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16 January, 2020

RE: 2019 Inspection of the Milne Inlet Tote Road & Associated Borrow Sources Mary River Project, Type A Water Licence 2AM-MRY1325

Baffinland Iron Mines Corporation (Baffinland) provides the attached 2019 Inspection of the Milne Inlet Tote Road and Associated Borrow Sources, completed by Tetra Tech Canada Inc. (Tetra Tech). This report was prepared to evaluate the condition of the Milne Inlet Tote Road (Tote Road), and the potential for permafrost degradation associated with the historical borrow sources along the Tote Road. The 2019 work reassessed areas identified in the 2009 and 2014 inspections, targeting and identifying changes and upgrades made to the road. Baffinland has continued to make upgrades to portions of the Tote Road since the 2014 site visit, including realignments, grade improvements, cuts, widenings, and repairs.

The Tetra Tech assessment outlines and prioritizes areas of the Tote Road that require reclamation to address instability, permafrost degradation and thaw, and areas of ponding water. A total of seventeen (17) sites were identified as 'Priority A' or greater. Baffinland has reviewed the findings of the assessment and developed the Execution Plan provided in Attachment 2 for the locations identified as 'Priority A' or greater. Baffinland has already initiated the implementation of the Execution Plan in 2019 at KM7.2, a photo of the remedial action is included in Attachment 3.

Should you have any questions regarding this submission, please do not hesitate to contact Christopher Murray (christopher.murray@baffinland.com).

Regards,

Sylvain Proulx
Chief Operating Officer

Attachments:
Attachment 1: 2019 Inspection of the Milne Inlet Tote Road and Associated Borrow Sources
Attachment 2: Execution Plan for Tote Road Remedial Action
Attachment 3: KM 7.2 Remedial Works

Cc: Karén Kharatyan (NWB)
Chris Spencer, Jared Ottenhof (QIA)
Bridget Campbell, Godwin Okonkwo, Jonathan Mesher, Justin Hack (CIRNAC)
Tim Sewell, Shawn Stevens, Megan Lorde-Hoyle, Lou Kamermans, Christopher Murray, Francois Gaudreau, Brian Marshall, Amanda McKenzie, Allison Parker (Baffinland)

Baffinland

Attachment 1

2019 Inspection of the Milne Inlet Tote Road and Associated Borrow Sources

2019 Inspection of the Milne Inlet Tote Road and Associated Borrow Sources

PRESENTED TO
Baffinland Iron Mines Inc.

DECEMBER 19, 2019
ISSUED FOR USE
FILE: ENG.EARC03171-01

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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was retained by Baffinland Iron Mines Inc. (Baffinland) to assess the permafrost conditions along the “Tote Road” and associated borrow sources as a follow up to site work completed in 2009 (EBA Engineering Consultants Ltd.) and 2014 (Tetra Tech EBA Inc.). The Tote Road was constructed in 2008 and is about 100 km long connecting the Mary River Mine/Camp to Milne Inlet. It has a 30 m road alignment right-of-way (ROW) and has over 90 borrow sources along its length, of which 81 were documented and evaluated in 2009 and revisited in 2014. The first 150 tonne B-train trucks started hauling crushed ore to Milne inlet in 2014, ore is now being hauled at quantities of more than 5 million tonnes a year. Mary River is located within a zone of continuous permafrost in north central Baffin Island, Nunavut.

Most of the Tote Road routing follows glacial valleys that have been infilled with granular material that varies in texture from silty sand to sandy gravel with cobbles and some boulders. Wedge ice occurs throughout the region and can be observed in the photosat images as polygonal patterned ground. Segregated ice (horizontal lenses) and massive ice (tabular bodies of pure ice up to more than 10 m thick) also occur in the upper permafrost soils. Ground ice distribution is erratic, but it is generally found in greater concentrations in naturally wet basins. The active layer, top layer of ground that is subject to annual thawing and freezing, is expected to range from less than 0.5 m to 1.5 m or more. Examination of the route in 2014 and 2019 indicated that there was ice wedge melt out and ongoing settlement resulting from thaw of massive ice bodies in borrow sources.

The Tote Road was constructed in winter from natural granular material scrapped from the active layer (top layer of ground that is subject to annual thawing and freezing) in each of the borrow sources. Material below the active layer was too ice bonded to excavate in winter.

The field assessment of the Tote Road was carried out between September 5 to 9, 2019 and consisted of driving the Tote Road and helicopter supported reconnaissance. The visual assessment was coupled with examination of photosat imagery. The 2019 work was follow-up work based on the 2009 and 2014 inspections, targeting and identifying changes and upgrades made to the road. Baffinland has continued to make upgrades to portions of the Tote Road since the 2014 site visit including realignments, grade improvements, cuts, widenings, and repairs.

Baffinland provided Tetra Tech with a list of areas of concern that have been identified by the Qikiqitani Inuit Association (QIA), Nunavut Impact Board (NIRB), and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). Areas of concern included ponding water, road raises, turbid water upstream of the road, cracking along the road embankment, sediment transport through culverts near borrow locations, sinkholes, and slope stability issues. These areas were inspected and recommendations for improvements provided.

Problem sites were grouped into four broad categories based on reclamation criteria and stability of the road embankment. Priority A+ to A++++, with the highest risk of failure affecting both the borrow pits and Tote Road where failure of the road embankment may pose a risk to vehicle and operator safety, accounts for 12% of the sites. Priority A, where active ice thaw is affecting both the borrow pits and Tote Road with a potential safety hazard for continued use of the road, accounts for 5% of the sites. Priority B, where active thaw settlement and water accumulation is ongoing in unstable terrain within an abandoned borrow pit, not currently affecting the Tote Road but are trapping surface runoff which can lead to settlement, accounts for 22% of the sites. Priority C, where the terrain is judged to be relatively stable, accounts for 64% of the sites.

Compared to the 2009 evaluation the percentage of Priority A and A+ sites have increased from 9% to 17% by 2019, with Priority A+ sites having increased from 5% to 12% between 2014 and 2019.

There are ten Priority A++++ areas identified along the Tote Road where significant safety hazards are felt to exist and immediate action to remediate the problems is strongly recommended. Thawing of ice-rich soils is indicated where the road surface is unstable and settlement extends under the road, and where cracking and slumping of side slopes occurs where borrow pits are adjacent to the edge of the embankment.

It is recommended that problem site remediation focus on restoring stability by replacing cover material removed during excavation, developing and promoting drainage, caring for natural runoff from the borrow sites, and improving the topography to encourage revegetation. Constructing side berms, adding material to raise the embankment height, flattening the sideslopes of road embankment where thaw has not yet progressed, and/or improving drainage so water does not pond at the toe of the embankment are recommended steps for reclamation of the Priority A+ to A++++ sites. With the increased traffic volumes and heavier loaded vehicles, Priority A+ and A++++ sites should be addressed with remediation options first with Priority A++++ sites attended to immediately. Material sourced for use as protection against permafrost should be harvested from a location where it would not cause further permafrost degradation.

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LIMITATIONS OF REPORT

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

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) is pleased to submit this report to Baffinland Iron Mines Corporation (Baffinland) regarding the assessment of permafrost conditions along the “Tote Road” and associated borrow sources. This work is a follow up to a site visit in 2009 and report by EBA Engineering Consultants Ltd. (EBA 2009) and a second site visit and report by Tetra Tech EBA Inc. in 2014 (Tetra Tech EBA 2015).

This inspection/assessment involved visual assessment of the “Tote Road” and borrow sources to observe any changes since 2014.

1.1 Project Description

An access road was constructed from August 2007 to October 2008 to connect the Mary River Mine/Camp to tidewater at Milne Inlet on Baffin Island. The original purpose of the road was to provide a route for trucks to haul a bulk sample of iron ore from the Mary River deposit to a port site at Milne Inlet, a distance of about 100 km. This road was only expected to have a limited life (perhaps less than two or three years). Initial construction plans were to use three permitted quarries and borrow sites, but the haul distances were considered impractical and construction materials were supplemented by numerous sources within the 30 m road alignment right-of-way (ROW). This resulted in over 90 borrow sources along the length of the road, of which 81 were documented and evaluated in 2009 (EBA 2009) and revisited again in 2014 (Tetra Tech EBA 2015).

The Tote Road roughly follows an overland cat-train access route established in the 1960s. The road design and construction are described in a comprehensive as-built report by Knight Piésold Consulting, entitled “Milne Inlet Tote Road Construction Summary,” dated February 5, 2009.

For the most part, the initial Tote Road embankment was constructed during the winter from natural granular materials that were scraped from within the active layer (seasonal freeze/thaw layer) in each of the borrow sources. The materials from below the active layer were typically too ice bonded to be able to be excavated during the winter.

Baffinland has continued upgrading some portions of the Tote Road since the 2014 site visit; this includes some realignment, grade improvements, cuts, widening, and repairs. This work has included implementing the Hatch (2013) Issued for Construction drawings, as well as the Tote Road Earthworks Execution Plan (TREEP) developed by Golder in 2017 (Golder 2017).

The first production loads of iron ore were being transported to the Milne Port at the time of the 2014 site inspection and ore is now being hauled at quantities of more than 5 million tonnes per year. The crushed ore is hauled in purpose-built B-train trucks, each capable of hauling a total of 150 tonnes of ore.

In September 2019, Tetra Tech undertook follow up work based on the 2009 and 2014 inspections, targeting and identifying changes from the previous inspection and the ongoing upgrading of the road. This included:

1. Inspection of the majority of borrow areas, noting changes from the 2009 and 2014 inspections;
2. Commenting on the applicability of previously developed reclamation objectives and criteria;
3. Development of a conceptual work plan for each borrow/quarry site as required;
4. Inspection of the Tote Road to evaluate areas of instability or potential instability; and
5. Preparation of a report (this report) that documents the above.

This report follows the precedent established by the 2009 work and continued in the 2014 report, grouping the borrow sources into priority areas. Corrective actions are recommended for the various borrow sources.

Figures 1 to 13 show the Tote Road alignment, the various borrow pits, and generally our best approximation of the locations where the road has been realigned based on this year's reconnaissance photos and the 2018 satellite imagery that was provided. To be consistent with the 2009 and 2014 reports, the centre line chainage remains the same on these figures (may not always agree with KM post markers).

1.2 QIA, NIRB, and CIRNAC Concerns

Baffinland provided Tetra Tech with a list of areas along the Tote Road that had been identified by the Qikiqitani Inuit Association (QIA), Nunavut Impact Review Board (NIRB), and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) as being of concern to them in 2019. Several of these locations had also been identified by Tetra Tech as areas of concern in both 2009 and 2014. Examination of these identified areas of concern were therefore also a focus of the site inspection in 2019. The areas of concern identified by the above groups were as follows:

QIA Concerns

- Tote Road KM 89.8, 49.9, 49, 29.4, 21.9, and 7.2 – Water accumulation in historic borrow areas along the road are possibly impacting the long-term stability of the road.
- Tote Road KM 7.2 – Borrow source has fill placed. The grade of the road appears to be near the original ground with water ponding encroaching on the road, possibly due to degradation of permafrost.
- Tote Road KM 52.2 – It appears that the road was raised at this location but the reason for raising the road was not able to be confirmed with the maintenance department.
- Tote Road KM 92 – Stranded turbid water observed upstream of the road.
- Tote Road KM 73 – Observed cracking on both sides of the road possibly, due to permafrost degradation.
- Tote Road KM 72.3 – Borrow sources on both sides of the road. On the uphill side, the borrow source appears to be the source of sediment transport through the culvert to the downhill side of the road.
- Tote Road KM 33 – Sinkhole developed, likely due to culvert failure.

