokarst. The stream west of the road from about KP096 to KP099.1 is flooded with some of the lakes on the floodplain now connected with the stream channel. From ~KP096.6 to KP098.0, proposed route climbs subparallel to winter route, within 40-100 m upslope of winter route. At ~KP098 (winter route ~km 84.9), the all-season route crosses the winter route and continues to climb heading southeast until ~KP099.1, then switches back to the north, rejoining the previously-proposed route at ~KP101. Air photos A28094 - 238-240 (W-E), 254-256 (E-W).	 Large debris flow north of helipad HP99 runs into stream crossing at ~KP096.6.  Looking south-southeast along winter road from KP098.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
98.0	101.7 (old 102)	Sh, L GC-GP H 3,2,4	Existing lower switchbacks wind their way around knolls. Old switchbacks are not used for all-season route which is generally routed both further north and south than winter route but ends at the same place at the top of Wolverine Pass. Numerous sinkholes and areas of exposed soils and old or continuously ravelling slope failures originate on steep convex slope sections are avoided with the new route. Route avoids large recent soil debris flows in large gullies north and south of the alignment, mapped by GSC and periodically reactivated (see also mapping on 2012 imagery). Route also avoids multiple crossings of an apparent debris flow gully, north of the upslope section of the route, now crossing only once, low on the slope at ~KP097.4. Other small areas with low vegetation look like seepage areas and possibly small slope failures. Route crosses somewhat wetter area between KP098 and KP101, but avoids possible slope failures seen on the imagery. Air photos A28094 - 238-241 (W-E, north side of switchbacks, missing 238 and 240 - no stereo), 254-256 (E-W, south side of switchbacks).	 Looking west at sinkhole (HP99 pond), avoided by route.  West of KP101 looking southeast upslope. Route avoids sinkholes between helipads HP101 and HP102, right side.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
101.7 (old 102)	103.3	Sh, L GC-GP H 3,2,4	GSC and Mollard disagree on the mapping of this section, but this is probably a matter of scale. The existing winter road tends to skirt along toes of steeper slope sections, and the all-season route tends to aim for higher ground. From ~KP102.7 to KP103, and KP103 to KP103.3 the proposed all-season route skirts across the toes of two small alluvial fans originating from upslope, first staying a little lower on the slope and then a little higher on the slope compared to the winter route, staying closer to on-contour between KP102.7 and KP103, and thereafter descending and crossing the winter route again to meet the next low ridge (see next section). The alluvial fans are reasonably well vegetated but there are some areas with little or no trees and exposed rock near the peak of the ridge suggests activity could resume under the right conditions. No stereo coverage A28094 - 239-241 (missing 240). A28094 - 254-255 marginally covers this transition, but it is at very edge of airphotos and is subject to distortion.	 Looking southeast from KP103. Proposed road generally skirts the upslope toes of the knolls (seen here at KP104 and KP105), avoiding wet areas.

Table C-1: Summary of Mapping and Field Observations

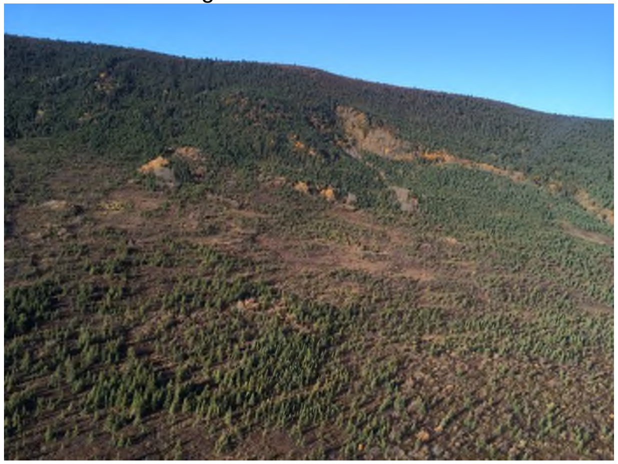
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
103.3	109.5	Sh, L GC-GP and Cx	Between ~KP103.3 and KP109.5, the route runs upslope of the knolls. Surficial geology is mapped by GSC on the upper slopes and near the knolls as shale and limestone overlain with residual or colluvial veneer as described below, and between and/or upslope of the knolls as colluvium. Anticipate possible occasional debris flows and slope failures, despite the gentler slopes, particularly events that originate upslope. Based on similar mapping by GSC along Front Range and soil samples obtained there and along upper route at KP116, expect till-like soil textures on this slope. Anticipate seepage in areas with shorter trees. No obvious signs of patterned ground or thermokarst in this section. From KP103 to KP105.8, the route stays on the higher ground where possible and skirts the toes of knolls. Between KP105.8 and KP106.6, the route is just above toe of knoll and just below some apparent surface sloughs, which will be removed when area used for borrow. Probably these are bedrock-controlled. From KP106.6 and KP107.1, route minimizes length in drainage crossing, which looks as though it may be related to an old cross-slope meltwater channel starting at KP105.9 above knoll and leading to gully at KP106.8 (old KP107). Bowl above gully has patchy vegetation, with occasional small areas that might be exposed soil, mostly along the main channel. The west fork, is steeply gullied with exposed ground at about 2 km upstream of the road route, which suggests that this stream could become a debris flow at times. Between KP107.1 to KP109.5, route skirts upslope toes of knolls and stays above gullied terrain. Air photos A29094 - 252-254.	 Looking south from about KP104.  Gullies from upslope of knolls drain down to road elevation, here above KP108.5, which drains to KP106.8 gully.

Table C-1: Summary of Mapping and Field Observations

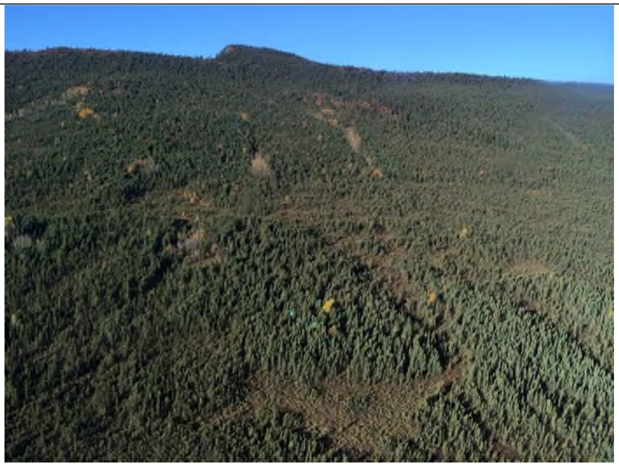
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
109.5	115.0	Sh, L GC-GP	From ~KP109.5 to KP115, the route runs upslope of the large knolls, mapped by GSC as shale and limestone overlain by a discontinuous residual or colluvial veneer of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels. Route generally avoids the wetter areas. Anticipate seepage in areas with shorter trees. No obvious signs of patterned ground or thermokarst in this section. Between KP109.5 to KP110, route skirts upslope toes of knolls and stays above gullied terrain. From ~KP110 to KP110.8, route skirts around lower edge of bowl-shaped area (possible old slope failure scar, KP110 to KP110.2, but may be bedrock-controlled, re ridge just north and knoll south), and then on upslope side of knoll, and upslope of drainage gullies at ~KP110.6 and KP110.8. Between KP110.8 and KP112, alignment avoids wet area and climbs on/off north end of large knoll, crossing upslope swale at ~KP111.8. From KP112 to KP114, the route skirts around the upslope toes of knolls and stays just upslope of gullied terrain. Good control of drainage required. Between ~KP114 and KP114.5, the route traverses along the crest of a small ridge and then descends to a stream crossing. Suspect near-surface bedrock on this ridge as its orientation is subparallel with exposed crest of knoll at KP113. Consider slight reroute just west of ridgetop to increase distance from apparent slough on downslope side. Air photos A28099 - 38-41.	 Terrain above KP111, some gullying and seepage areas  Looking southeast across stream crossings at about KP114.5 (Photo credit: Allnorth).

