TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	David Harpley	**Date:**	October 24, 2016
c:	Alan Taylor	**Memo No.:**	4
From:	Rita Kors-Olthof, Kevin Jones	**File:**	YARC03070-01.001
Subject:	GNWT #8 – Permafrost Summary Table with Proposed Mitigations Response to Second Round Information Request EA1415-01 Prairie Creek Mine All-Season Road		

1.0 INTRODUCTION

This technical memo has been prepared for Canadian Zinc Corporation (CZN) by Tetra Tech EBA Inc. (Tetra Tech) to respond to the Second Round Information Request from the Government of the Northwest Territories (GNWT) #6: This information request is a request to summarize the proposed mitigation measures related to permafrost.

2.0 DETAILS OF INFORMATION REQUEST

MVEIRB provided the following commentary and recommendations/requests to CZN for additional information, in turn provided to Tetra Tech on September 26, 2016:

Comment: *Throughout the EA process to date, there have been several lines of dialogue regarding permafrost. While GNWT appreciates commitments that Canadian Zinc has made to date regarding development of a monitoring plan and applying best practices to borrow areas when permafrost is encountered (Canadian Zinc Working Commitments Table, September 1, 2016), additional information is still required at the environmental assessment stage to ensure there are no significant adverse environmental effects related to permafrost from all road construction activities. Prior to making formal recommendations on this topic, GNWT requests that Canadian Zinc provide a summary table of all proposed mitigation measures related to reducing or eliminating impacts associated with permafrost.*

Recommendation: *GNWT requests that Canadian Zinc provide a summary table of all potential permafrost areas and proposed permafrost mitigation measures. This should include a commitment(s) related to reducing or eliminating impacts to permafrost from all road construction activities.*

3.0 SCOPE OF WORK AND METHODOLOGY

This technical memo presents a summary table of permafrost areas and associated proposed permafrost mitigation measures. Related information on anticipated permafrost conditions and mitigations relevant to this memo was presented in several documents prepared previously by Tetra Tech (2015a, 2015b, 2015c, 2016b, 2016d, 2016e, 2016f, 2016g, 2016h, 2016i). These documents should be read in conjunction with this memo, in order to provide the context and additional details of the information provided here. A complete list of references is included at the end of this memo.

The summary table is based on the information collected and mapped to date along the proposed route of the Prairie Creek Mine all-season road, and as described in the documents listed in the references.

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4.0 SUMMARY OF PERMAFROST AREAS AND MITIGATIONS

Table 1 below provides a station-by-station summary of permafrost areas and suggested mitigations if/as needed for the conditions anticipated between those stations based on the information currently available. It is noted that as additional information is obtained as a part of the site-specific investigations that will be undertaken during detailed design, it is likely that the boundaries of the permafrost areas can be refined, along with the permafrost conditions anticipated in those areas. Accordingly, the recommendations for mitigations will also be refined. It is noted that the stations (kilometer posts) are approximate only, and correspond generally to the boundaries as shown on the most recent sets of terrain stability maps (Tetra Tech 2016b, 2016i). References that are particularly applicable to a specific road section are noted in the "References" column of the table. References that include information applicable to all of the listed road sections are not specifically noted in the table.

Table 1: Summary of Permafrost Areas and Possible Mitigations

Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
0	6.4	6.4	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
6.4	6.9	0.5	Mb -Xr	Soil stripes are present about 150 m or more upslope of road.	No immediate mitigations anticipated to be required.	-
6.9	13.3	6.4	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
13.3	13.4	0.1	Dja -Xr 20-50 P	Soil stripes are present about 300 m upslope. Gradual thaw could have potential to add water to unstable slopes or stream crossing below.	No immediate mitigations anticipated to be required.	-
13.4	14.2	0.8	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
14.2	14.6	0.4	Dr -Xr	Soil stripes and indistinct circles are present about 200 m upslope of road.	No immediate mitigations anticipated to be required.	-