NIRB Concerns

- Tote Road KM 29 to 32 – Noticed areas with slope stability issues.

CIRNAC Concerns

- Tote Road Bridges – Sediment noticed below the bridges. The abutments of the bridges at KM 80 and 97 appear to have shifted.

These areas were inspected while on site in 2019 and are discussed in Sections 2.0 and 4.0 and in Table 1 and observations at the bridges are discussed in Section 5.0. The QIA concerns are highlighted in green on Table 1 and the NIRB concerns in light blue.

1.3 2019 Reconnaissance

The field assessment of the Tote Road and borrow sources was carried out by Kevin Jones, P.Eng., from September 5 to 9, 2019. Kevin worked under the direction of Connor Devereaux, Environmental Superintendent for Baffinland. Kevin was accompanied/escorted by Trevor Murphy of Baffinland during the field inspection. The field work involved both truck based, and helicopter supported reconnaissance of the road and borrow pits.

2.0 SITE CONDITIONS

2.1 Permafrost

The Mary River Mine is located in North Central Baffin Island. The closest community is Pond Inlet, on the coast about 150 km north of the mine. The normal mean annual air temperature reported for Pond Inlet is -14.6°C (1981–2010 Canadian Climate Normals). The cold climate sustains continuous permafrost throughout Northern Baffin Island with ground temperatures anticipated to be -8°C to -10°C along the route. For the most part, the Tote Road routing follows glacial valleys that have been infilled with granular material that varies in texture from silty sand to sandy gravel with cobbles and some boulders. Most of the deposits are either post-glacial river terraces or proglacial lacustrine basins. The lake basin segments are table-top flat with finer grained silt and fine sand prevalent. The terrace-like features are poorly sorted (dirty) gravels. The active layer is expected to be thin in the lake sediments (less than 0.5 m) whereas the higher, well-drained terraces probably support an active layer of 1.5 m or more.

Ground ice occurs throughout the region in the upper permafrost soils as predominantly:

- Wedge ice (vertical crevasses of ice);
- Segregated ice (horizontal lenses); or
- Massive ice (tabular bodies).

The wedge ice is the most striking feature in the region of naturally well-drained granular uplands. These show up in aerial oblique photos, such as Photo 1 as polygonal patterned ground comprising a series of orthogonal cracks that are the surface expression of ice wedges that occur to depths up to 3 m or more into the permafrost.

Wedge ice that is exposed at the surface within the borrow pits after the ice-poor active layer soils were removed begins to thaw from the top down, resulting in a linear depression such as shown in Photo 2. The thaw-depression will typically trap water that sometimes becomes mobile, running along the top of the ice. These features often extend under the road embankment. The thaw initiating within the adjacent pit can feed water into the ice wedge under the side slope of the road embankment resulting in thermal erosion that frequently leaves a transverse void below the side slope. When this happens in a road that is in service, the expanding void can precipitate a failure of the slope of the embankment and occasionally a failure under the travelling surface as well. This is a safety concern for operations over the road in these types of areas. This mechanism of wedge ice thaw, feeding water into cavities that extend under the road is the cause of a large number of significant settlements on side slopes, shoulders, and under the travelling surface of the road observed during the route reconnaissance such as the site shown in Photo 3.

Segregated ice occurs as thin lenses in all the finer grained silty soils. It is most prominent in soils of glaciolacustrine origin. The ground ice distribution is erratic, but it is commonly found with greater concentrations in naturally wet basins. When these soils are exposed within the pit bottom, the consequences are sinkhole depressions that soon become water-filled, interrupting any natural surface drainage. An example of a pit floor affected by melt out of segregated ice is shown in Photo 4.

In 2009, massive ice was identified at only one location (KM 62.7). Massive ice is generally large tabular bodies of ground ice. They have been attributed to either regions of groundwater discharge or buried ancient glacial ice. Observations of the deposit at KM 61.7 in 2014 indicated that there was also probably lots of massive ice in this deposit. Extensive settlement has occurred in this deposit due to thaw resulting from removal of the material in the active layer in this deposit since 2009 as shown in Photos 5 and 5A from 2009 and 2019, respectively.

Examination of the thaw settlements throughout the route in 2014 and 2019 indicate that in addition to ice wedge melt out, there is ongoing settlement resulting from thaw of massive ice bodies in many of the other borrow sources as well.

2.2 Borrow Site Summary and Grouping

The 2009 work was carried out to guide possible progressive reclamation activities for the numerous borrow pits. Minor reclamation has been conducted to date, but many remain untouched. Ongoing road upgrades include: minor changes to the alignment, minimizing grades, and increasing embankment widths to improve safety and compliance with applicable Mine Safety Regulations. Cut and fill construction methodologies have been used to source and obtain materials adjacent to the road alignments to support this work. In most locations, the current condition of some of the pits can be directly compared to the conditions observed in 2009 and 2014. A summary of the 2009 and 2014 conditions noted at each of the sites examined is included in Table 1 as are the observations from the 2019 inspection. The sites have been grouped into four broad categories that reflect the reclamation criteria and stability of the road embankment as follows:

- Priority A+ and A++++ pits (12%) – The 2014 and 2019 evaluation added another level of Priority (A++++) to the ranking system used in 2009 to break out areas where there is the potential for failure of the road embankment posing risk to vehicle and operator safety, given the increased level of road utilization. Areas with this type of potential failure were a particular focus of the 2019 evaluation where thaw settlement initiated by pit excavation is actively affecting the road integrity, and there is a higher risk of failure.

- Priority A pits (5%) – Areas are those where active ground ice thaw is affecting both the borrow source and the adjacent road. These constitute a potential safety hazard for continued use of the road.

- Priority B pits (22%) – Where active thaw settlement and water accumulation is ongoing in unstable terrain within an abandoned pit, those where active thaw and sinkhole formation is ongoing. These are not currently affecting the road but are trapping surface runoff which exacerbates thaw; and leads to settlement.

- Priority C pits (64%) – Are those where the terrain has been judged to be relatively stable. They will require some site grading and surface dressing to improve site aesthetics and ensure long-term stability, but the timing is not as significant.

There are quite a few sites that are not on the list. They are generally small, shallow depressions where limited material was removed. They can be considered as Priority C.

The locations where QIA or NIRB concerns were raised are also indicated and discussed in Table 1.

In comparison with the 2009 evaluation it can be noted that there has been an increase in the percentage of Priority A and A+ sites since 2009 from 9% to 17% by 2019. Priority A+ sites have increased from 5% to 12% between 2014 and 2019. There has been some reclamation in some of the pits and further material removed from others. In a few locations the priority has been downgraded because the pits seem to have self-stabilized or realignment has moved the road away from areas previously identified as being a safety concern.

A detailed photographic record from the Tote Road reconnaissance was prepared and is provided with this report. The photo locations are shown by photo number on the route maps in the Figures Section.

3.0 BORROW PIT RECLAMATION METHODS

Table 1 includes a brief comment for each site on where the borrow pit reclamation focus should be and is followed by more detailed comments on suggested processes to follow. The table displays the comments and suggested improvements presented in 2009 and 2014 and adds information and recommendations from the 2019 inspection. In some cases, realignment and widening of the road has removed some of the areas with stability concerns. In many of the locations, recommendations provided in 2014 are still appropriate. As noted in the 2009 and 2014 reports, the reclamation process should be structured around the basic principles of:

- Restoring stability to actively thawing ground ice by replacing some of the cover material removed during excavation;
- Developing drainage that will limit standing water that can exacerbate thaw within the pit;
- Caring for natural runoff from the pits in a manner that will reduce the risk of erosion and sedimentation over undisturbed tundra; and
- Improving site topography to encourage natural revegetation and enhance site aesthetics.

The sites identified as Priority C are the least sensitive and could generally be reclaimed by site grading and dressing of the slopes. A typical Priority C site is shown in Photo 6. The Priority A and B sites are judged as not currently stable and therefore will require attention directed to the ongoing thaw of permafrost and surface water management. The following discussion provides guidance for planning reclamation that will address these objectives. The Priority A++++ sites warrant immediate attention because there is a potential for failure of the road surface given the significant increase in haul traffic that is now using the road.

3.1 Restoring Surface Stability

The Priority A+ and A pits are experiencing ground ice melt out that is affecting the adjacent road embankment. Past experience in other locations has shown that the consequences can be a serious safety hazard. It is recommended that the road embankment be upgraded at these sites on a first priority basis, with the A+ and A++++ sites being the highest priority. The upgrading will require strategic placement of granular cover over the thawing soil with the ultimate purpose of drawing the permafrost back up into the fill. The steps for reclamation should include the following:

- Construction of side berms a minimum of 3 m wide on the road shoulders where active cracking and settlement is observed. The berms should be a minimum of 1.5 m thick and also to an elevation above that where there is the possibility of being overtopped by ponded water in the future. It is also preferable for them to be at an elevation of 1 m to 1.5 m below the final top of road fill at the location.
- Add material to raise the embankment height. Suggested final fill height increases at the various sites is included in Table 1. The height increase should be to achieve a minimum embankment height of 1 m, and in some cases, 1.5 m to 2 m is suggested.

- Improve drainage such that water does not pond at the toe of the embankment. In some cases, this may require filling sinkholes and ice wedge melt out features with imported gravel.

An alternative to berm construction for sites where the thaw has not yet progressed under the road embankment but is affecting the side slopes is to widen the grade and flatten the side slopes. The current road shoulder should be widened 0.5 m to 1 m and the slope flattened to 3H:1V. Table 1 provides guidance on those sites where slope flattening is an option. They include many of the Priority B sites. Where slope flattening is applied, consideration should be given to the extent that water can continue to pond at the toe of the slope. One of the primary benefits to be gained from slope flattening is to push any ponded water further from the embankment slope.

Some Priority A and B sites have developed substantial sinkholes within their pit bottoms. Where these have been observed, regrading the surface to fill the sinkholes has been recommended. In some cases, this may require importing fill from another nearby site that is still active and can confidently produce material without exposing new wedge ice. Those sites are identified in Table 1. As an alternative, there may be the potential to source suitable materials from cut sections along the proposed railway as noted in Section 1.3.

Further discussion of road instability locations that present a significant safety hazard (A++++) are presented in Section 4.0.