Table C-1: Summary of Mapping and Field Observations

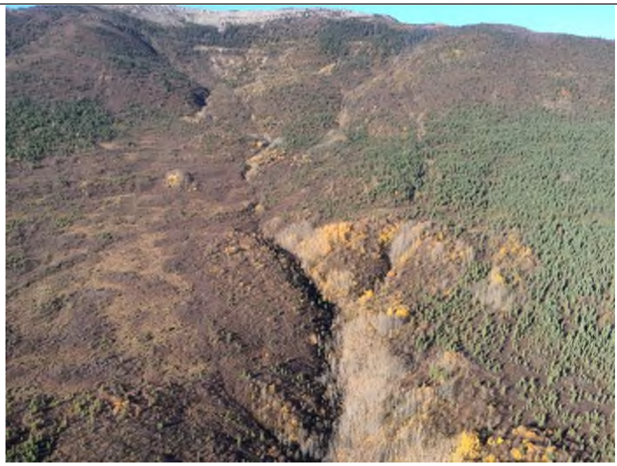
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
115.0	116.0	Sh, L GC-GP	Between KP115 and KP116, route descends from just above the large knolls (mapped as shale and limestone) down to glaciofluvial plain, crossing a swale with probable multiple small streams in it at ~KP115.5. Soils encountered during terrain typing upslope of KP116 were identified as silty sandy clay with trace gravel in debris flow gully upslope deposition areas in tributary gullies above main gully. Both upslope routes rejected in this section – in flatter tributary crossing and in steeper downslope section. Apparent bedrock exposed in scoured gully section further downslope. No stereo air photo coverage.	 Looking upslope at gullied terrain above KP116.  Looking downslope at scoured gully section above borrow BP116 and KP116 beyond (Photo credit: Allnorth).

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
116.0	117.5	(gGph-Cx)/ (Sh,L)	Route within glaciofluvial plain, skirting lower edge of Silent Hills. At ~KP116 (old KP115), now crossing downslope of apparent large debris flow gully with major scour on north gully slope upstream of crossing, visible on 2007 Google Earth, more prominent on 2012 imagery. No obvious patterned ground or thermokarst along this section, although there is a small round pond just SW of KP117. This pond could also just be a kettle. Other nearby ponds to the E seem to be associated with meltwater channels. GSC maps a small bedrock outcrop just E of the alignment at ~KP117.1, visible on bing coverage. Road east of LiDAR coverage.	 From knoll west of KP117 at small round pond, looking east to Grainger Gap. (Photo credit: Allnorth)
117.5	118.5	g,s,Gpr/Cx	Route crossing glaciofluvial plain between the slopes of the Silent Hills west and large meltwater channel east. Ascent/descent on west approach to meltwater channel is ~KP117.9 to 118.5 alongside stream south of road. No air photo coverage. No obvious patterned ground or thermokarst in this section, although there is a small opening at KP118 which could be a low wet area, and a small pond just N of KP118.2.	 From KP118, terrain upslope of route to KP117 (upslope of knoll RHS). (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
118.5	119.2	g,s,Gp	Crossing of large meltwater channel. Ascent/descent approaches into channel on east approach is estimated from ~KP118.9 to KP119.2 based on NTS 1:50,000 scale map and bing coverage. Off LiDAR. No air photo coverage. No obvious patterned ground or thermokarst in this section.	 East of route, looking west towards meltwater channel crossing at about KP119. (Photo credit: Allnorth)
119.2	121.2	Cx2/(Sh,L)	Proposed road is just within Cx2/ (Sh,L) traversing the lower slopes of a knoll north of the route, and just north of a large meltwater channel. No air photo coverage. No obvious signs of patterned ground or thermokarst on this section of route, although there are some possible thermokarst features in the meltwater channel to the south. Inconclusive: off orthophotos W of ~KP120.3, bing coverage only.	 Looking west at pond south of KP121 in headwaters of Grainger River. Road just upslope of meltwater channel.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
121.2	121.5	g,s,Gpr/Cx	All-season route traverses wide glaciofluvial plain. No airphoto coverage. Route crosses old N-S cutline at ~KP121.4. No obvious signs of patterned ground or thermokarst on this section of route.	 Looking southwest along route from KP121.6, route stays north (right) of large pond centre at KP121. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
121.5	122.9	g,s,Gpr/Cx	All-season route traverses wide glaciofluvial plain and skirts below toe of large gAf feature to SE. Significant ridged features are not obvious, but route crosses on relatively high ground compared to terrain NW and SE, avoiding bogs. One stream crossing at about KP122.4, which appears to originate from boggy area upslope and above that is the large alluvial fan. About 60 m S of road, S of HP123, stream (or opening) becomes wider for about 200 m: possible thermokarst? There is also a cross-slope drainage feature between fan and bog that looks like a possible small meltwater channel. Small pond in it, feature appears to drain to same stream crossing. Bog area is identified as peatland (potentially ice-rich permafrost) between KP122 and KP123 (SE of the proposed alignment). The current alignment avoids this sensitive organic terrain. Narrow opening is noted just north of alignment at about KP122.5, about 50 m long. Contours suggest local low area (pond? thermokarst?) that drains to stream just west at KP122.4, can be checked during layout and detailed design. Otherwise, no obvious patterned ground or thermokarst in this section. See Figure 13. Air photos A28099 - 35-36.	 Peatland southwest of tree patch. (Photo credit: Allnorth)  Winter road on right side north of ~KP122.7. Note beaver dams and fan edge in both photos. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
122.9	123.3	Cx	There is a lake to the west, whose outlet drains east into Grainger River. Outlet stream has three beaver dams south of the fan and north of the all-season route, from about KP122.85 to KP123.3. All-season road will not be affected by the beaver dams as it will be well upslope to the south. Currently-proposed stream crossing is downstream of the eastmost beaver dam. Site visit September 22, 2014. Water at KP123.3 flows east, beaver dam is ~50 m upstream west of proposed crossing of stream adjacent to large rock bluff. Proposed full bench cut in rock. Thickly treed with small trees, most <5 cm, generally < 10-15 cm in diameter. Top of bluff forms ridge with swale on south side draining west. East end of bluff ends in vertical drop to stream level. Streambed formed of cobbles, floodplain is silt, sand, gravel and is overgrown with willow where vegetated. Winter route meets/separates from the all-season route at about KP122.5 at the west end. All-season route crosses apparent Cx terrain from upslope south between about KP122.9 and KP123.2. Looks like old failures, probably post-glacial. From about KP123.2 to KP123.3 may also be Cx but there appears to be shallow bedrock control at this edge of feature. No obvious patterned ground or thermokarst in this section. See Figure 13. Air photos A28099 - 35-36.	 Looking southeast from KP123.3. Road upslope of beaver ponds. Colluvial terrain on bedrock. (Photo credit: Allnorth)  Looking west from KP123.4 at proposed stream crossing.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
122.7	123.3	gAf	Water flows east and west off this fan. The fan is split with a rocky knoll, so that water can flow on northeast side to the east (older alluvial fan deposit), and on west side to the south (newer alluvial fan deposit), then east. Temporary winter route (1 km long) will be on newer fan deposit, all-season route will cross to south side of stream just east of east edge of newer fan deposit. Winter route is a little shorter than the all-season route, as it goes direct across the alluvial fan. No obvious signs of distress on newest-looking (southerly) winter route on south side of outlet stream, but it is not clear why there were so many iterations of winter road to climb the south bank. Shoreline of lake appears sharp-edged and steep, so it may be that changes in beaver activity radically changes the water level, thus changing the most suitable access point. No obvious thaw along shoreline. Also note that stream from KP122.4 runs down to old crossing, whereas newer winter road crosses it higher on the bank, and this higher area probably freezes up sooner. Winter route meets/separates from the all-season route at about KP122.5 at the west end. See Figure 13. Air photos A28099 - 35-36.	 Looking northeast along west branch of alluvial fan, north of stream at about KP123.3. Winter route crosses fan.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
123.3	124.7	gAf - gAp	Water flows east along this braided channel. Includes old alluvial fan deposit from the north described above between ~KP123.3 and KP124.0. Note that the older (east) fan deposit conceivably could become active again. Large rock bluff on east side of Grainger Gap, and water flows against it. A tributary stream between two parallel ridges on the north joins the main stream. See Figure 13. Air photos A28099 - 35-36.	 Looking west along winter road from about KP124. Note low bluff right dividing the fans. (Photo credit: Allnorth)
124.7	124.8	gAp	Considerable braiding around the bend at Grainger Gap. GSC maps the entire pass as a large meltwater channel. Bridge crossing proposed at east end of Grainger Gap, crossing river from north to south, just southwest of existing winter road crossing. TP-15 in debris slide visible at toe of treed slope, above alluvial plain. New crossing reduces distance in stream area. Any record of river icing during previous winter operations? Could be useful for design of bridge and approaches. Air photos A28099 - 34-36.	 Looking south at KP124.8 area: bridge crossing and TP-15. Steep slope/alluvial fan avoided. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
124.8	125.6	gAp	Braided stream continues alongside north side of winter road. All-season road turns south at KP124.8 (~60.4 km on Mollard's stations), criss-crossing winter road to about KP126.4. Intent of all-season road is to stay above the low wet ground along the Grainger River, plus obtain more direct route to Nahanni Butte access. Post-field work, the all-season route is proposed to closely follow toe of slope along outside edge of floodplain at north end of this section, but then move out towards winter road to avoid ravelling from upslope, especially between about KP125.2 and KP125.6. Potential also for larger rocks tumbling or toppling from bedrock exposed above scree/talus slope. Upslope areas will be considered for borrow. See Figures 13 and 14. Air photos A28099 - 34-35.	 Looking east-southeast, route avoids beaded streams and steep toe along edge of fan. (Photo credit: Allnorth)
125.6	126.0	gAp	Post-fieldwork route crossed the toe of an alluvial fan (gAf) between ~KP125.6 and KP126. Still on approx 500 m contour. Potential for debris deposition along or over road, and/or plugging of culverts. Stream location(s) not necessarily predictable. Apex too high to be practical for routing, and too deep/steep in any case. Keeping route at or just beyond toe might reduce frequency of events potentially affecting road, but might require steeper grades heading south. After further consideration, route remains near winter road on Grainger River floodplain, between beaded streams and Grainger River to avoid thermokarst and upslope hazards. See Figures 13 and 14. Air photos A28099 - 34-35.	 Looking north from about KP126.4 at Grainger floodplain.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
126.0	126.6	gAp	Post-field route was in D, L GP-GC, above floodplain (gAp) to KP126.8. After further consideration, route now remains close to winter route on floodplain (gAp) in this section to ~KP126.6. GSC maps bedrock as dolomite and limestone, with discontinuous residual or colluvial veneer of clayey gravels, gravel-sand-silt mixtures, and poorly-graded gravels. Near-surface soils encountered during terrain typing upslope include sands in ridges (TP-25), silty sand clays or clayey sandy silts with some gravel in lower-lying areas, increasing gravel with depth; till-like (BH-15, BH-16). Slope gradients are mapped at generally 26 to 70%, in places >70%, with local relief 150-450 m. Route descends at 2% from 490 to 480 m elevation, climbing again after creek crossing at the end of this section. Except for beaded streams above road, no obvious patterned ground or thermokarst in this section. See Figure 14. Air photos A28099 - 34-35.	 Looking east from BH-16 towards TP-25 at helicopter site. Now upslope of KP127. Consistent with terrain further north on slope above floodplain.