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
14.6	16.1	1.5	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
16.1	17.0	0.9	Cvb//Rks -R^bXr 50-70 U	Permafrost present above road; also below road from about 16.2 to 16.7; solifluction evident in both areas. Gradual thaw with climate change or exposure of thaw-sensitive soils could have potential to add water to unstable slopes.	Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Cut slope and/or fill slope may benefit from buttressing.	2015a 2015b 2015c 2016g 2016h
17.0	17.6	0.6	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
17.6 17.8 18.2 19.1	19.3 18.0 18.4 19.2	1.3 0.2 0.2 0.1	Cvb -R^brXr 50-70 U Dk -Xr 50-70 U Cbv/Obv -Xr 60-90 U	Permafrost present above road forming solifluction lobes. Flat area above road at 19.1 displays soil circles about 280 m from road. Gradual thaw with climate change or exposure of thaw-sensitive soils could have potential to add water to unstable slopes. Separated from road by stable ground from 18.9 to 19.3.	Recommend further evaluation at time of detailed design. Fill slopes may be preferable to cut slopes if widening is required at this section.	2015a 2015b 2015c 2016g 2016h
19.3	39.2	19.8	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
39.2 40.2	41.3 41.3	2.0 1.0	Mj-X Ov/Mb -X Ovb/Cr -R^jX 10-30 U	Permafrost present above road, and from 40.2 to 41.3 also below road in old landslide area. Gradual thaw with climate change or exposure of thaw-sensitive soils could have potential to add water to unstable slopes.	Recommend close control of road drainage, particularly 40.2 to 41.3. Further evaluation recommended for crossing old slide area to determine preferred configuration of cut slope and fill slope.	2015a 2015b 2015c 2016g 2016h