3.2 Drainage Improvements and Erosion Protection

Ponded water within the borrow pits retards winter freeze-back of the active layer and will result in retrogressive thickening of the active layer. Once this process starts, it is difficult to reverse. Shallow ponding (less than 0.5 m deep) that is short-lived following freshet is not a concern. Those ponds that are retained throughout the summer and continue to deepen with time will be counter-productive to the reclamation efforts.

Table 1 identifies several options for improving site drainage at specific pits. In most cases, there is an obvious routing for trapped surface water from the pit to a nearby stream or onto the tundra. Some pits are identified in the table where additional field work will be required to determine the drainage improvement options for those sites. This will probably involve site surveys to establish the natural topographic grades or if there are options that involve minor ditching.

Substantial ditch excavation into undisturbed active layer soils should be avoided wherever practical. Where new ditching is the only practical option, care should be taken to determine the nature of soils and ground ice that will remain exposed following excavation.

In cases where surface water will be directed to undisturbed tundra, it must be dissipated rather than channelled to avoid local erosion. Dissipation can be achieved by strategic use of cobbles and boulders to dissipate energy just before the water exits the pit area.

3.3 Surface Grading

All the pits will require surface grading that will range from filling sinkholes in the Priority A and B pits to simply dressing the current surface in most Priority C pits. Obvious ridges that can impede surface drainage should be removed and final surface contour developed to ensure drainage. The surface should not be left completely smooth. It is common practice at the end of surface grading to track the surface with tractor grouser bar ruts. These will trap fines and dissipate energy from runoff. The shallow grooves left in this manner will also improve the possibility for long-term natural revegetation by providing seed traps.

The backslopes in most pits are remarkably stable. Those steep slopes greater than 2 m in height should be graded to a final slope of 3H:1V. It is preferable to flatten the slopes by mounding new fill at the toe rather than cutting further into undisturbed tundra. The steeper pit slopes observed were generally of a height less than 2 m and were not visibly active. These shallow cut slopes that are currently stable are better left to seek their own long-term condition rather than risk further disturbance to the underlying permafrost.

4.0 TOTE ROAD SAFETY HAZARDS

As noted in Section 2.2, some of the borrow pits are adversely affecting the stability of the road due to thaw of ice-rich materials immediately at the edge of the road or toe of the road embankment. In many cases the road surface is unstable, and settlements are extending under the road, indicating thaw of ice-rich soils. In other locations, thaw in the adjacent borrow pit has led to embankment side slopes at the natural angle of repose with deep holes of up to 5 m or 6 m immediately at the edge of the embankment. Cracking and slumping of the side slopes is occurring in many of these locations.

The areas where more significant safety hazards are felt to exist on the Tote Road are identified in Table 1 as Priority A++++. Specific locations are discussed in the following:

1. KM 7.2 (pit 83A) – See Photos 7 and 8. Considerable water is trapped in the ponds created due to thaw of massive and wedge ice. Embankment is unstable, and water appears to be quite deep on the right side. Water should be removed as much as possible and pit backfilled with material to retard thaw and provide stability to the road.

2. KM 7.9 (pit 83) – See Photo 9. Ponded water is causing thaw and cracking of the embankment side slopes. Ponded water could lead to thaw under the embankment. Water should be removed, and pit backfilled to enhance permafrost aggradation that will provide stability to the road. Care will be needed to provide protection against erosion.

3. KM 19.8 (pit 72) – See Photos 10 and 11. Thaw of very ice-rich ground continues in this pit. Side slopes are too steep, and the shoulder and side slopes show signs of instability. To guard against road failure, this pit should be backfilled or at a minimum a 2.0 m or so high berm should be placed along the toe of the steep slopes to provide stability and push ponded water away from the toe of the slope.

4. KM 20.7 (pit 71) – See Photos 12 and 13. Continued thaw of wedge ice is increasing settlement depth and there continues to be evidence that the ice wedge ground that the road is constructed on is thawing. This pit should be backfilled, and the surface regraded to cause the permafrost to aggrade and thereby stabilize the embankment side slopes and lessen the potential for thaw of the wedges below the embankment.

5. KM 21.9 (pit 68) – See Photo 14. Thaw of ice-rich ground leading to deep ponding, an over-steepened side slope, and embankment instability. Pit should be backfilled and drainage away from the road re-established to enhance stability and retard further thaw.

6. KM 29.1 (pit 61B) – See Photos 15 and 16. Thaw continues in this pit leading to steep side slopes and instability. The central portion of the pit had been backfilled since 2014 and this has significantly improved stability. The north and south ends of the pit should be similarly backfilled to improve stability and retard further thaw along the pit.

7. KM 56.7 to 56.9 (pits 32 and 33) – See Photos 17,18, and 19. The new road alignment runs through the old pit which had experienced extensive melt out of ice-rich permafrost. The old embankment is now failing quite significantly. Water is ponding on both sides of the new road bringing concern of instability as further thaw is expected. Drainage from the pond on the left of the embankment passes through the new embankment through a culvert into the area between the new and the old road, from there it flows towards the lake (see Photo 19). With no maintenance on the old road, there is concern for the continued performance of the culvert on the old road. If it was to fail or become blocked, water levels beside the new road would rise significantly, perhaps leading to more thaw along the new road. Two remedial measures are therefore suggested. Provide wider berms along the full length of both sides of the new road (like those shown in Photo 17) or backfill the old pit in its entirety. Also, remove the culvert on the old road and breach the road so continued reliance on the old culvert is not required.

8. KM 63.0 to 63.8 (pits 28 and 29) – See Photos 20, 21, and 22. Thaw settlement continues in all the pits along this portion of the realigned Tote Road. There is evidence of instability of the embankment where there is settlement in the pits due to thaw of vey ice-rich (probably massive ice) in the pits. To improve stability the side slopes should be flattened to at least 3H:1V or flatter if possible to reduce the potential for thaw under the shoulder of the road.

9. KM 72.4 (pit 22) – See Photos 23 (2014 photo), 24, and 25. Discussion with one of Baffinland's road maintenance superintendents while inspecting this site indicated that there had been a significant rapid failure on the east side of the road with approximately half of the road settling into the ponded water in the old borrow pit. These pits should be remediated as soon as possible. This should involve backfill placement to above the original ground level following removal of as much of the water from the ponds as possible. The potential drainage locations from the pits should be graded appropriately to reduce water velocities, and water not channelized as much as possible (may need to armour the slope below the pits and incorporate check dams as required).

10. KM 89.8 (pit 14) – See Photos 26 and 27. This is a very deep pond resulting from thaw of a massive ice body initiated because the protective active layer material was removed. Thaw is continuing and appears to be occurring under the side slopes of the road which are very steep and unstable. This pit should have the water removed and then it should be backfilled at least up to the elevation of the original ground. If sufficient material is not available to do this, 5 m wide berms should immediately be constructed along the toe of the slope to an elevation 1 m below the top of the embankment. This will hopefully start to arrest the thaw and provide additional stability to the road embankment.

With the higher traffic volumes and much heavier loaded vehicles on this road, it is strongly recommended that the identified areas of observed significant instability on the Tote Road be addressed as soon as possible to remove safety hazards.

Some additional safety hazards identified at other locations along the road include:

- The Mine Safety Act requires safety berms with a height at least equal to 3/4 of the tire height on the typical haul truck when the embankment height or drop from the road edge is over 3 m. Safety berms have been constructed in many but perhaps not all the required locations. This may be due to other restrictions such as snowmobile crossings and snow removal requirements. A specific note of this was made for the road near the KM 52 marker post where there is high steep slope off the lakeside edge of the road.
- The Mine Safety Act requires haul roads to have a width three times the width of the typical haul truck using the road. The road often narrows at culvert locations, but Tetra Tech does not have the data to be able to assess if the road meets these requirements at all locations, it simply appeared to be narrow. This is likely because the road has been significantly widened since initial construction, but in many locations the culverts

have not been extended and therefore the road has not widened at all culvert locations. Baffinland has indicated that locations with a narrow road surface are signed appropriately to indicate the narrow conditions. The side slopes at the culvert locations where the road narrows are also often over steepened and embankment stability is therefore compromised.

- The side slopes of the embankments are often close to the angle of repose of the material. Embankments would be more stable and the underlying permafrost soils supporting the side slope better protected against thaw if they were no steeper than 2.5H:1V.

5.0 OBSERVATIONS AT BRIDGES

CIRNAC had raised some concerns about two of the bridges on the Tote Road as noted in Section 1.2. Tetra Tech had also noted some deformation, primarily tilting of the bridge abutment bin walls during the 2014 inspection.

Although not a structural engineer, Kevin was asked to undertake a visual inspection of the bridge bin-wall abutment foundations while on site. The observations are summarized in the following:

- KM 17 Bridge – Photos 28 and 29 show the west and east bin wall foundations, respectively. The upper bins have tilted on both abutments.
- KM 63 Bridge – Photos 30 and 31 show the north and south bin wall foundations. Photo 32 shows the opposite side of the south abutment. The upper bins have tilted on both abutments.
- KM 80 Bridge – Photo 33 shows the south bin wall foundation. The upper bins have tilted on both abutments. Photo 34 shows significant amounts of road surfacing gravel that has fallen into the water though the centreline joint of the bridge deck. This was a concern raised by CIRNAC.
- KM 97 Bridge – Photo 35 shows the west bin wall foundation. The upper bin wall is not as tall as the other bridges and there is less tilting; however, the bottom chord of the bridge truss appears to be in contact with the lower bin wall. This perhaps indicates that there has been some settling of the precast concrete footing supporting the bridge truss. There was evidence of road surfacing gravel in the water below the centreline of this bridge as well.

As can be seen in the photos, the upper bin in all foundations have rotated inwards towards the end of the bridge trusses. This is postulated to be because the lateral load from the retained backfill and road embankment on the upper bin is larger than can be resisted by the bin wall side plate which supports the upper bin's corner post. This leads to buckling in the upper side plate in the lower bin as is clearly shown in Photo 32. Regarding the design of the bin walls, it is expected that a stiffener should be present in the upper bin wall side plate but was not observed. This would have stiffened the side plate enough to be able to resist the lateral load being transferred downward by the corner post of the upper bin wall onto the side plate of the lower bin will. Alternatively, a corner post on the upper bin wall that extended down into the bottom bin wall would potentially have eliminated the issue.

Unfortunately, Tetra Tech cannot suggest a retrofit at this time, and would suggest seeking input from a structural Engineer and the bin wall supplier to see if they can suggest a structurally suitable remediation for these abutments.

It might be possible to lessen the amount of surfacing gravel falling through the centreline joint of the bridge decks by removing the surface gravel and then placing some sort of plate/timber over the joint, followed by replacement of the surface gravel. If considered, this should be discussed with the bridge supplier as it could impact bridge performance.

6.0 OBSERVATIONS AT OTHER LOCATIONS

While on site, Tetra Tech was asked to visually assess a few other locations not associated with the Tote Road or its associated borrow pits. These are discussed in the following sections.