Table C-1: Summary of Mapping and Field Observations

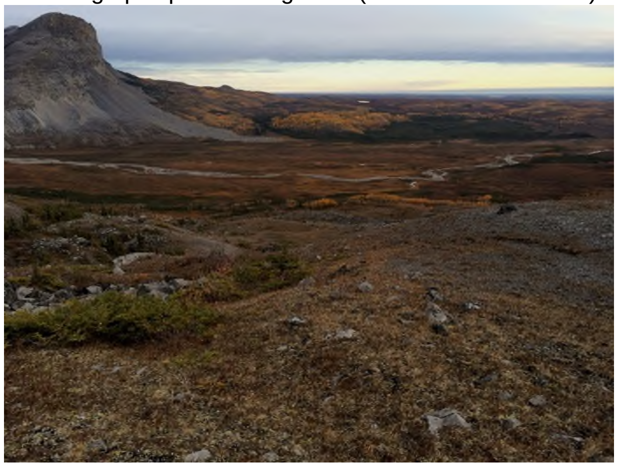
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
126.4 (upslope of route)	126.6 (upslope of route)	rSx	Intermediate reroute was proposed upslope of winter road and not crossing the rock glacier. Post-fieldwork, part of the rock glacier is proposed by Allnorth as a borrow source, and the road will be about 380 m downslope of the toe of the feature, and about 550 m below TP-17 area. Feature is about 200 m wide and 700 m long. There are some mounds of very coarse-grained materials (TP-17 area), but also some areas with matrix textures resembling fine crushed gravel (TP-16). Further study is proposed by Allnorth to further assess source. Air photos A28099 - 34-35.	 Looking upslope at rock glacier (Photo credit: Allnorth)  Looking downslope at rock glacier towards road and Grainger River below, note wide variation in materials.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
126.6	127.3	tMsd	Upper route skirts along transition between D,L GP-GC upslope and tMsd downslope. Crossing a series of mounds and ridges with swales or gullies between, low enough on slope that most of the gully sections are not too steep. One ridge at ~KP127.0 to KP127.1 looks sharp-edged enough upslope of road that it could be exposed rock. Linear feature about 200 m horizontal upslope between ~KP126 and KP127; possible harder bedrock layer? No obvious patterned ground or thermokarst in this section. Careful drainage across the road will be important throughout. Reroute just above winter route is in tMsd, rejoins upper route at ~KP127.3. Route climbs diagonally up 8% or gentler sideslopes in this section. See Figure 14.	 Looking downslope from rock glacier. Stream at KP126.6 and winter road visible along near side Grainger River.
127.3	128.3	tMsd	Route skirts along the downslope side of a long ridge, just below transition between D,L GP-GC upslope and tMsd downslope, then traverses across swale on upslope side. Small pond along upslope toe of ridge at about KP127.8. No obvious thermokarst or patterned ground. Most of ridge on air photos A28099 - 10-11; NW end of ridge on A28099 - 34-35.	 From KP127.3 looking southeast along route at ridge. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
128.3	129.0	D, L GP-GC	Route skirts above transition to tMsd downslope, and just downslope of L-shaped ridge KP128.8 to KP129.0. This ridge has a prominent low wet area just upslope. Origin of ridge unclear, but light coloured and blocky enough it could be exposed rock. Proposed as borrow by Allnorth. Route in this section generally on locally higher ground, crossing lower wet areas as needed. Air photos A28099 - 10-11.	 Looking downslope at L-shaped ridge KP128.8 to KP130. (Photo credit: Allnorth)
129.0	129.8	D,L GP-GC and/or T,gMmhr	Route skirts along transition between D,L GP-GC upslope and t,gMmhr downslope, also staying just upslope of the more prominent drainage paths. There appears to be a headscarp just below/at road, between KP129.6 and KP129.8. A little more finetuning of road location is necessary here, but should be workable - overall gradients are similar to adjacent terrain. Consider if better to delay the climb and cut across slide path, or start the climb a little further north to attain slightly gentler terrain upslope of scarps. Both have risks: material in slide path (if sloughed material remains) could be softer and less suitable for foundation of road, or future sloughing could result in material piling on uphill side of road or plugging culverts; but building road higher up might mean that continued failures	 From KP129 looking southwest along route to about KP129.6. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
			could retrogress into road grade. Allnorth has rerouted about 100 m downslope to avoid feature. Air photos A28099 - 10-11.	
129.8	130.5	gAf upslope, t,gMmhr downslope	Route stays essentially on contour, skirting around the toe of a large fan mapped by GSC. Boundary on S side indistinct; it may on occasion run into the north edge of the next fan to the south, at about KP130.9, where a bowl also begins below the fan and concentrates the surface water drainage further downslope. Again, there is a headscarp just below/at road, between KP129.8 and KP130. This feature appears to have a fairly steep dropoff below the road and edge of alluvial fan, which is not visible on the 2012 imagery due to a shadow, nor on Google Earth due to clouds. Allnorth has rerouted about 100 m downslope to avoid feature. Air photos A28099 - 10-11.	 From 300 m west of KP130, looking northeast across series of gullies and fans. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
130.5	133.0	t,gMmhr	All-season route is upslope of the drumlinoid ridges, and skirts around the toes of alluvial fans from upslope. Route climbs diagonally from KP130.7 over a knoll between drainage paths at KP130.5 and KP130.9, and then diagonally up through bowl, traversing across the downslope end of a small ridge between ~KP131.2 and KP131.3. No obvious patterned ground or thermokarst in this section. Air photos A28099 - 10-11. Stereo coverage goes only to about KP131.4. Mollard (1984) maps some low flat-topped ridges between about KP131 and KP134.5 that may be till and/or granular materials.	 Looking southwest towards stream at KP131.2; small ridge just south. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