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
41.3 41.3	42.1 43.1	0.8 1.8	Ov/Mb -X Ovb -X Ovb/Cr -R^jX 10-30 U Cr//Ob -R^jX U Mb/Ov –X	Permafrost above road could contribute water to slope upon thawing. Gradual thaw with climate change or exposure of thaw-sensitive soils could have potential to add water to unstable slopes in old landslide area.	Glaciofluvial terrace partly mitigates effects of water from upslope. Recommend close control of road drainage to reduce potential effects on unstable slopes below terrace.	2015a 2015b 2015c 2016g 2016h
43.1	44.4	1.3	FtF^{A}p/Ow -X Ov/Mb over Mb -X Ob -X Muh//Ov -X Op -X	Road traverses on or near various permafrost areas. Gradual thaw with climate change could add water to potentially already-wet organic terrain.	Consider thicker and wider road embankment fill and/or corduroy/geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils.	2015a 2015b 2015c 2016h
44.4	45.7	1.3	Ov over Mj -XFc Ow//Mj -X	Road traverses downslope of permafrost areas. Gradual thaw with climate change could increase surface water drainage.	No immediate mitigations anticipated to be required.	-
45.7	46.2	0.5	Cju/Ov -F^jX 5-25 P	Road crosses permafrost area. Gradual thaw with climate change or site disturbance could increase rate of creep and lateral spread.	Recommend close control of road drainage. Wider road embankment and/or support with corduroy or geotextile could help mitigate effects of creep and lateral spread.	2015a 2015b 2015c 2016h
46.2	46.7	0.5	Ob//gsFGuj -X	Road crosses permafrost area. Gradual thaw with climate change could add water to potentially already-wet organic terrain.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils.	2015a 2015b 2015c 2016h
46.7	47.6	0.9	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
47.6	47.8	0.2	Cv/Mu/Ov -R^msX 40-60 P	Permafrost present above road. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes. Road crosses above creek near 47.8.	Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Cut slope and/or fill slope may benefit from buttressing and/or erosion protection.	2015a 2015b 2015c 2016g 2016h
47.8	48.4	0.6	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
48.4	49.5	1.1	Cajh/Ov -RmXL 20-40 U	Road crosses on or below permafrost area. Gradual thaw with climate change or exposure of thaw-sensitive soils could have potential to add water to seeping unstable slopes. Road crosses above creek near 48.8 and 49.2.	Recommend close control of road drainage. Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Cut slope and/or fill slope may benefit from buttressing and/or erosion protection.	2015a 2015b 2015c 2016g 2016h
49.5	50.4	0.9	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
50.4 50.7	50.7 50.8	0.3 0.1	Ob//Fv -XL Ob//Ff -XU	Road crosses permafrost area. Gradual thaw with climate change could add water to potentially already-wet organic terrain.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
50.8	51.2	0.4	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
51.2	51.5	0.3	Cjar/Ovb -RmsXL 15-30 U	Road crosses permafrost area. Gradual thaw with climate change or exposure of thaw-sensitive soils could have potential to add water to seeping unstable slopes.	Recommend close control of road drainage. Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
51.5	51.7	0.2	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
51.7 52.1	52.1 52.8	0.4 0.7	Mvb over Mj -LX Ov/Mpj -UX	Road crosses permafrost area. Gradual thaw with climate change could add water to already-wet and/or seeping organic terrain.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
52.8	53.7	0.9	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
53.7	53.8	0.1	sczCj/Ov -X^fL 5-30 U	Road crosses lower slope in unstable permafrost terrain. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to seeping unstable slopes.	Recommend close control of road drainage. Avoid cut slopes. Consider wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads.	2015a 2015b 2015c 2016g 2016h
53.8	54.2	0.4	sczCj/sczCp -XL 10-25 P	Road crosses potentially unstable permafrost terrain. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to seeping slopes.	Recommend close control of road drainage. Avoid cut slopes. Consider wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads.	2015a 2015b 2015c 2016h
54.2	54.5	0.3	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
54.5	55.7	1.2	Cj/Ov -RuXL 0-25 P	Road crosses potentially unstable permafrost terrain. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to seeping slopes.	Recommend close control of road drainage. Avoid cut slopes. Consider wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads.	2015a 2015b 2015c 2016h
55.7	55.9	0.2	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
55.9	56.3	0.4	Cha//Ovb -RusLX 30-50 U	Road crosses unstable permafrost terrain. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to seeping slopes. Possible thermokarst in 2-3 m diameter pond below road.	Site-specific evaluation recommended to confirm characteristics of small pond and determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Recommend close control of road drainage.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
56.3	56.4	0.1	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
56.4 57.0 56.4	56.9 57.7 57.8	0.5 0.7 1.3	Cbv//Rs - -R^s^bX 20-50 U Cj.Ovb -RsXL 5-25 U Ov -XL Ow/Cv -LX 20-40 P	Road crosses unstable terrain with permafrost terrain upslope, downslope, and/or on route. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to unstable slopes. Water from upslope could destabilize downslope permafrost	Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016h

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
57.8	59.7 58.8 59.6	1.9	Op/FGd -HX FGu//Ovb -EHX	Mostly terrain where permafrost may be present but is not a dominant process. Isolated sections with permafrost near or at road. Suspected kettle at 58.8 unlikely to affect road.	Confirm during detailed design if feature at 58.8 is kettle or sinkhole. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016h
59.7	63.4	3.7	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
63.4	64.1	0.7	Lp//Ob -X Mj//Ov -X	Road crosses permafrost area. Gradual thaw with climate change could add water to already-wet organic terrain.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
64.1	67.0	2.9	Obv/LGj -XL Ob//LGr/N -X Obp/LGu - Xt Ob -X	Permafrost may be present but is not a dominant process in the terrain at the road. Road traverses near areas of permafrost terrain on both sides of route.	Recommend close control of road drainage.	2015a 2015b 2015c 2016h
67.0	70.1	3.1	Cb//Ch -R^UX Ch -R^UX Cbv -R^UX Gradient varies 5-50, all U	Permafrost may be present but is not a dominant process in the terrain at the road. Road skirts along the crests of slope failures in unstable permafrost terrain on both sides of route.	Site-specific evaluations recommended if any realignments are being contemplated in this section, or if cut or fill slope configurations will impinge on unstable slopes. Recommend close control of road drainage.	2016h