6.1 Erosion and Instability near the Tote Road

Kevin met with Dominic Ritgen of Baffinland to examine some areas of concern located along the Tote Road near the Milne Inlet port. Two of the areas examined are discussed in the following:

- **KM 2.5** – Photo 36 shows that active layer soils are sliding downslope and have reached the edge of the road. Upslope on a small plateau is the source of the soils that have moved downslope towards the road. A small instability is visible above the plateau as seen on Photo 37. Further upslope is the large borrow pit (87). The north end of the pit is a very deep and it has at times contained water levels near the original ground level. It is postulated that when the water levels were very high in pit 87, water may have been released through the active layer. The water would have flowed down onto the slope below perhaps initiating the small instability on the slope above the plateau and leading to thaw on the plateau and slope above the road. This caused the mud flow that has reached the edge of the road. To minimize the chance of continued mud flow it is recommended that the water level always be low in pit 87. To accomplish this, it is recommended that overburden from the quarries around the port be used to infill the north end of pit 87. Baffinland might also consider placing a blanket of coarse run of quarry material on the upper terrace to lessen the mobilization of the material from this area. If this does not solve the problem a stabilization approach similar to what was done much further south around KM 91, might have to employed on the lower portion of the slope adjacent to the road at KM 2.5.

- **KM 4.0** – Photos 38 and 39 show erosion below the culvert under the road to the north of the terrace. Photo 40 shows where water is now primarily discharged through a new culvert (CV-174) onto the top of the plateau where it is ponding and leading to some thaw. Photo 41 shows where the water flowing to the south has caused some thermal degradation and erosion on the southern edge of the plateau. Directing some of the water to the south is a good idea but it is recommended that the top of the plateau where the water is ponding should be blanketed with a 30 cm to 50 cm thick layer of coarse granular material. The erosion area to the south should be reshaped/filled and then also blanketed with a similar thickness of coarse granular material. Key is placement of the material in a way that will not channelize flow, rather it should be a wide blanket that encourages sheet flow rather than channelized flow. The very large erosion area on the north side of the plateau will be difficult to remediate due to the steep slope. As a start, it is recommended that a large blanket of rip rap should be installed below the culvert as far down the slope as possible. Again, the idea is to encourage sheet flow rather than having the channelized flow that now exists below the culvert. If possible, the erosion channel further downslope should be rip rapped and additional large check dams constructed to slow water velocity.

6.2 Natural Instability Locations

Natural failures often occur in permafrost terrain and with the levels of climate change occurring in much of the arctic recently, the frequency of failures is increasing. Natural failures are often a result of either erosion caused by surface water flow or a deepening of the active layer due to higher than normal temperatures.

- Photo 42 is of a natural failure just east of KM 71 on the Tote Road. This failure appears to be simply the result of thermal erosion in a small draw leading to thaw and erosion of the active layer and underlying permafrost soils.

- Photos 43, 44, and 45 are from a location roughly 16 km east northeast of the mine near the headwaters of the Mary River. Baffinland staff indicated that earlier this summer a large sediment load was seen in the Mary River near the mine. The source of the sediments was determined to be the natural failures located at 71° 22' 40.12"N, 78° 53' 49.65"W. These are a relatively common type of natural failure that occur in permafrost terrain known as active layer detachment slides. Discussion with environment personnel indicated anecdotally that 2019 had been the warmest summer on record since the mine was opened. Active layer detachment slides often happen when warmer than normal summer temperatures occur. This causes thaw to progress deeper than typical, leading to thaw into previously what were permafrost soils (a deepening of the active layer). If the permafrost at the bottom of the active layer is ice-rich it will lose strength and the thawed soils within the active layer will slide on the underlying frozen material, even on very flat slopes. This is the case at these natural failures. After failing, the thawed active layer moved downslope until reaching the creek and then sediments washed down the Mary River.

- Photo 46 is from 2014 and Photo 48 is from the same location in 2019, east of the proposed railway along the deviation to the south of the Tote Road. The location of this natural failure is 71°23'57.07"N, 80°11'57.75"W. This failure has occurred in a deposit of glacial fluvial sand and gravel overlying a large body of massive ice (see Photo 47). The initial trigger for the failure is postulated to be due to surface water erosion at the toe of the plateau that exposed the massive ice body leading to thaw and collapse. From 2014 to 2019 the thaw and collapse has expanded significantly. This type of terrain and the surface expression is a great indicator of the presence of massive ice in this area.

6.3 Slope Instability and Erosion along the Haul Road from the Open Pit

Photos 48, 49, and 50 show several large erosion channels that have formed downslope of the main haul road from the open pit. The erosion has been the source of considerable amounts of sediment into the creek below the road that flows directly into the Mary River. The flowing water and erosion has caused permafrost thaw which reduces the soils strength making them considerably more prone to erosion. Most of the channels start immediately below the outlets of culverts on the road. Prior to construction of the road the flow on this slope would have been mostly sheet flow with most of the water flowing through the active layer soils and therefore the slope was not prone to erosion. Concentrated flow from the culverts now channelizes the flow causing both thermal and mechanical erosion.

Remediation of these erosion channels is a considerable challenge because:

- The slope is very steep;
- The drop from the edge of the road is significant;
- The natural permafrost soils are ice-rich;
- The very thin vegetation mat overlying the soil is easily disturbed; and
- Access to the slope is limited.

As a start it is suggested that, if possible, a blanket of rip rap be installed below the culvert outlets. The blanket should be designed to encourage sheet flow rather than the concentrated flow now occurring. This can be promoted by having the elevation of the rip rap blanket higher immediately below the culvert outlet, tapering off away from the outlet. It might be possible to direct more of the flow along the upslope side of the haul road, but this has a high probability of impacting road foundation stability because it may degrade the underlying permafrost.

To be able to develop appropriate remediation methods it will be necessary to carefully investigate permafrost conditions on the slope and along the haul road and to have an accurate topographic survey carried out for the slope. Further recommendations for remediation are beyond the scope of this project.

7.0 CONCLUSIONS

The focus of this project has been to compare the state of the previously existing borrow pits used in the construction of the Tote Road with the conditions observed today, roughly five years later. The 2009 evaluation identified general guidelines for developing a practical and acceptable plan for reclamation of the borrow pits. The 2009, 2014, and 2019 site observations have established that there are clear links between some borrow pit locations adjacent to the road and thaw settlement observed on the road embankment as well as leading to risk of collapse of the road itself in several locations.

Roadside borrow pits were utilized during the initial construction of the Tote Road but Baffinland apparently no longer extracts material from roadside borrow pits. If material is needed for road maintenance from new locations adjacent to the road, it is suggested that an untouched “buffer” zone be maintained between the edge of the road and any new borrow pits. This would eliminate the potential for thaw induced settlements impacting the stability of the road surface. Also, visual examination of permafrost terrain features evident on the surface of a borrow prospect can identify in advance, those deposits that may be potentially prone to thaw settlements and instability if disturbed.

The photo library and documentation in this report and the 2009 and 2014 reports have provided a basis for monitoring changes and adapting the reclamation process in a step-wise manner. The Priority A+ and A pits should be addressed first with attention to the Priority A++++ pits, immediately. Where new gravel cover is necessary for protection of the permafrost, care must be taken to ensure it is harvested at a location that does not contribute to further degradation of the permafrost.

8.0 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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PERMIT TO PRACTICE
TETRA TECH CANADA INC.