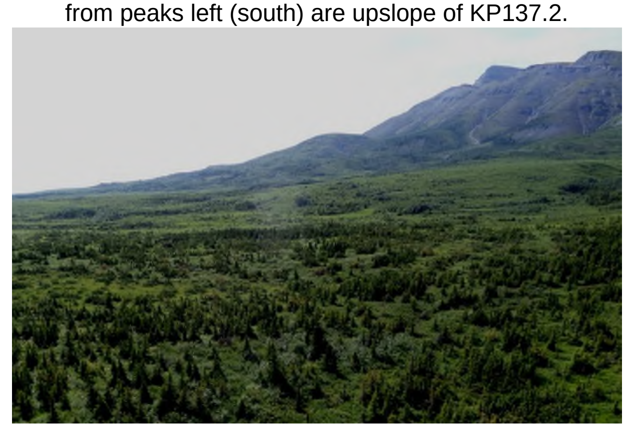
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
133.0	137.2	t,gMmhr	Road upslope of the drumlinized ground terrain, and within the subdued rolling to hummocky terrain. Some of the meltwater channels mapped by GSC in the drumlinized terrain downslope are also seen along the road route, e.g. small present-day stream in apparent wide old channels at KP133.1, KP133.2, KP134.9, KP136.1, KP136.5, KP137.2 (the latter noted on the ground by Allnorth). Possible exposed soil along stream about 550 m upstream of KP136.5 indicates potential for debris flows. However, slope gradients are <7% above road to suspect area, and stream channel otherwise looks well-vegetated so such events may be relatively rare. Exposed ground (soil or rock) along upstream reaches of channel above KP137.2 is probably more indicative of near-surface bedrock there, but could result in debris flows. Gradient of ~10% for 200 m above road. Debris flows at KP136.5 and KP137.2 can affect road by either scouring or deposition, depending on mobility of material. Aerial coverage indicates old slope movements ended below road (Google Earth 2007). Debris flow channels may also shift from current locations. Mollard (1984) maps some low flat-topped ridges between about KP131 and KP134.5 that may be till and/or granular materials, and a series of possible eroded slumped glaciofluvial ice contact deposits (kame terraces) from deglaciation, mainly upslope of the road, from about KP134.5 to KP141.	 Looking west from just above lower route. Prominent gullies from peaks left (south) are upslope of KP137.2.  Looking south at ridge and mound above KP137.2 to KP139.5. (Photo credits: Allnorth)

Table C-1: Summary of Mapping and Field Observations

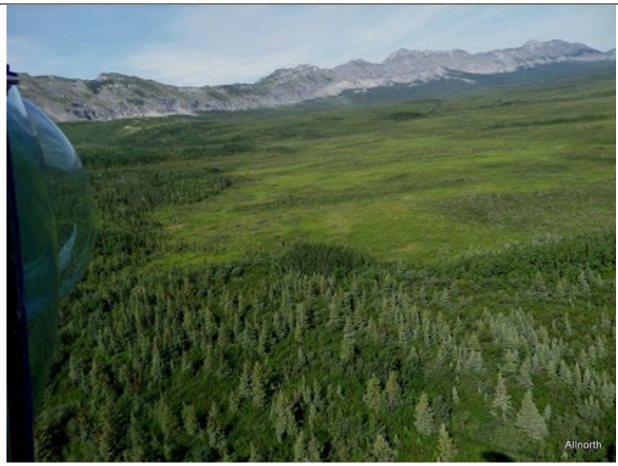
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
137.2	138.0	D,L GP-GC; rSx2	Road skirts along/over toe of possible rubble in talus lobe at 137.2 - 138 - This appears to be the feature mapped rSx2 on GSC Map 10-1979, and elevation on LiDAR and on GSC mapping checks out also (610 m). GSC maps D,L GP-GC well upslope of road along top of ridge - bedrock peaks. Debris flow lobe or part of rSx2 at ~KP138.1? Could also be part of melted-out ice-contact deposit. Mollard (1984) maps a series of possible eroded slumped glaciofluvial ice contact deposits (kame terraces) from deglaciation, mainly upslope of the road, from about KP134.5 to KP141. There is a series of four circular features in a row over a distance of about 200 m located about 500 m downslope of KP136.7, readily visible on 2012 imagery, barely visible on Google Earth 2007. Not found in the field due to weather, so not further investigated. Not expected to affect road.	 From southeast of KP138, looking west-northwest along route, along toe of deposits upslope west (left). (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
138.0	140.0	t,gMmhr	Terrain more subdued now, fewer elongated features and more subdued hummocks and gently rolling, compared to terrain further south on route. Gravel anticipated. No obvious patterned ground or thermokarst. Mollard (1984) maps a series of possible eroded slumped glaciofluvial ice contact deposits (kame terraces) from deglaciation, mainly upslope of the road, from about KP134.5 to KP141. There is a small pond in the debris about 360 m upslope of the road at about KP138.5.	 Looking upslope from lower route towards KP138 along north side of strip of trees. Where trees extend cross-slope mid-photo right is just below route location north. Route gradually descends south. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
140.0	144.5	tMpd	Moraine plain with drumlins to outlet of Triangle Lake. Road route follows east side of small meltwater channel between south end outlet of small lake north of Triangle Lake at KP142.3 and north end of Triangle Lake at KP143.4. Smaller meltwater channel with pond upslope of road joins channel at south end of small lake. Possible thermokarst at and near lake outlet about KP141.9 to KP142.3 in beaded channels parallel to lake shore and at outlet, about 80 to 160 m east of road. This may also be merely wetlands filling in shallow lake area. Beaver dam ~260 m west of road at about KP143.5 along pond within meltwater channel. Drumlinoid ridge mapped subparallel and visible on Google Earth SE of small lake between KP142 and KP143, east of road.	 From west of upper route at KP142.7, looking northeast at meltwater channel and lake north of Triangle Lake. Current proposed route is downslope east of meltwater channel, then upslope west of lake.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
144.5	146.8	tMps	Moraine plain with flutings from outlet of Triangle Lake to stream from wetland between road and Bluefish Lake to the west.	 Looking west-southwest at Triangle Lake. Outlet at about KP144.7 is in silty sandy clay.
146.8	150.0	tMp	About 275-700 m downstream of route at KP146.9 stream crossing, there is a series of small ponds that appear to be created by beaver dams. Looks similar on 2007 Google Earth as on 2012 imagery, although two smaller features immediately downstream of the 400 m feature look larger in 2012. Faint trail visible on Google Earth between 0.3 and 1.3 km above the road between ~KP147 and KP149.	 From downslope of KP146.7, looking southeast at ponds downstream of KP146.9 road crossing. (Photo credit: Allnorth).

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
150.0	151.0	tMv-Cx and/or tMp	Route ascends from the south out of escarpment area, GSC mapping transition still uncertain.	 Looking south from KP150.6 to KP151. (Photo credit: Allnorth)
151.6	-	gAf	Road alignment has been rerouted higher on slope and crosses at the apex of the fan. Fan is proposed as borrow. See description below.	 Downslope of KP151.3, looking south-southwest at proposed borrow area. (Photo credit: Allnorth)
152.6	-	gAf	Fan below road route.	

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
151.0	154.0	tMv-Cx and/or tMp	Route runs approximately parallel to, and 300-400 m downslope of mapped linear escarpment. Transition between tMv-Cx upslope and tMp downslope is not certain here according to GSC. Linear escarpment is clearly visible on Google Earth 2007 imagery. Proposed road now crosses near apexes of alluvial fans at KP151.6 and KP152.6. KP151.6 area is proposed as borrow. Presence of fans indicates likelihood of future debris flows. Crossing at apex is good for limiting length of road subjected to impact by debris but does include possibility of road being scoured out at these crossings.	 Looking upslope from below route at KP152.1. Large gullies right and centre along peaks lead to KP151.6 and KP152.6. (Photo credit: Allnorth)
153.6 (old 154)	159.0 (old 159.4)	tMv-Cx	Route climbs in the moraine veneer - colluvial complex, upslope of previously-proposed route. Hazard continues from debris slides/debris flows from upslope, including a suspected old alluvial fan is present below about KP155, with two gullies crossed near the apex at this location, and a possible old slope failure from about KP155.2 to KP155.7 where the road route crosses below and then above the suspected headscarp (Figure 15); a section with a fairly recent crossing of the road alignment at KP158.9 to KP159.0 (previous route downslope skirted just below debris toe); and just at/upslope of the road for 50 m at about KP159.1 (Figure 16).	 Terrain units at HP154, downslope of KP155.