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
70.1	82.1	22.0	Along road: Mvb/Obv/Ru -X Mu/Ov -XL Ca//Cv -R^UX Cv -R^UX Cb -R^UX Cu -R^UX Gradient varies 5-80, all U	Permafrost is present in the terrain at the road. Road skirts above mostly the crests of slope failures in unstable permafrost terrain on both sides of route. In one section, about 70.5-70.8, road cuts through a headscarp. Seepage noted beginning at 81.9.	Site-specific evaluations recommended if any realignments are being contemplated in this section, or if cut or fill slope configurations will impinge on unstable slopes. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
82.1	82.9	0.8	Mu/Ov -XL	Permafrost terrain above and below road. Permafrost may be present but is not a dominant process in the terrain at the road.	Recommend close control of road drainage.	2015a 2015b 2015c 2016h
82.9	85.5	2.6	Mu/Ov -XL	Permafrost terrain at road, or just above road along this section. Seepage prominent on gentle slope.	Recommend close control of road drainage so as not to concentrate flow on unstable slopes below to river.	2015a 2015b 2015c 2016h
85.5	87.0	1.5	Mu/Ov -XL Cr/Obv -R^jX 20-50 U	Permafrost terrain at road, or just above road along this section. Seepage prominent on gentle slope at/above road. Permafrost terrain below road is unstable.	Recommend close control of road drainage so as not to concentrate flow on unstable slopes below to river.	2015a 2015b 2015c 2016h
87.0	88.0	1.0	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
88.0	89.3	1.3	Cr//Obv/Cj -RjX 10-25 U	Unstable permafrost terrain mostly above road in old slump area; also at road from 88.0 to 88.3.	Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope if road widening is needed here. Additional culverts or permeable fills may be helpful maintaining road drainage in case of renewed movements from upslope.	2015a 2015b 2015c 2016h

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
89.3	91.1	1.8	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
91.1	94.2	3.1	Ob/szCh -FcX 10-30 P szCh/Obv -FcX 10-30 P Ob -X Ob – Xt	Potentially unstable permafrost terrain at road, except between 92.3 and 92.8. Thermokarst below road in two locations. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to unstable slopes.	Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016h
94.2	95.7	1.5	szFp -X Fp//Ov -X Op -Xt	Permafrost terrain at and near road in floodplain, including nearby thermokarst.	Recommend fill-only embankment. Consider thicker, wider road embankment fill and/or corduroy/geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016g 2016h
95.7	96.9	1.2	Fp -X	Road skirts just above valley bottom and permafrost/thermokarst terrain, and along toe of unstable slope.	Recommend fill-only embankment. Consider thicker, wider road embankment fill and/or corduroy/geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
96.9	101.9	5.0	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-

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Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
101.9	103.3	1.4	Mb//Ov -X Obv//Mu -LX 0-15 P	Road located on or just downslope of permafrost terrain. Seepage on slope 103.1 to 103.3. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
Original Alignment						
103.3	106.7	3.3	Obv//Mu -LX 0-15 P Obv//Mb -X 5-15 P Mj/Ov -X Obv//Mj -LX 10-30 P	Road located on or just downslope of permafrost terrain. Seepage on slope. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
106.7	109.9	3.2	Ov//Fv.Mu -X Ov/Mb//Fv -X Obj/Mb - LX 20-50 P Mb/Ov//Ob -X Mjh/Ov//Ob -X Mb/Ovb -X 10-25 P	Road located on or just downslope of permafrost terrain. Seepage on slope above road. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
109.9	116.5	6.6	Mj/Ovb -LX 15-40 P Ovb/Muj -LX 10-25 P Ovb/Muj -LX 15-40 P and variations thereof	Permafrost terrain along, upslope and/or downslope of road. Seepage on slope above road. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads. Site specific evaluations recommended on steeper ground. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h