Signature ____________

Date Dec 19, 2019

PERMIT NUMBER: P 018

NT/NU Association of Professional Engineers and Geoscientists

REFERENCES

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TABLES

TABLE 1: SUMMARY OF PIT OBSERVATIONS AND CLOSURE RECOMMENDATIONS

		2009 DWH								2014 KWJ		2019 KWJ			
Site WP No. 2009	Km Post	General Location Comments	Pit Water 2009	Erosion Potential	Ground Ice Features	Active Layer Stability	Reclamation Focus	Priority	2009 Comments	Priority	2014 Comments	Priority	Ground Photos	Aerial Oblique Photos	2019 Comments
8	98.3	Off ROW permitted	Minor ponding	Low	Abundant wedge ice	Fair	Drainage improvements	C	This pit is within off ROW permitted and should be regraded and closed with future material taken from Area 1.1	C	No change	C		2547	No change
9	97.9	Off ROW permitted	Minor ponding		Extensive wedge ice	Fair	Regrading surface and slope	B	This pit within permit area should be reclaimed. Pad and flatten south slope of road to limit further thaw of wedges and erosion. Improve drainage without further impact on natural tundra wedge ice lying to the south of disturbed area.	B	Some regrading has been carried out which has improved drainage and pit remains stable	B			No Change
10	97.5	Off ROW permitted	Major ponding	Low	Massive ice	Unstable, extensive thaw occurring	Pump out ponds, berm road side slope on south side such that no water can pond at toe. Regrade pit bottom	B	Pit is still within quarry permit area but should be reclaimed soon. Extensive thaw settlement is occurring. Future materials should be taken from source 11.	B	Thaw settlement is continuing and pit should be reclaimed as noted in 2009.	B			Thaw settlement is continuing and pit should be reclaimed as noted in 2009 and 2014.
11	97.3	Off ROW permitted	Major ponding	Low	Wedge ice	Moderately stable	Improve natural drainage and develop a plan for an ongoing pit at this location	C	This is currently the best source of gravel in the vicinity of Mary River Camp. It is permitted for development off the ROW, and the material is relatively well-graded alluvial gravel. This pit has ongoing value for the development. A pit development plan should be prepared that will allow efficient stockpiling of the material in a manner that deals with surface water and thaw generated water. The plan should include site reclamation.	B	Separate memo issued by Tetra Tech to comment on the Hatch 2013 reclamation plan for this pit. In general there has been a considerable amount of thaw and associated settlement since 2009. Plan calls for regrading, filling low areas and making provision for draining collected pit water.	B	2729 to 2744	2598, 2599, 2600	The north end of the borrow pit was being backfilled and graded while on site. The regrading activities are being carried out appropriately. The majority of the pit is unchanged since the 2014 inspection. The outflow location into the lake to the south (photos 2735 & 2536) indicate that there has been no outflow in this direction since the 2014 inspection. Water is now directed to the south from the south end of the pit and simply flows out onto flat marshy tundra thereby reducing the potential for erosion.
KM 97 BRIDGE													2719		
11A	96.5									C	Active borrow pit on left side, some evidence of thaw subsidence, will require regrading	C		2548	No change
11AA	95.4											C			Stable pit
11B	93.8									C	Reclaimed borrow area that has recently been used as a source of material, pit/quarry is in very stable condition, no further work required.	C			No Change
12	93.2		Runoff impounded	Severe	Unknown	Unknown	Culvert needed	A	The road crosses a natural valley at this site, and water is trapped against the upstream road embankment. The pond must be drained by culvert installation to prevent thaw and collapse of the embankment and risk of significant downstream erosion. The disturbance from scavenging active layer material on ROW is minor at this site.	B	Water continues to pond at this location but is now released through a culvert. Water is quite turbid in the pond. The road has been regraded and widened at this location and now appears to be stable	B			Water continues to be turbid but road is stable
13	92.7		Runoff impounded	Moderate	Unknown	Unknown	Culvert replacement/repairs needed	A	This site has a drainage interruption issue that needs attention. Not a soil borrow site.	C	The drainage issue has been addressed at this location with the installation of a culvert that is operable.	C			No Change
	92.0												2654		QIA - Turbid water was noted in several small ponds along the left side of the road. Discussion with the environment department indicated that they had inspected the small drainages that lead down to the road and did not see any erosion at all. The reason for the turbid water has not been able to be determined. Tt suggests analysis of the water to see if the colour is a result of a chemical/mineral (natural iron?) impact or is the turbidity a results of sediment in the water. If sediment is determined to be the cause of the water colour it would be most feasible to connect the several small ponds together with a ditch and then discharge it through a culvert to the downhill side of the road into a settling basin before it flows into the nearby lake.
13A	91.0									C	Realignment to improve grade. It appears that material has been obtained from roadside pits both north and south of this location. So far these pits appear to be stable.	C			
14	89.8		Substantial	Moderate	Unknown	Unstable	Pit directly adjacent to south toe of road embankment. Ponding threatens to undermine road	B	The active layer was pushed up to form the embankment at this site. Substantial ponding is present in disturbed area. Site needs to be regraded and drainage established to the south where a new culvert can be installed that will lead to a natural drainage course.	A	Thaw settlement and ponding is continuing to worsen and pit reclamation should be considered very soon to avoid potential road embankment instability.	A++++	2655, 2656	2597	QIA -Noted road stability issues. Instability is very evident, water is very deep and the embankment side slope on the right side of the road is very steep and shows cracking on the shoulder and side slope. Stabilization should be undertaken as soon as possible (see Section 4.0)
	89.3									A	Realignment of road with a cut on the west side of road exposed massive ground ice in the ditch, extensive thaw settlement is expected unless this exposed ice is covered by 1.5 m or more of fill to re-establish an active layer.	A			
	89.0									B	Realignment of road is in a cut section, cut has exposed frozen soils in the west side ditch, with the removal of the active layer it is expected that thaw settlement will occur perhaps leading to loss of support for the toe of the embankment.	B			
15	87.8		Moderate	Moderate	Substantial segregated ice throughout silty material	Unstable	Improve drainage along the south embankment side slope convey ponded water to the existing culverts	B	Material exposed at this site is predominantly silt. Thaw-subsidence will continue. The strategy for reclamation must be to improve drainage using existing culverts and continue to regrade the surface until the active layer stabilizes. Keep ponded water from accumulating against the toe of the embankment. The exposed silt at this site is very mobile; thus, erosion protection measures may be required when improving site grading.	B	Thaw subsidence has continued, road has been recent regraded and raised but water is still ponding at the toes of the very steep side slops of the embankment at this location. There is concern for embankment stability and the side slopes should be flattened to enhance stability	B			
	87.0									C	Not a borrow pit but water is being impounded on the upslope side of the embankment and appears to be leading to some thaw settlement. A culvert should be installed at this location to remove the ponding issue.	C			Drainage has been inproved
15A	86.5									C	Material was actively being removed from this location, it is a silty sandy gravel material and there is potential for sediments to be released form this pit which is simply cut into the hillside beside the road, Pit should be monitored to evaluate thaw and sediment generation.	C		2549	Ponding is now noted, no change in recommendations from 2014
16	86.2		Moderate	Severe	Minor	Stable	Long-term drainage improvements	B	This is a deep pit pond that has established on the south side of the road. Soils in this area are controlled by a weak carbonate sandstone that readily decomposes into fine uniform sand. The pond is currently functioning as an effective sedimentation pond. Water is clear and the pond seems to be stable in a region of minor thaw-subsidence. It is recommended that the pond remain and that a new and higher culvert be placed through the road to allow the surface water to drain into the creek and subsequently the lake. The road embankment should be raised a minimum of 1.5 m at this location to protect the permafrost and provide cover for the new culvert.	B	Recommendations for raising the road embankment should be followed but in general the area displays little change since 2009.	B			
	84.8										Photo of stable road			2550	
16A	84.3									C	New pit on right, appears very stable	C		2550	
16B	82.3									C	New pit on left appears very stable	C			
	80.1										Photo of stable road				
16C	80.0									C	Assumed new pit near south abutment of new bridge, Materials assumed to have been used for bridge approach fill construction, pit appears stable, requiring no reclamation effort.	C		2551	No change from 2014
KM 80 BRIDGE											New bridge		2715, 2716, 2717, 2718		Surfacing gravel in the river below centreline of the bidge

TETRA TECH

TABLE 1: SUMMARY OF PIT OBSERVATIONS AND CLOSURE RECOMMENDATIONS

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Site WP No. 2009	Km Post	General Location Comments	Pit Water 2009	Erosion Potential	Ground Ice Features	Active Layer Stability	Reclamation Focus	Priority	2009 Comments	Priority	2014 Comments	Priority	Ground Photos	Aerial Oblique Photos	2019 Comments
	78.3										Stable road embankment and multi culvert installation				
	77.6										Photo of stable road			2552	
17	75.0		Not practical	Low	Not apparent	Stable	Surface dressing and erosion protection	C	This is a long section where the active layer soils have been pushed up from both sides to form the embankment. North (left) side is dry and stable — surface dressing only required. The south (right) side has a deep pond (Photo 681). The surrounding terrain is flat thus little opportunity for natural drainage. The ponds are not affecting the embankment, and ground ice seems minimal. The ponds can be left following site grading with some armour placed on the adjacent side slope to prevent erosion and dusting.	C	Pond on south side of the road looks the same as it did in 2009. Overall there is very little change in the borrow pit.	C			No change from 2014
18	74.7			High	Not apparent	Stable	Protect outlet at north end from erosion	B	Sandy active layer soils have been removed on ROW for embankment construction. Minor thaw subsidence or ponding within pit floor. Outlet for water at north end flows downhill into a creek. Substantial risk of erosion on that sandy slope during freshet. Recommend armouring the outlet with coarse materials and cross berm for erosion protection. Dress pit floor.	C	There does not seem to be evidence of sediment movement downslope to the creek so armouring may not be necessary.	C			No change from 2014
19	73.8		Uncertain	Moderate	Substantial wedge ice	Unstable	Protection of road side slope	B	This site is locally very ice rich. Water ponded along road shoulder is a threat to the road. Drainage improvement options are not obvious and should be reviewed further in the field. If ponds cannot be drained, construct a berm to an elevation above water level that will push water back 3 m from embankment slope.	C	Site seems to have stabilized naturally, there is less ponded water and there is no current concern for the stability of the road embankment so berms may not be required	C			No change from 2014
20	73.4		No	Low	Not apparent	Stable	Dress pit floor	C	Small active layer pit. Dry and stable. Dress the surface.	C	No change	C			
21	73.1		No	Low	Not apparent	Stable	Potential future use	C	Top of hill, small quarry in rock. Could be a source of materials for road repair and dressing or filling sink holes in nearby pits. Can be easily reclaimed by surface grading.	C	No change	C			QIA indicated that there were cracks on sides of road at KM 73 which is anticipated to be associated with this pit. No cracking noted at the time of the 2019 inspection but borrow pit remains in a similar state.
22	72.4		Drain and fill all ponds within 3 m of the toe of embankment	Moderate	Wedge ice, possibly massive ice	Active sinkhole formation	Road embankment safety	A	The pit on the north (left) side has become a large sink hole that is actively undermining the side slope and crest of the embankment. Wedge ice appears to extend under the road, and there is a potential for water to flow through any wedge cavities. Active cracking is occurring well into the driving lane. This is a priority site for repairs. Substantial risk of a road surface collapse exists. The sinkhole pond should be either drained or pumped and the road grade raised. A berm 3 m wide should be constructed in areas of active embankment sloughing. The site should be frequently observed when the road is used for haul traffic.	A++++	Sinkholes have continue to increase in size with water being impounded immediately at the toe of the embankment in many locations. The road grade has been raised here which will help to protect the permafrost underlying the embankment. However, the extensive ponded water and large settlements point to the need to fill in the pits or at a minimum create toe berms along both sides of the embankment where water is currently ponding. This remains a particular priority pit as there is potential for catastrophic failure of the road embankment.	A++++	2653	2555	QIA - noted issues at KM 72.3 and the uphill (left) borrow pit appears to be a source of sediment. Continued settlement and slope instability, and road maintenance noted that the left side of the road collapsed into the pond on left side earlier this year. Further work is needed as soon as possible to curtail further thawing and potential road collapse (see Section 4.0 for suggested repair). Filling in the pits will lessen the potential for sediment release if some check dams and armouring (rip rap) is also applied to the left of the road below the borrow pit.
23	71.8		Regrade and fill	Low	Extensive, distributed	Sinkholes active in pit floor	Regrade and fill	B	This site has active sinkholes below surrounding terrain. Some water trapped. May require imported fill from other sources to regrade the pit floor.	B	No change	B			No change from 2014
	69.8										Photos of stable road			2556	
24	68.5	Communication Tower		Low	Not apparent	Stable	Flatten embankment slope by filling out into pond displacing water	C	Small water-filled pothole left following material excavation. No obvious natural drainage potential. Complete reclamation would require infilling. Nearby material sources are not obvious.	C	No change	C			No change from 2014
24A	66.4									C	Pit is stable and requires no reclamation other than simple regrading.	C			No change
25	66.0		Clean ditch along toe of slope	Low	Not apparent	Stable	Regrade surface	C	Colluvial soils scavenged from hillside above road for embankment. Site is stable requires cleanup and dressing with improvements to drainage along toe of slope.	C	No change	C			No change from 2014
26	65.2	Active Pit	Well drained	Low	Not apparent	Stable	Regrade surface	C	This pit remains active with reasonable construction material. Drainage is currently good, but further excavation within ROW will probably initiate ponding. Should material continue to be removed, a pit development and reclamation plan should be prepared.	C	No change	C			No change from 2014
27	64.7		Poorly drained	Low	Not apparent	Moderate	Fill and regrade	C	This is a small pothole filled with water. Site should be regraded and fill added to improve drainage.	C	No change	C		2557	No change from 2014
28	63.9	Active Pit	Dry	Low	Not apparent	Stable	Dress surface	C	Both sides of road. Naturally well-drained silty gravel. No sinkholes. Grade surface at closure.	C	No change	C			No change from 2014
29	63.7			Severe	Massive ground once observed in pit. Wedge ice under road.	Unstable, extensive thaw	Rebuild road grade	A	This is the most ice rich site noted. Remnants of massive ice were found in large thaw depression on south side of road. Ice wedges are actively melting under road side slope Cracks and depressions extend to the shoulder. To reduce risk of road collapse, the grade should be raised at least 1 m through this area and berms a minimum 3 m wide constructed on the south side slope. Final reclamation of this site will require further assessment of the best method for ensuring drainage from the sink hole without risking siltation of the creek valley immediately to the south.	A++++	Extremely ice rich material exist on both sides of the road. Thaw settlements have been significant since 2009. Many areas of settlement exist immediately beside the road embankment and there is evidence of settlement of the road itself. There is a significant risk of catastrophic road collapse in several locations. Settlement areas beside the road should be backfilled as soon as possible to arrest further thaw settlements form impacting the stability of the road. Increasing the road surface elevation by 0.5 m would also help in changing the thermal regime in the embankment itself.	A++++	2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664	2558, 2559, 2560, 2595,2596	This series of pits has gotten worse, recommendations from 2014 reamin appropriate. See Section 4.0 in the report for additional details.
30	63.1		Dry	Low	Not apparent	Stable	Regrade	C	River terrace. Active layer gravel removed over a large area. Site is dry and naturally well drained. Regrade surface for reclamation.	B	Recent removal of material from the active layer has initiated thaw and instability in this kame type deposit. It is anticipated that there is considerable ground ice in this deposit. It is suggested that further material should not be removed from this deposit. The stability of the deposit should be monitored closely because of its proximity to the river.	B			No change from 2014
	62.7										New alignment				
30A	62.3									B	New alignment is visible. Considerable material was recently removed from the active layer on the east side of the old alignment over a very large area. Ice wedge melt out was already being noted in this area. There is potential for some slope instability and sediment transport towards from this area. This should be monitored to see if some form of sediment capture system might be required downslope form the pit development area.	B			No change from 2014
KM 63 BRIDGE											New bridge, note some apparent movement/tilting in the bin wall foundations for the new bridge.		2704, 2705, 2706, 2707, 2708, 2709, 2710, 2711, 2712		
31	61.7	Midway Pit, Off ROW permitted	Minor ponding	Low	Wedge ice on south-facing slope	Stable	Regrade	C	The active layer has been stripped over a substantial surface area. Gravel is well graded and free draining. The site can potentially produce more gravel by progressive stripping as it thaws or by drill and blast. A pit development plan including reclamation planning should be developed if borrow material harvesting is continued at this location.	B	Extensive thaw settlement is occurring in the a large area where the active layer soils were removed. This is indicative of massive ice in this deposit. Material is of good quality and lots of additional material could be obtained from this pit. Care must be exercised to control runoff from the area during development. Photo 1530 does show some instability due to thaw settlement near the road. this area should be stabilized by regrading combined with placement of fill at the toe of the slope to arrest thaw.	B		2593,2594	Road has been realigned to the west to improve grade. It does not appear that the pit has been used since 2014 other than as a laydown area. Continued thaw of massive ice on the south side of the pit has increased settlement. With road realignment there is no longer concern of stability on the road.
	58.0										Photos of stable road and old airstrip			2561	