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
159.0 (old 159.4)	159.1 (old 159.5)	tMv-Cx	Route climbs steeper now, in the moraine veneer - colluvial complex sooner. KP159.0 is at northeastmost prong of forked feature noted below, which ends about 24 m above road alignment according to 2007 Google Earth coverage. Looks about the same on 2012 imagery, at about 27 m distance. Terrain in deposition zone above was potential proposed borrow, not currently designated. Testpits TP-19, TP-20, and TP-21 upslope show variable material; see also next section. Toe of prong is presumably deposition area, but future flows could overrun road or plug culverts, resulting in maintenance and/or safety issues. See Figure 16.	 Looking upslope from route about KP159.0 at debris flow at northeast prong. (Photo credit: Allnorth)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
159.1 (old 159.5)	159.4 (old 159.8)	s, siAp	Rotational slide / debris flow above road alignment at Liard River off Nahanni Butte from SE peak, flowing down in three-pronged fork almost to road alignment or alongside it (OF3915). Middle fork has stream mapped in it on LiDAR. Repeated slide / debris flow events have potential to reach road and/or Liard River. 2012 imagery suggests recent events within 50 m of river, and less recent event (revegetated) reaching the river. The route skirts the left (NE) flank of the debris toe for about 150 m climbing out of the valley bottom. Hazard to traffic and road grade. Road likely to be a deposition area or it may be subject to scour from debris flows. Debris slide deposits proposed as borrow; field work inconclusive, as deeper testholes are needed to assess quality and feasibility. Only shallow testpits so far in apparent deposition area upslope of road. See Figure 16.	 Terrain upslope of road in debris flow deposition area.  Stream southwest of TP-21 at edge of debris flow prong.

Table C-1: Summary of Mapping and Field Observations

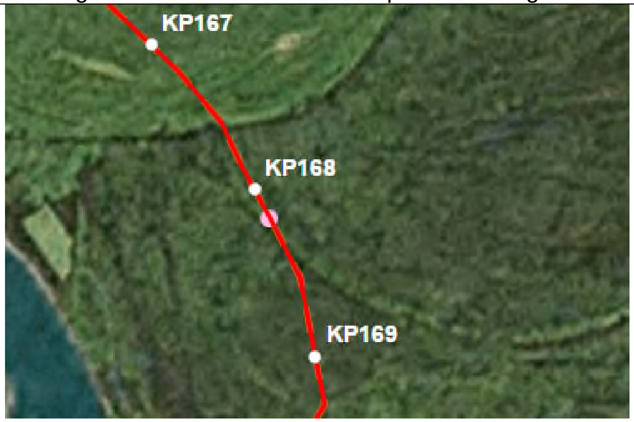
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
159.4	160.0	-	Liard River crossing (ferrry or ice road). Note 400 m offset from previous road stations (was KP159.8 to KP160.4).	
160.0 (old 160.4)	167.6 (old 168.0)	si,sApc-fO	Old Nahanni Logging Road parallels the east/south side of the Liard River south of proposed crossing of Liard River. Prominent scrolling on Liard River floodplain, easily visible in autumn by prominent vegetation colour differences. The proposed road follows sections of the Old Nahanni Logging Road, but goes further inland for part of the route, and straightens part of the route.	 Looking southeast from ~KP161.5 upstream along Liard R.
167.6 (old 168.0)	169.2 (old 169.6)	si,sApc	Old Nahanni Logging Road parallels the east/south side of the Liard River south of proposed crossing of Liard River. Prominent scrolling on Liard River floodplain continues. Occasional areas of fenland in narrow scrolled strips.	 Scrolling on Liard River floodplain (Bing coverage).

Table C-1: Summary of Mapping and Field Observations

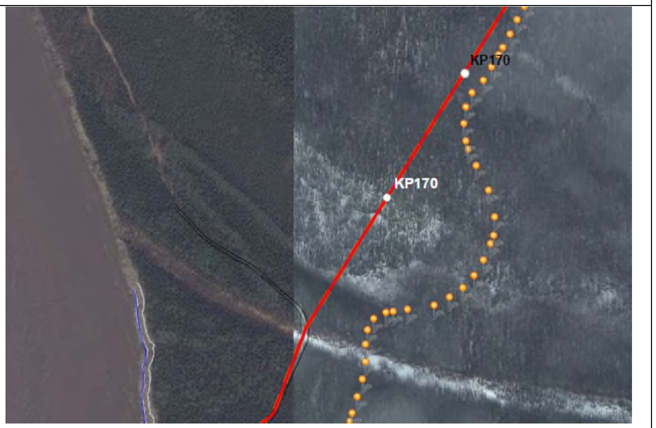
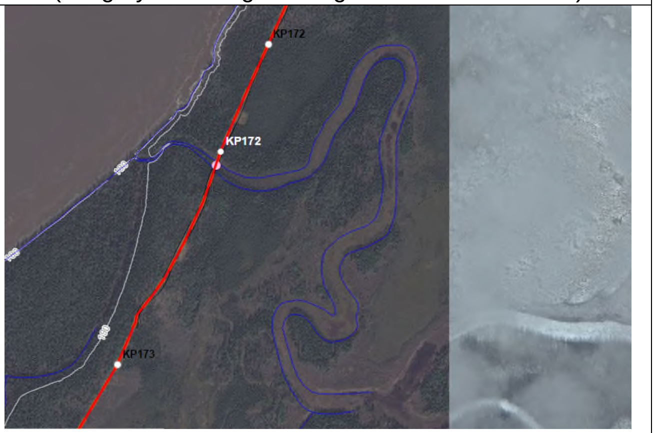
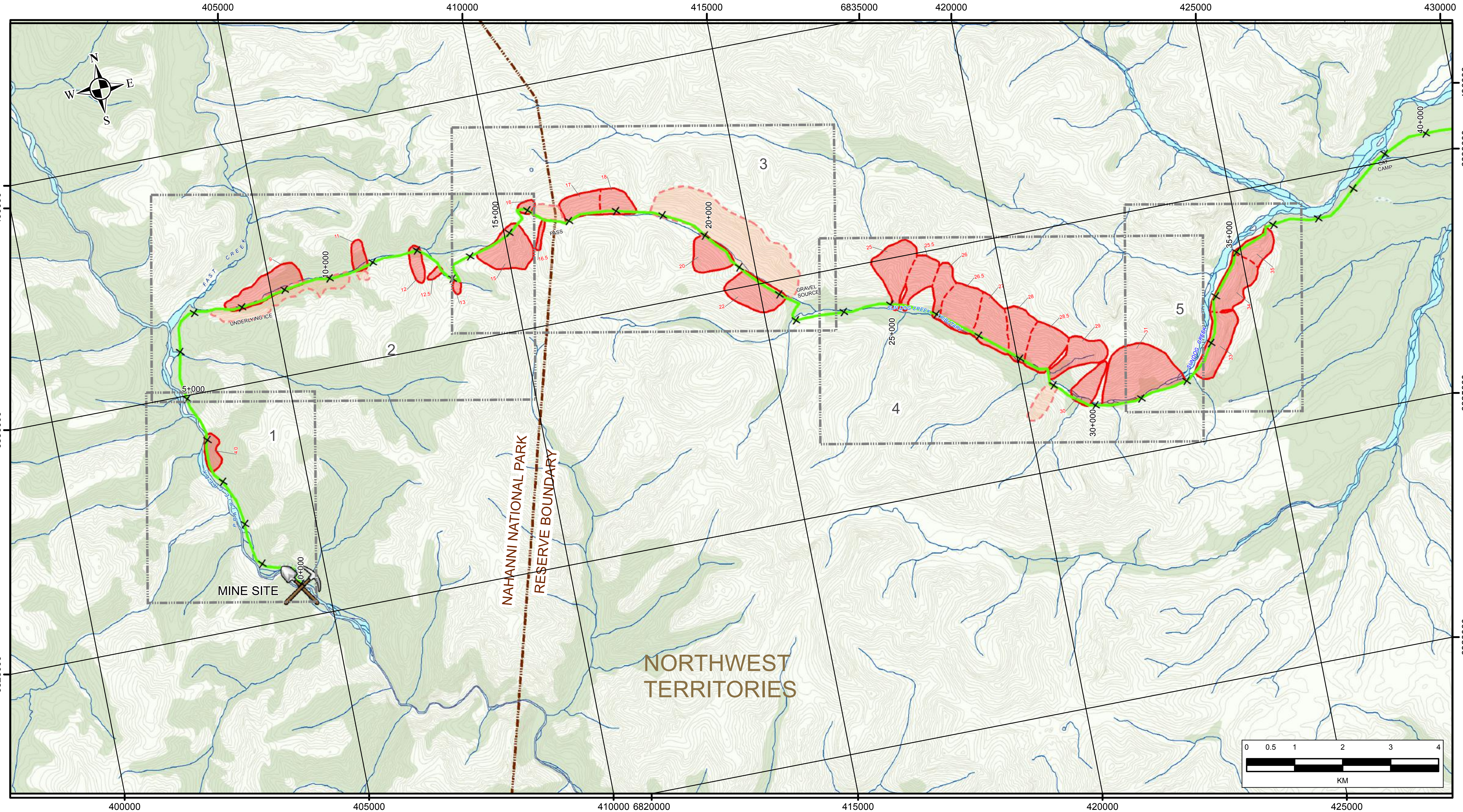
Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
169.2 (old 169.6)	170.3 (old 170.7)	-	Old Nahanni Logging Road parallels the east/south side of the Liard River south of proposed crossing of Liard River. Prominent scrolling on Liard River floodplain continues. Road crosses fenland along north side of Bay Creek. (Off south edge of GSC Map 10-1979; can see continuation of terrain types on bing coverage.)	 Fenland and scrolling (new stations = white markers). (Imagery from bing coverage on Allnorth website.)
170.3 (old 170.7)	174.1 (old 174.5)	-	Old Nahanni Logging Road parallels the east/south side of the Liard River south of proposed crossing of Liard River. Prominent scrolling on Liard River floodplain continues, here modified by Bay Creek drainage - meandering stream with numerous oxbows.	 Bay Creek drainage and Liard River. (Imagery from bing coverage on Allnorth website.)