Table 1: Summary of Permafrost Areas and Possible Mitigations

Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
116.5	123.0	6.5	FGu/Ov -LX Ftj/Obv -X Op/FGu -X 0-15 P Op//FGu -X 0-20 P Obv//FGu -X 0-10 P And variations thereof	Scattered areas of permafrost terrain upslope and/or downslope of road. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016h
123.0	123.8	0.8	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
Alternative Alignment						
103.3	107.0	3.7	Ovb/Mp –FcX 0-15 P Cuj.Obv -FjcLX 0-20 P Obv/Cuj -FjcLX 0-15 P Ov/Ffp/Ob -UX	Permafrost terrain along, upslope and/or downslope of road. Seepage on slope above road. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads. Site specific evaluations recommended on steeper ground. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
107.0	109.4	2.4	Ov/Ffp/Ob -UX Obv//Op –X 0-3 P Ovb -LX 0-10 P Cj/Ovb -FjcLX 5-25 P	Permafrost terrain along, upslope and/or downslope of road. Seepage on slope. Gradual thaw with climate change or exposure of thaw-sensitive soils could add water to potentially unstable slopes.	Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to distribute loads. Site specific evaluations recommended on steeper ground. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h

Table 1: Summary of Permafrost Areas and Possible Mitigations

Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
109.4	114.0	4.6	Ovb/Mbj/Cj -FjcLX 3-20 P Obv/MjpMu -LX 0-20 P Fp/Ovb/Fu -X Ff.Ow -UX Ov/Fp -X Pbp/FGp -X 0-10 P and variations thereof	Permafrost terrain at and near road in floodplain and fans below steeper slopes.	Recommend fill-only embankment. Consider thicker, wider road embankment fill and/or corduroy/geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
114.0	120.9 (123.8)	6.9	Mb/Ov over Rr -X Mv -LX 30-60 P Ow -X 0-10 P Ov -X and variations thereof	Permafrost terrain areas mostly below road in floodplain and fans below steeper slopes. Permafrost areas become sporadic southbound. Possible thermokarst south of road at 122.1.	Recommend close control of road drainage.	2015a 2015b 2015c 2016h
123.8	125.6	1.8	Fgb/Ov -X	Permafrost in valley west of northeast end of Grainger Gap. Meltwater, if any, would run towards Grainger River.	No mitigations anticipated to be required.	-
125.6	126.6	1.0	Mr -X 20-30 P	Permafrost area above road, thermokarst near road in vicinity of 126.5. Thaw may increase surface water runoff or seepage downslope. Rock glacier well upslope of road.	Route avoids both permafrost area and thermokarst. Periodic evaluation of road drainage capacity recommended to determine if improvements in drainage are needed due to meltwater from upslope.	2015a 2015b 2015c 2016h

Table 1: Summary of Permafrost Areas and Possible Mitigations

Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
126.6	133.2	6.6	D,L –X rSx^{2} -X	Permafrost is present but appears not to have resulted in instabilities in the immediate vicinity of the road. Permafrost more likely further upslope. Local rockslide or slump areas upslope appear to contain permafrost.	No mitigations anticipated to be required along road, although areas proposed to have cut slopes should be checked for possible higher ice contents. Use of higher elevation areas not recommended as borrow due to likely higher ice contents, unless site evaluation shows otherwise.	-
133.2	135	1.8	t,gMmhr -X Mju//Fb -X 5-30 P Ob//N-Xt 0-10 P	Areas of permafrost above and below road. Road has only one short crossing of potentially unstable permafrost from 134.5 to 134.6.	Site-specific evaluation recommended at crossing area of potentially unstable permafrost to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016b 2016d 2016e 2016f 2016h
135	154.3	19.3	tMpd -X tMp -X Fb -UX Ff -UX tMv^{1} -Cx^{2} -X over L,Sh,D	Although permafrost is present, no obvious permafrost-related instabilities were noted. The road crosses a stream that may contain permafrost within its floodplain at about 149.3. Larger fans below 151.0 and 154.3 have no permafrost, though a fan downslope of 152.2 does.	No mitigations anticipated to be required along road, although areas proposed to have cut slopes should be checked for possible higher ice contents. Use of higher elevation areas not recommended as borrow due to likely higher ice contents, unless site evaluation shows otherwise.	2015a 2015b 2015c 2016h