TABLE 1: SUMMARY OF PIT OBSERVATIONS AND CLOSURE RECOMMENDATIONS

		2009 DWH								2014 KWJ		2019 KWJ			
Site WP No. 2009	Km Post	General Location Comments	Pit Water 2009	Erosion Potential	Ground Ice Features	Active Layer Stability	Reclamation Focus	Priority	2009 Comments	Priority	2014 Comments	Priority	Ground Photos	Aerial Oblique Photos	2019 Comments
32	56.9R		Moderate	High	Substantial wedge ice	Unstable	Improve site drainage	B	Pit excavated in ice-rich sandy gravel. Active thermokarst and ponding. Regrading to fill ponds required. Develop drainage to the east along north side of road. Construct a coarse boulder apron at outfall onto tundra.	A	Thaw and settlement has continued and there is now considerably more ponded water. Discussion with the construction crew indicated that the road might be realigned at this location but the new road would likely go through the large ponds. The pond should be filled to reduce the potential for further thaw settlement and the loss of support for the road embankment.	A++++	2668, 2669, 2670, 2671, 2672, 2673, 2674	2562, 2592	There has been significant road realignment at this location. Water is ponding along portions of the new road and cracking is noted on the shoulders and side slopes of the new road. The old road is now very unstable and side slopes are failing in many locations. Water must be pushed back from the edge by placing additional fill on the side slopes of the new road embankment to enhance stability. Of significant concern is the fact that the water currently ponding along the new road is only drained away by a culvert in the old road near the sharp corner. With no maintenance on the old road, Tt has concerns that the culvert will become inoperable/blocked and water levels in the pond will rise significantly leading to more thaw and further threaten stability on the new road. Suggest removal of the culvert and breaching the old road embankment to lower water levels. See Section 4.0 for further discussion.
33	56.7L		Severe	Moderate	Not visible	Unknown	Drainage enhancement	B	Pit water is intended to drain to a small culvert under road at west end of pit. Continued settlement has left invert of culvert too high. Consider draining along north (left) toe of road grade to natural draw about 100 m south and placing a new culvert through road at that location. Consult Photo 649.	A					
34	55.8		Minor	Low	Not apparent	Unknown	Grading	C	Regrade and improve drainage.	C	No change	C			No change
35	55.4	Risk of road collapse	None	Low	Wedge ice	Unstable	Protecting road embankment	A	A small excavation on the upslope side of the embankment has allowed water to penetrate into Wedge Ice initiating thermal erosion. The road grade was actively collapsing into thaw depressions at the time of the visit. There is a high safety risk of total collapse. The road must be bermed on both sides for a distance of 3 to 4 m and the embankment raised to accommodate settlements that have occurred. The side slopes should be dressed along with disturbed areas. The site should be monitored during periods of high road use until stability of the permafrost is assured.	B	Stability has improved with some berming of the embankment and the embankment does not seem to be at risk of failure now but should be monitored once the road sees increased traffic.	B			No change
36	53.1		Minor	Low	Not apparent	Stable	Protecting road embankment	C	Small pothole pit beside road. Material stockpile. The shoulders of the road should be dressed and slopes flattened.	C	No change	C			No change since 2014
37	52.2	Road collapse	Dry	Low	Wedge	Unstable	Protecting road embankment	A	Active sinkhole on immediate north side of embankment has extended under the road resulting in grade collapse about 1/2 m. Selective excavation of the road fill and underlying ice at this site is recommended followed by rebuilding grade with compacted material. Raise the final grade 1 m or more above current elevation and flatten side slopes.	A++++	Settlement continues and the road embankment is now very steep on the north side, recent extraction of material has removed more of the active layer and thaw is ongoing. The embankment side slope is very unstable and this is a safety issue as there is a risk of catastrophic failure. The large sinkhole should be backfilled as soon as possible.	A		2563, 2591	QIA noted that the road appeared to have been raised at this location. Actually the road was significantly realigned to improve grades and is now located at a lower elevation and borrow pit 37 is now well away from the new road. Therefore the stability of the old road is not of significant concern, The thaw degradation that was noted to be ongoing is still happening in the pit and there is the potential for sediment laden water to be released from the old pit. The priority has been downgraded to reflect the lessened safety issue but is still rated A because of the potential sediment issue. Regrade pit surface, assess potential water release locations and armour outflow and install check dams as required to control sediment release.
38	51.9		Dry	Low	Not apparent	Stable	Grading	C	Dress the slopes and bottom.	C	No change	C			No change since 2014
39	51.7			Low	Wedge ice extending under road	Unstable	Stabilize road surface, dress side slopes and fill sinkholes	B	Sinkhole under road at north end, cracking onto road surface. Build road grade up, dress disturbed area, and flatten embankment side slopes.	B	Continued settlement away from the road, some recent regrading has improved the stability of the road but this area should be closely monitored to see if the sinkhole redevelops.	B			No change since 2014
40	51.2	Hole in Road		Low	Wedge ice extending under road	Unstable	Ensure safety of road	A	Wedge Ice that extends under the road has thawed resulting in collapse. Road grade dropped about 1 m. Sinkholes in pit allow standing water adjacent to side slope. Raise the road grade about 1 m at this location, and construct side berms to protect permafrost and push any free water 3 m minimum away from toe of slope. Regrade the abandoned pit and upgrade the site drainage.	A	Pit and road in similar state although ponded water seems to have decreased. Recent road grading may have obscured any recent settlements	A+	2701, 2702		Thaw is ongoing and pit is deepening, steepening the side slope. Drainage out of the pit flows to the south towards the lake (Photo 2702). There is some thermal degradation happening in the natural drainage probably due to increased water flow in the spring. Ideally this pit would benefit from being backfilled as this would arrest thaw, improve embankment stability and reduce spring flows.
41	50.6L		Minor	Low	Localized wedge ice	Moderately stable	Regrading	C	Regrade and improve drainage from sinkholes.	C	No change	C			No change since 2014
42	49.7L		Mostly dry	Low	Ice wedges, south end	Sinkholes south end	Regrading	C	Regrade to fill and cover sinkholes at south end.	C	No change	C		2564	QIA - noted water accumulation and potential for instability at KM 49.9 Do not see evidence of ponding in the pits at this location and road seems to be stable.
43	49.6R		Dry	Low	Not apparent	Stable	Dress surfaces	C	Long pit where active layer soils have been pushed up to make embankment.	C	No change	C			
	49.0											A+	2698, 2699, 2700		QIA - noted ponding and road instability. There is a cut that was made to improve grade and a communications tower is situated on the top of the terrace on the west side of the road. There is ponding on the east side of the road. An ice wedge can be seen to be degrading on the terrace and is very evident on thee cut slope on the west side of he road (Photos 2698 and 2699). Material should be placed over the degrading ice wedge both on the terrace and on the cut slope. The ditch (Photo 2700) to the south of the wedge is unstable as is the side of the road, suggest some regrading and slope flattening to help improve stability. Close monitoring of the road should be undertaken and if any dips are noted at the ice wedge locations further remediation may be required.
	47.2										Photo of stable road				
43A	46.8										Photo of stable road	C		2590	No change since 2014
44	46.7L		Minor	Low	Not apparent	Stable	Dress surfaces	C	Pothole pit, some water. Dress slopes and improve drainage.	C	No change	C			No change since 2014
45	46.1		Dry	Low	Not apparent	Stable	Dress slopes	C	This is a confined but deep pit, currently dry. The backslopes are steep and may require minor cleanup and dressing.	C	No change	C			No change since 2014
46	44.0		Dry	Low	Not visible	Moderately stable	Repair grade	A	This road cut exposed ground ice that is actively thawing. The road grade should be built up at this location about 1/2 m.	B	Road stability has improved at this location but should be monitored closely with increased traffic.	B			Minor realignment has improved stability.
47	42.2R		Partial	Low	Not visible	Moderate	Regrade	C	Small pit with one large sinkhole. Regrade and fill sinkhole — not affecting road.	C	Sinkhole has increased in size but has not yet affected the road, should regrade and fill in hole.	C			May have been some material remoied since 2014 but pit is table.
48	38.0R		Dry	Low	Not visible	Stable	Regrade	C	Dry pit on ridge. Regrade to dress surfaces.	C	No change	C			No change since 2014
48A	37.2	new pit							New pit?	C	New pit?, active layer has been scraped off, some limited settlement near the road but no water ponding was observed.	C		2566	No change since 2014
49	37.5R		Dry	Low	Not visible	Stable	Dress surface	C	Linear pit from pushup. Well drained. Dress the surface.	C	No change	C			No change since 2014
50	37.2R		Dry	Low	Not visible	Stable	Dress surface	C	Similar to 49.	C	No change	C			No change since 2014
51	36.5 L&R		Ponding on left	Low	Wedge Ice	Moderate	Improve drainage and regrade	B	Active layer removed along road on both sides. Well developed ice wedge cracks evident across pits and continuing under embankment. Beginning to affect road at north end. Stockpiles remain in left pit. Further removal of surface soils at this location not recommended without a pit development plan. Reclamation should grade pit surface, infill ice wedge cracks and flatten embankment side slopes in regions showing distress. Improve drainage.	C	Drainage seems to have improved and this may have lead to improved road stability, still do not recommend additional material removal without a pit plan. Reclamation recommendations remain the same.	B		2567, 2589	Pits look similar, ice wedge melt out is evident in the pits and upon close inspection the wedges can be traced under the road, appearing slightly darker,. When driving slight dips are evident in the roads where the ice wedges are under the road. This indicates that some thaw is continuing. This calls for close monitoring to warn of potential collapse. It is very important to keep the pits dry.