Table C-1: Summary of Mapping and Field Observations

Start of Interval (km)	End of Interval (km)	Terrain Unit (Hawes, 1975)	Route Description	Photos
174.1 (old 174.5)	177.8 (old 178.2)	-	Existing Nahanni Butte access road from intersection of old Nahanni Logging Road to Liard Hwy. Still within Bay Creek drainage area.	-
177.8 (old 178.2)	184.17 (old 184.5)	-	Along existing access road to Nahanni Butte to Liard Hwy. Crossing fens and bogs.	-

APPENDIX D
AVALANCHE MAPPING (DONE BY OTHERS)



LEGEND

- AVALANCHE PATH
- POTENTIAL AVALANCHE PATH
- PROPOSED ACCESS ROAD
- 100 FOOT CONTOUR
- STREAM

NOTES:

1) DATUM: NAD 1983 ZONE 10U
PROJECTION: UNIVERSAL TRANSVERSE MERCATOR

2) THIS MAP SHOULD ONLY BE READ WITH THE ACCOMPANYING REPORT.

3) ACCESS ROAD LAYOUT DIGITIZED FROM: SNC LAVALIN DRAWING "PRAIRIE CREEK MINE PROPOSED ACCESS ROAD PLAN AND PROFILE" REV. PC - OCT 12, 2006.

4) SMALL AVALANCHE PATHS (SIZE ≤ 2) EXIST OUTSIDE OF THE AREAS DELINEATED BUT THOSE ARE TOO SMALL TO BE MAPPED AT THIS SCALE.

5) BASE MAPPING SOURCE: HTTP://ARCGISONLINE.COM

6) ONLY AVALANCHE PATHS WHICH ARE ESTIMATED TO AFFECT THE ACCESS ROAD AREA SHOWN. BOUNDARIES OF AVALANCHE PATHS OR AREAS REPRESENT A TRANSITION FROM HAZARD TO NO HAZARD. ANY FACILITIES PROPOSED ADJACENT TO MAPPED BOUNDARY LINES SHOULD BE EXAMINED WITH RESPECT TO AVALANCHE HAZARDS.

7) THIS MAP IS A SNAPSHOT IN TIME. CHANGES IN TOPOGRAPHY THROUGH FILL PLACEMENT, CUTSLOPES, GLACIAL RETREAT OR ADVANCE LANDSLIDING, AS WELL AS TREE REMOVAL MAY REQUIRE REDRAWING OF AVALANCHE ZONES IN THOSE AREAS.

8) THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:75,000 FOR 11" X 17" ("B" SIZE) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE

SCALE:	1:75000
DATE:	MAY 18, 2012
DESIGNED:	BG
DRAWN:	JN
CHECKED:	
APPROVED:	

PROFESSIONAL SEAL:

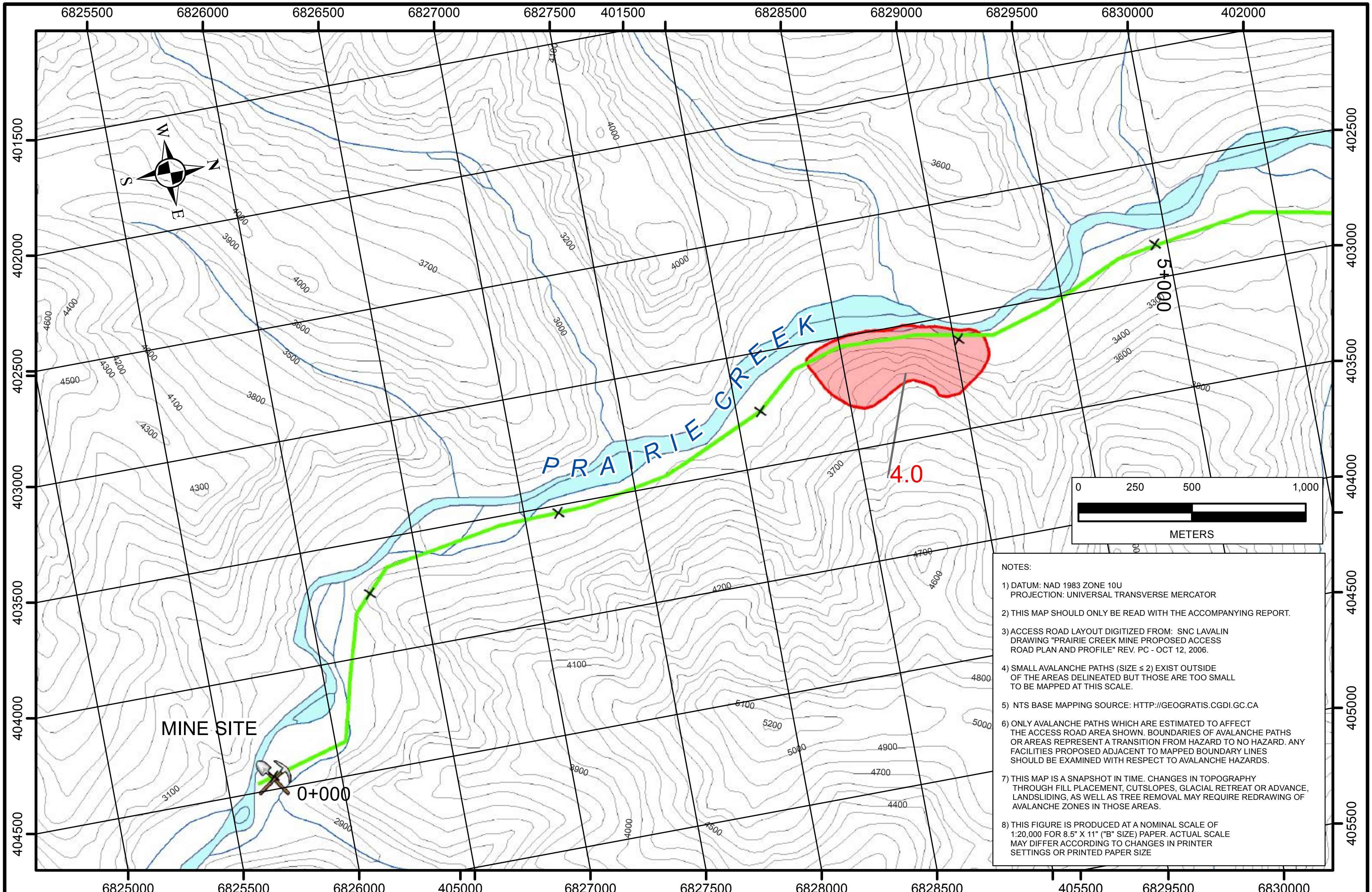
CLIENT: CANADIAN ZINC CORPORATION

PREPARED BY: ALPINE SOLUTIONS AVALANCHE SERVICES

PROJECT: PRAIRIE CREEK MINE WINTER ACCESS ROAD

TITLE: AVALANCHE HAZARD INDEX MAP

PROJECT NO:	DWG NO:	REV:
	1	A



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5) NTS BASE MAPPING SOURCE: HTTP://GEOGRATIS.CGDI.GC.CA

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8) THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:20,000 FOR 8.5" X 11" ("B" SIZE) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE

LEGEND

- AVALANCHE PATH
- POTENTIAL AVALANCHE PATH
- PROPOSED ACCESS ROAD
- 100 FOOT CONTOUR
- STREAM

SCALE:	1:20,000
DATE:	MAY 21, 2012
DESIGNED:	BG
DRAWN:	JN
CHECKED:	
APPROVED:	