Table 1: Summary of Permafrost Areas and Possible Mitigations

Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Permafrost Polygon Mapped	Anticipated Permafrost Conditions	Possible Mitigations	References Applicable to Section
154.3	159.3 (Liard River)		tMv[1] -Cx[2] -X over L,Sh,D Cju -R^xX 20-40 U Cjr -F^xX 20-40 U Cx[2]rSx[2] -X	Large earthflows are mapped below the road. These have permafrost, though it is not known whether or not permafrost is a significant contributing factor to the slope failures. Beginning at 158, the earthflows also extend above the road and some debris flow features are noted.	Site-specific evaluation recommended to determine if ice-rich soils are present and develop optimum configuration(s) of cut slope and fill slope. Recommend close control of road drainage to maintain natural drainage paths.	2015a 2015b 2015c 2016h
160.0 (Liard River)	171.0	11.0	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-
171.0	171.7	0.7	Op -UX	Permafrost in organic terrain north of Bay Creek. Road realignment is proposed here to avoid eroding bank of Liard River, but inland side of realignment has permafrost.	Recommend fill-only embankment if road will encroach on permafrost. Consider thicker, wider road embankment fill and/or corduroy/ geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
171.7	181.2	9.5	Ov -UX Ob//Ov/Fp -UX Ov/Ft -UX Fp/Ov -UX Ob -UX	Areas of permafrost beside and/or under road route, including built road.	Recommend fill-only embankment. Consider thicker, wider road embankment fill and/or corduroy/geotextile-supported fills to mitigate possible thaw settlements or settlements in seasonally soft soils. Recommend close control of road drainage.	2015a 2015b 2015c 2016h
181.2	184.2	3	-	Permafrost may be present but is not a dominant process in the local terrain.	No mitigations anticipated to be required.	-

5.0 LIMITATIONS OF REPORT

This memo and its contents are intended for the sole use of Canadian Zinc Corporation and their agents. Tetra Tech EBA Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the memo when the memo is used or relied upon by any Party other than Canadian Zinc Corporation and their agents, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this memo is at the sole risk of the user. Use of this memo is subject to the terms and conditions stated in Tetra Tech EBA Inc.'s Services Agreement. Tetra Tech's General Conditions are attached to this memo.

6.0 CLOSURE

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

Respectfully submitted,
Tetra Tech EBA Inc.

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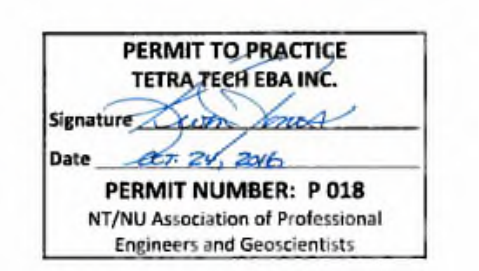

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Attachment General Conditions

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GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.1 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’s Client. TETRA TECH 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’s Client unless otherwise authorized in writing by TETRA TECH. Any unauthorized use of the report is at the sole risk of the user.

1.2 ALTERNATE REPORT FORMAT

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

Both electronic file and hard copy versions of TETRA TECH’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. TETRA TECH’s instruments of professional service will be used only and exactly as submitted by TETRA TECH.

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

1.3 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH 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.

1.4 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 does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

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

1.5 LOGS OF TESTHOLES

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

1.6 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes 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 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.

1.7 PROTECTION OF EXPOSED GROUND

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

1.8 SUPPORT OF ADJACENT GROUND AND STRUCTURES

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

1.9 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.

1.10 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.

1.11 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.

1.12 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.

1.13 SAMPLES

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

1.14 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

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