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		2009 DWH								2014 KWJ		2019 KWJ			
Site WP No. 2009	**Km Post**	**General Location Comments**	**Pit Water 2009**	**Erosion Potential**	**Ground Ice Features**	**Active Layer Stability**	**Reclamation Focus**	**Priority**	**2009 Comments**	**Priority**	**2014 Comments**	**Priority**	**Ground Photos**	**Aerial Oblique Photos**	**2019 Comments**
52	35.7R		Dry	Low	Not apparent	Stable	Regrade	C	A relatively large pit but dry and stable bottom. Dress slopes and bottom.	C	No change	B		2567, 2589	Pits look similar, ice wedge melt out is evident in the pits and upon close inspection the wedges can be traced under the road, appearing slightly darker. When driving slight dips are evident in the roads where the ice wedges are under the road. This indicates that some thaw is continuing. This calls for close monitoring to warn of potential collapse. It is very important to keep the pits dry.
52A	35.5											C			Pit stable no issues
53	34.9		Dry	Low	Not visible	Moderately stable	Regrade and fill sinkholes	C	Long, linear pit with a few sinkholes. Regrade and fill sinkholes. Material removed recently	C	No change	C			
54	34.7		Dry	Low	Not apparent	Stable	Regrade	C	Dress all surfaces.	C	No change	C			
55	33.5		Minor ponding	Low	Minor wedge ice	Stable	Regrade	C	Regrade to fill wedge cracks and dress surface.	C	No change	C			No change
56	33.4L		Dry	Low	Not apparent	Stable	Regrade	C	Small square pit. Dress all surfaces.	C	No change	C			No change
57	33.0L		Partial	Low	Not apparent	Moderate	Partial infill and regrade	C	Three small pits, two dry and one with water. Regrade or import fill to flatten or berm embankment side slope beside water-filled pit. Grade surface.	C	No change	C			QIA noted that a sinkhole was evident on the road and suggested that it was a result of a culvert failure. At the time of the 2019 inspection there was no evidence remaining and therefore it was assumed that the problem had been repaired.
58	32.4L		Partial	Low	Not apparent	Moderate	Regrade	C	Pushup pit. Rough bottom. Grade surface, improve drainage. Defined pit on left about 300 m further south is dry and needs no work.	C	No change	C			No change
59	30.6R		Dry	Low	Not apparent	Stable	Dress surfaces	C	High, well-drained side borrow site. Dress bottom and slopes.	C	No change	C		2568	No change
60	30.1R		Dry	Low	Not apparent	Stable	Dress surfaces	C	Similar to Site 59.	C	No change	C		2568	No change
61	30.1L		Dry	Low	Not apparent	Stable	Dress surfaces	C	Similar to Sites 59 and 60.	C	No change	C		2568	No change
61B	29.1									A++++	Site not reported on in 2009. Recent construction has removed considerable material form this location, extensive settlement is occurring (5 to 6 m) and is undermining the road embankment on the east side. Settlement and ice wedge melt out is also occurring on the west side. There is a significant risk of catastrophic failure of the embankment at this location. Material should be imported to fill in all of the settlement areas and improve the potential to arrest these extensive thaw settlements.	A++++	2693, 2694, 2695, 2696		QIA noted water accumulation and stability issues at KM 29.4 but the pit with issues is located at 29.1 on the Figure (assumed to be the area of concern). As noted in 2014 this entire pit should be backfilled with imported material after removing as much water as possible. See Section 4.0 for further information
62	28.7		Minor ponding	Low	Not apparent		Regrade	C	Near vertical slope on sidehill pit. Slope pit back at 3H:1V and add some shoulder to road. Improve drainage.	C	No change	C			No change
62A	27.8									B	Not reported on in 2009, appears that more material has been recently removed, thaw of ice wedges and ground ice is leading to ponding but it is away from the toe of the slope, road embankment seems stable for now,. Pit could be regraded to reduce ponding and resulting thaw settlements.	B			Extensive ponding remains in the pit, recommendations from 2014 still apply.
63	27.0R		Minor ponding	Low	Not apparent	Stable	Regrade vertical slope	C	Pit has a near vertical slope 2 to 3 m high. Slope back to 3H:1V and dress pit bottom to improve drainage away from road embankment.	C	No change, currently stable	C			Some ponding on the left side of the road, perhaps in an area were material was removed after 2014
64	26.7L&R		Major ponding	Low	Not apparent	Stable	Regrade backslope, develop drainage plan	B	Deep pits on both road shoulders, both flooded. Slope sides to 3H:1V and develop a drainage plan. It may be practical to ditch to the creek about 100 m to the north.	B	Water continues to pond on the east side of the road but road embankment continues to appear stable at this time.	B		2569	Ponding remains similar to 2014, embankment remains stable
65	25.8L&R		Minor	Low	Not apparent	Stable	Dress surfaces	C	Pushup pits on both sides. Well drained. Dress slopes and ensure future drainage.	B	Water continues to pond on the east side of the road but road embankment continues to appear stable at this time.	B		2588	Ponding remains similar to 2014, embankment remains stable
66	23.6L&R		Minor	Low	Not apparent	Stable	Dress surfaces	C	Pushup pits both sides. Currently self-draining to tundra. Not obvious erosion or sinkholes. Grade side slope into pond lying to the left side.	C	More water is now ponding in the NW corner of the pit and due to settlement is no longer free draining to the tundra	C		2570	Conditions similar to 2014
67	23.3L		dry	Low	Not apparent	Stable	Dress surfaces	C	Well drained pit on top of natural rise. Dress bottom and slopes.	C		C			Limited ponding in the north end of the pit
68	21.9R		Minor ponding	Low	Massive ice	Unstable	Fill and Cover Sinkholes	B	Melt out of massive ice actively developing sinkholes at toe of embankment side slope. A berm should be built on side slope and sinkholes infilled at 2 locations. Regrade to improve drainage to the northwest.	A	Thaw continues and is threatening embankment stability on the west side of the road. This pit should be regraded and backfilled with material to improve embankment stability.	A++++	2691, 2692		QIA noted water accumulation and road instability at this location. Pits should be backfilled and graded as noted in 2014 to cause the permafrost to aggrade and enhance the stability of the embankment side slopes. See Section 4.0 for more information
69	21.4L	Out of sequence — returned to inspect this site	Minor ponding	Moderate	Segregated ice	Unstable	Control drainage and limit sediment transport	C	Pit cut into side of knob. Thaw of icy soils is producing meltwater and sediment. Selective use of a boulder rip-rap blanket is recommended. Use rip-rap to control and filter drainage that is being dispersed onto tundra.	C	Drainage seems to have ceased and pit seems stable, may not need to consider the rip rap blanket now	C			No change since 2014
70	21.2L		Water-filled pothole pit beside road	Low	Unknown	Unstable	Water-filled pit	C	Pothole immediately beside embankment side slope. Drain and install culvert under road. May require widening shoulder and partial infilling to maintain long-term drainage.	C	No change	C			No change since 2014
71	20.7R		Water-filled wedge cracks	Moderate	Substantial wedge ice	Unstable	Prevent further ice wedge thaw	B	Active layer removed from top of hill, exposing substantial wedge ice. Substantial melt out and continued activity. Water collecting in wedge cracks. Develop drainage and fill expanding wedge cracks. Berm the side slope to prevent further thaw under road embankment.	A++++	Wedge ice has substantially degraded since 2009 thaw settlement is now undermining the road and road settlement is obvious. There is potential for catastrophic collapse of the road surface at this location. Reclamation should occur as soon as possible. This must involve complete filling of all the settlement areas to eliminate ponded water and arrest continuing thaw settlements.	A++++	2543, 2544, 2545	2571	Pit remains similar to 2014 and settlement and instability of the road side slope is evident. Filling of the pit as soon as possible is still recommended to improve safety . See Section 4.0 for further detail
72	19.8L		Water-filled pit	Moderate	Unknown	Moderate	Develop pit drainage	B	A 2 m deep pit with water. No obvious opportunities to develop drainage. Survey and determine options to drain while minimizing further cuts. May require berming along road to prevent thaw from undercutting embankment side slopes.	A++++	Extensive settlement is ongoing on the east side of the road and is now estimated to be upwards of 6 deep, cracking is evident on the west side and settlement is evident in several location in the road. This area needs to be reclaimed immediately to reduce the potential for catastrophic failure of the road.	A++++	2540, 2541, 2542	2572, 2587	Photos 2541 and 2542 show instability on the side slopes and observed conditions and suggested stabilization measures remain as indicated in 2014. See Section 4.0 for further information.
73	18.3L&R		Large water-filled pit	Moderate	Not apparent	Moderate	Develop pit drainage	B	Large pit pond immediately adjacent to road. Appears to be deep water. Currently no drainage. Can be drained by installing a culvert under the road. Flatten side slopes into pit to push water further from road shoulder.	B	Water in pit is much less than in 2009 and it appears that some additional material may have been recently removed.	B			More water is ponding in the left side (east) pit than noticed in 2014 but road appears stable.
KM 17 BRIDGE											New bridge, note some tilting and movement of bin wall foundations at both ends of the bridge. This may be imparting additional compression loads on the bridge.		2678, 2679, 2681, 2684, 2685, 2686		
74	16.9L&R		Linear pits both sides with water	Moderate	Not apparent	Moderate	Develop pit drainage	B	Long, linear pits both sides. Left side has larger pond. No thaw features apparent. Assess drainage options. Flatten embankment side slopes where water is at the toe of slope.	B	Little change, although there is now more ponding on right side. Should flatten embankment slopes as noted in 2009. Limited settlement of road surface above ice wedges can be seen and may be indicative of the start of thaw of the ice wedges.	A			More water is ponding in the pits than noticed in 2014 and there is concern that rate of thaw will increase potentially leading to embanknt instability but road currently appears stable. Determine if it is feasible to darin water from pit to reduce potential for increased thaw. Otherwise monitor closely to evaluate road stability.
75	15.0R		Some water	Low	Not apparent	Stable	Dress surfaces	C	Long pit, some water, no active subsidence, dress surfaces.	C	No change	A		2574, 2586	More ponded water and there is a short section at the south end of the pit where there is a very steep side slope and considerable drop from the edge of the road down into the water. Pond should be drained and the area where water is ponding should be backfilled.
76	14.2L		Dry	Low	Not apparent	Stable	Dress surfaces	C	Dry, well-drained pit floor. Stockpile of sandy gravel present. Dress surfaces.	C	No change	C			No change since 2014
77	13.4L		Pond	Low	Not apparent	Moderate	Pothole pit	C	Some refilling may be required in pothole pit beside road.	C	No change	C			No change since 2014
78	13.2L		One pond to north	Low	Not apparent	Moderate	Large area to dress	C	Shallow pit on top of rise. Pond in north end that can be drained to the north. Grade and dress surfaces.	C	Pond size is increasing and water is getting deeper, may start to impact road stability	C		2585	No change since 2014