PROFESSIONAL SEAL:

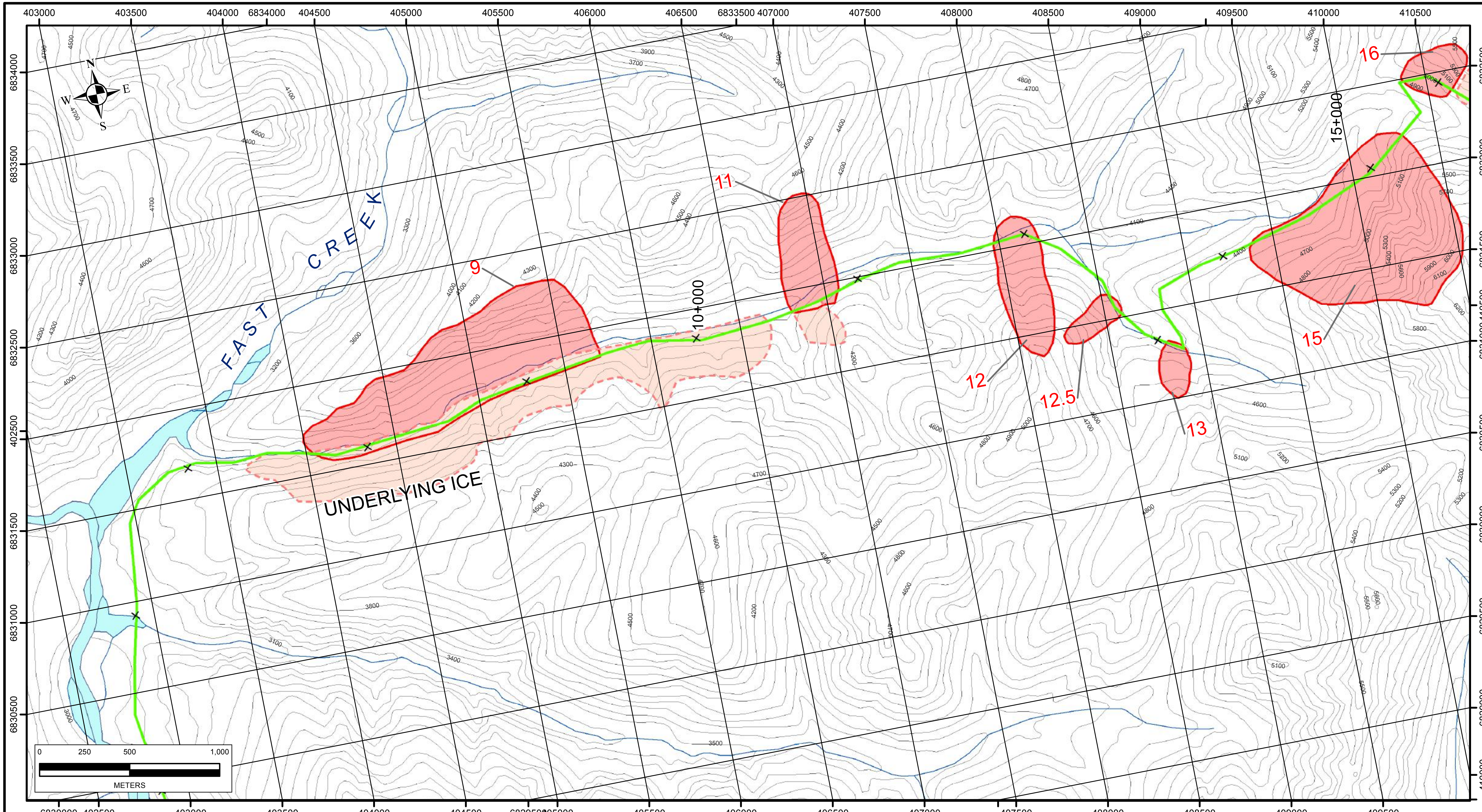
CLIENT: CANADIAN ZINC CORPORATION

PREPARED BY: ALPINE SOLUTIONS AVALANCHE SERVICES

PROJECT: PRAIRIE CREEK MINE WINTER ACCESS ROAD

TITLE: AVALANCHE HAZARD MAP

PROJECT NO:	DWG NO:	REV:
	2	A



LEGEND

AVALANCHE PATH
POTENTIAL AVALANCHE PATH
PROPOSED ACCESS ROAD
100 FOOT CONTOUR
STREAM

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DESIGNED:	BG
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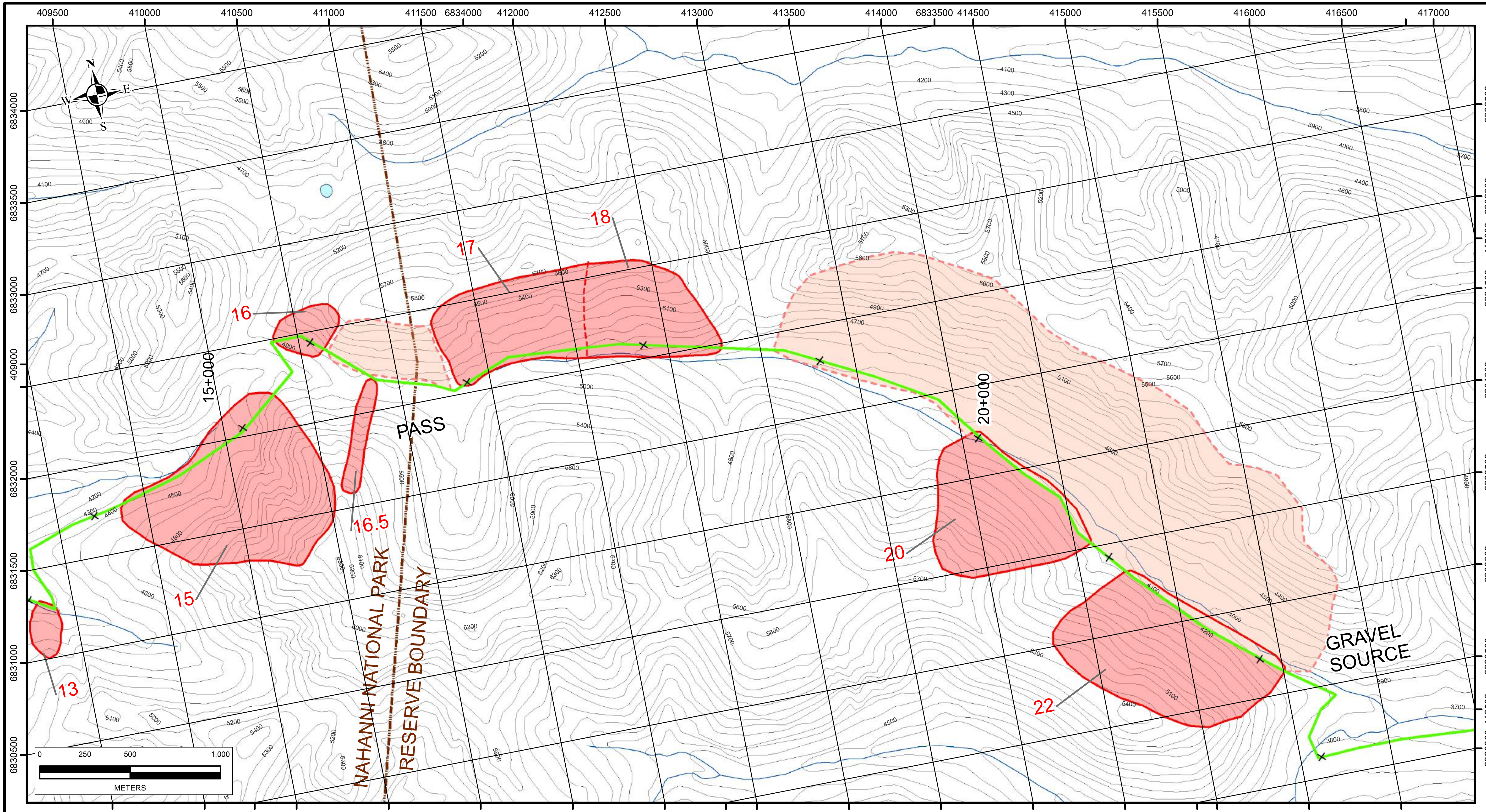
PREPARED BY: ALPINE SOLUTIONS AVALANCHE SERVICES

PROJECT: PRAIRIE CREEK MINE WINTER ACCESS ROAD

TITLE: AVALANCHE HAZARD MAP

PROJECT NO:	DWG NO:	REV:
	3	A



LEGEND

- AVALANCHE PATH
- POTENTIAL AVALANCHE PATH
- PROPOSED ACCESS ROAD
- 100 FOOT CONTOUR
- STREAM

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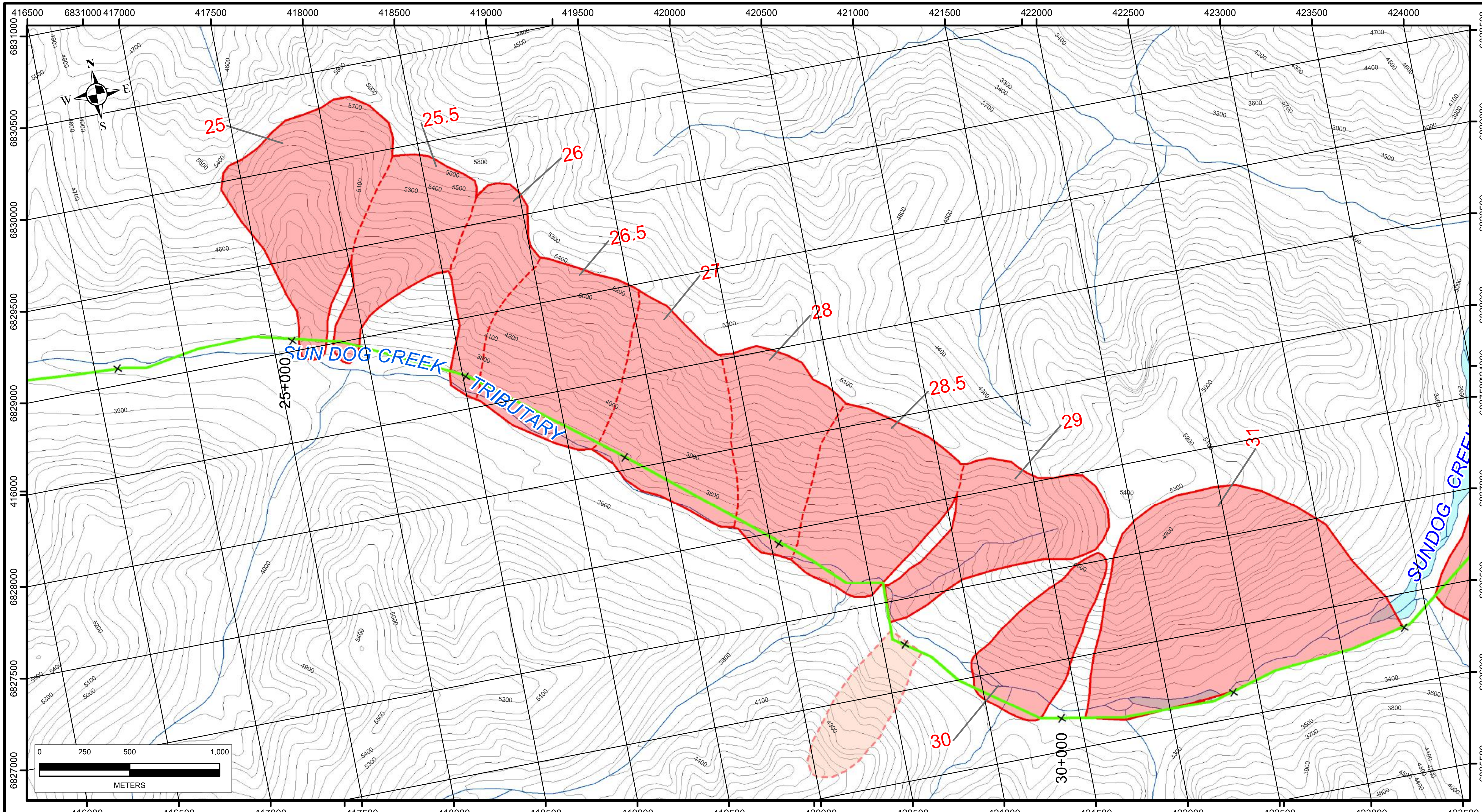
PREPARED BY: ALPINE SOLUTIONS AVALANCHE SERVICES

PROJECT: PRAIRIE CREEK MINE WINTER ACCESS ROAD

TITLE: AVALANCHE HAZARD MAP

PROJECT NO:	DWG NO:	REV:
	4	A



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- POTENTIAL AVALANCHE PATH
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TITLE: AVALANCHE HAZARD MAP

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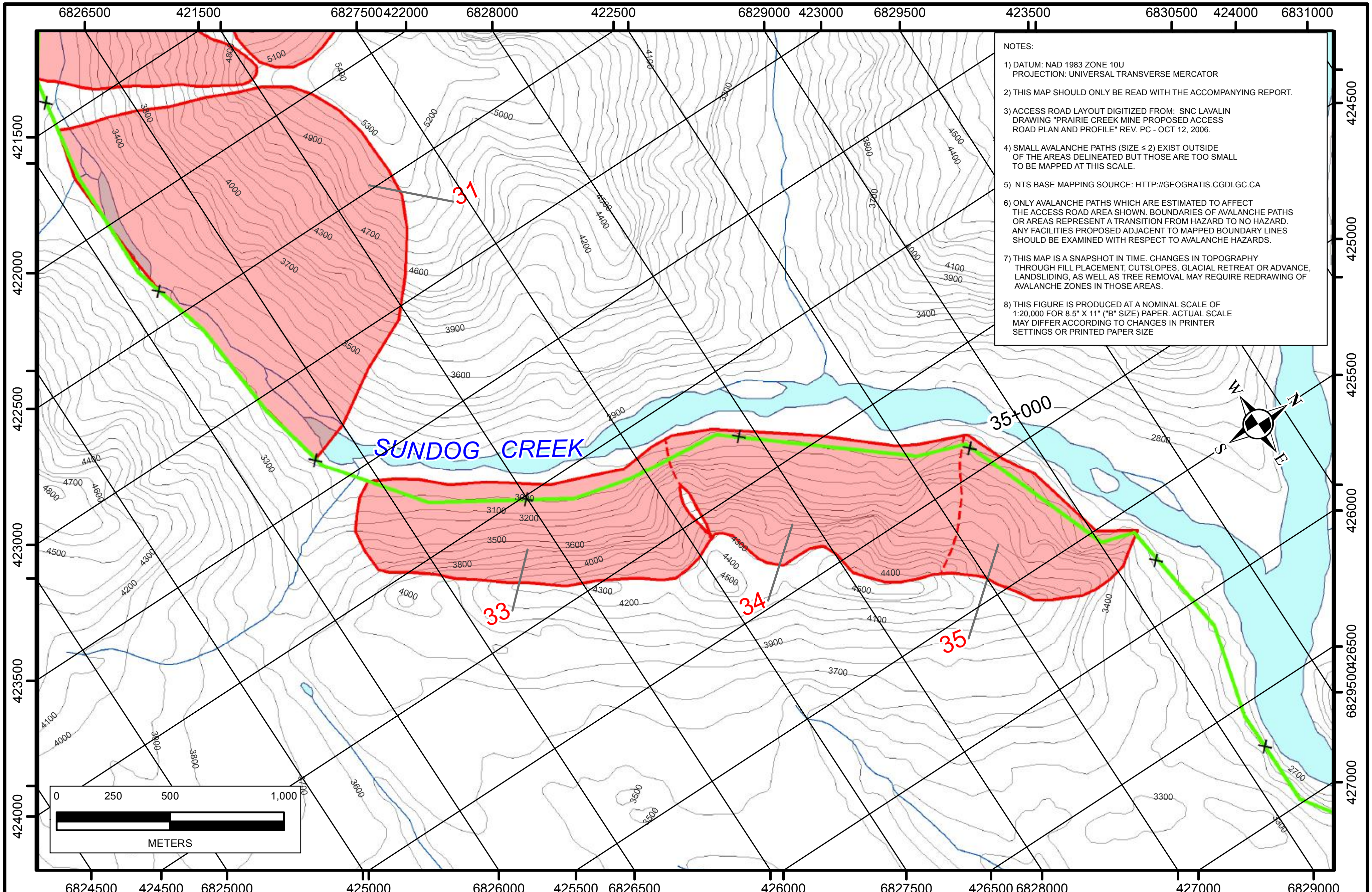
	5	A



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- 100 FOOT CONTOUR
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PROJECT: PRAIRIE CREEK MINE WINTER ACCESS ROAD

TITLE: AVALANCHE HAZARD MAP

PROJECT NO:	DWG NO:	REV:
	6	A