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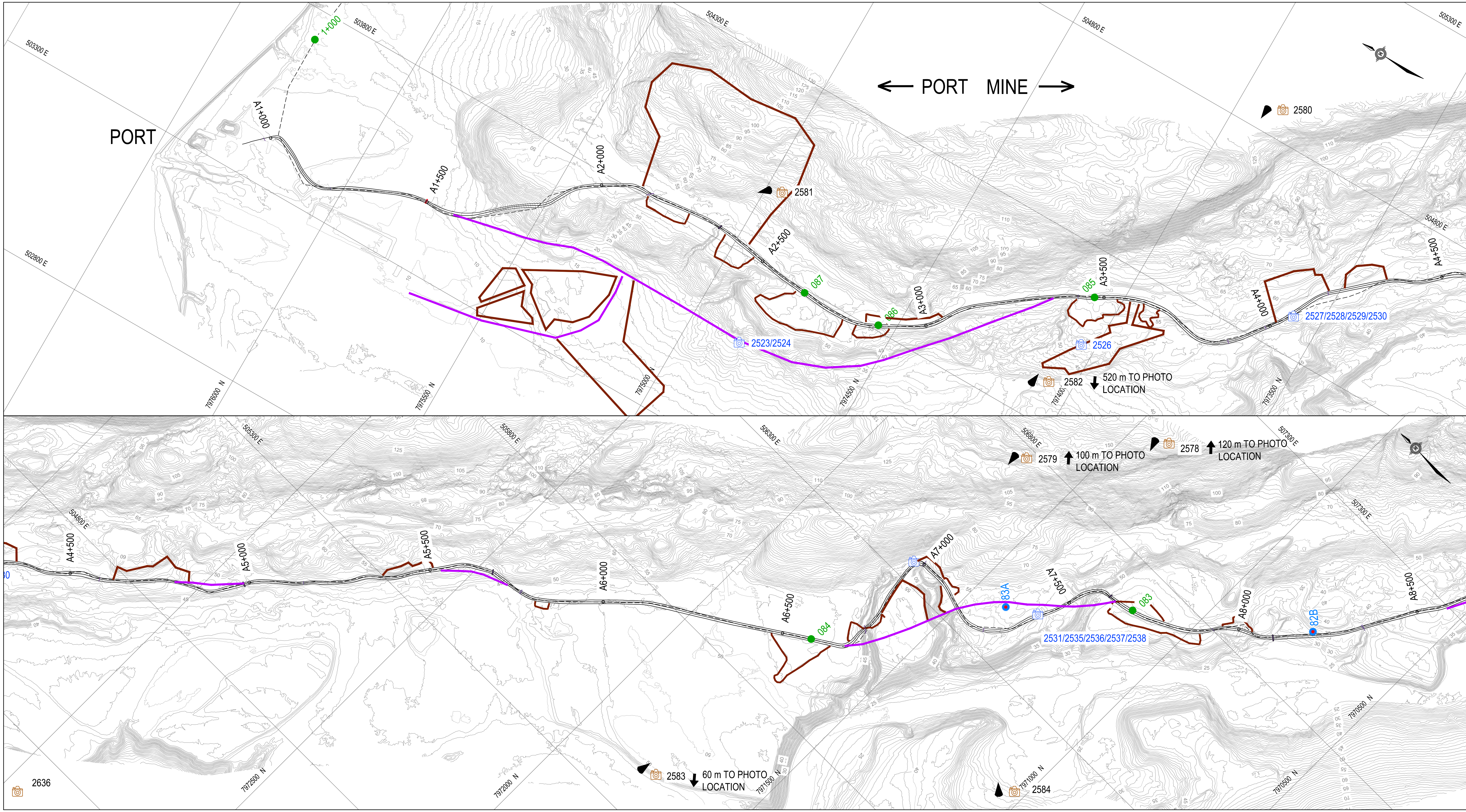
79	12.8L&R		Wet bottom	Low	Segregated ice	Unstable	Large surface area	**B**	Pit in silty sand, abundant ground ice. Active thaw in pit floor. Surface will need to be regraded to cover exposed icy sediments. Several visits may be necessary to stabilize the new active layer.	**B**	No change	**B**		2575	No change since 2014
80	9.7L		Water-filled wedge cracks	Low	Wedge ice	Unstable	Active sinkholes in wedge cracks	**B**	Extensive melt out of ice wedges resulting in water-filled troughs. Need to drain and fill sinkholes. Material should be imported as the entire pit is underlain by wedge ice and further removal of active layer material will exacerbate reclamation.	**A**	Water continues to pond and thaw settlement continues, need to undertake reclamation as suggested in 2009	**A**	2539	2576	See 2014 recommendations for stabilization. Also consider adding a toe berm to the left side of the road or at a minimum flatten the side slope near the natural pond to stabilize embankment on that side (east side).
81	9.4L`		Extensive pond	Moderate	Wedge ice	Unstable	Wedge cracks flooded in pit bottom	**B**	Flat bottom pit with no drainage. Develop drainage and fill wedge cracks evident below water level. Dress and grade surfaces.	**B**	No change	**B**			No change
82	9.4L`		Dry	Low	Segregated ice	Unstable	Sinkholes	**C**	Sidehill cut into bank beside road. Backfill and regrade with rip-rap quality material. Allow future drainage from cover.	**C**	No change	**C**			No change
82A	8.8									**C**	New borrow pit, relatively stable and well drained, some limited settlement but currently is well away from the road.	**C**			No change since 2014
83	7.7L&R		Left pit flooded, right pit wet	Moderate	Wedge ice	Unstable	Road shoulder unstable, develop drainage	**B**	Deep pits (about 3 m) no drainage. Ice wedge cracks and sinkholes. Backfill sinkholes and regrade steep slopes. Rebuild and flatten road side slopes. Regrade base and improve drainage.	**A**	Extensive settlement continues near the edge of the road embankment, threatening road stability. The recommendations from 2009 should be carried as soon as possible to reduce the chance of catastrophic failure of the road.	**A++++**		2578, 2584	Thaw has continued and instability is more prominent on the sides of the road. The priority has therefore been increased to A++++ and therefore reclamation as per the 2009 recommendation should commence as soon as possible. See Section 4.0 for further details.
83A	7.2									**A**	Realignment with pits on both sides of the embankment, extensive thaw settlement and potential road instability. The pits on both sides of the road should be immediately regraded and material added at the toe on both sides to lessen thaw settlement and improve embankment stability.	**A++++**	2531, 2535, 2536, 2537, 2538	2578, 2584	QIA noted that the road was surrounded by water at nearly the elevation of the road and noted that there appeared to be degradation of permafrost. Indeed, ongoing permafrost degradation is ongoing in the pit. The road appears much less stable in 2019 and the water levels have risen in the pits, leading to road instability due to thaw. This pit needs to be filled on both sides of the road after removing as much water as possible. Filling the pits a regrading will hopefully lead to aggradation of permafrost and enhance the stability of the road much worse. See Section 4.0 for further discussion.
84	6.9R		Flooded	Moderate	Wedge ice	Moderate	Develop drainage	**C**	Broad flooded pit. Develop drainage. Grade and dress pond edges and road side slopes.	**C**	No change	**C**		2583	No change since 2014
85	3.5R	Milne Inlet permitted pit	Dry	Low	Minor wedge ice	Stable	Silty sand susceptible to dusting	**B**	This is the main permitted pit for development at Milne Inlet. The site is a dry and naturally well-drained river terrace. The material is fine grained (silty) and may be susceptible to generating dust. Small dune-like features evident on surface. If the site is retained for future use, a pit plan should be prepared. In order to control dust, it may be necessary to provide ridges of coarse material at closure that will trap wind-blown sand.	**B**	With the creation of the Milne inlet quarry there is likely no need to consider further material withdrawal from this pit and it could be reclaimed in the manner suggested in 2009	**B**		2580, 2582	Pit is being reclaimed using overburden from the main quarry (pit 87) at the port. A granular fill berm was constructed downslope to act as a filter for any thaw water released form the frozen overburden. Thaw and settlement was still ongoing below (to the north) of the already stabilized area and it is recommended that this areas should also be covered with suitable overburden material retained by a downhill berm if additional material is available. This was discussed with Dominic Ritgen and he noted that was the plan.
86	3.1R&L	Milne Inlet permitted pit	Minor pond on left, right is dry	Low	Not apparent	Stable	Regrade to protect from dusting	**B**	Small pits, silty sand poor construction material. Grade and work cover to provide a coarser cap.	**B**	No change	**B**			No change
87	2.9R	Within permit	Localized ponding	Low	Not apparent	Stable	Regrade to protect from dusting	**B**	Large exposed pit; silty sand may need a coarser cover to protect from dusting.	**B**	No change	**B**			No change

FIGURES



LEGEND:

- 2591 - 2019 AERIAL PHOTOGRAPH LOCATION WITH DIRECTION OF VIEW AND REPORT PHOTO NUMBER(S)
- 100 m - DIRECTION AND DISTANCE TO AERIAL PHOTOGRAPH LOCATION WHEN TAKEN OFF THE FIGURE WINDOW
- 2775 - 2019 GROUND PHOTOGRAPH LOCATION WITH REPORT PHOTO NUMBER(S)
- 2009 WAYPOINT / BORROW LOCATION
- NEW OR BORROW SOURCE NOT REPORTED ON, IN 2009
- APPROXIMATE EXTENT OF BORROW AND LAYDOWN LOCATIONS
- APPROXIMATE ROAD REALIGNMENT
- HISTORIC ORIGINAL ALIGNMENTS NOT USED

0 500m

Scale: 1:10,000 @ 11"x17"

NOTES

BASED ON DRAWING DATA PROVIDED BY KNIGHT PIESOLD CONSULTING

BASE DATA: 1:10 000

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Baffinland Iron Mines Corporation

TETRA TECH

Mary River Tote Road Quarry Reclamation
Mary River, Baffin Island

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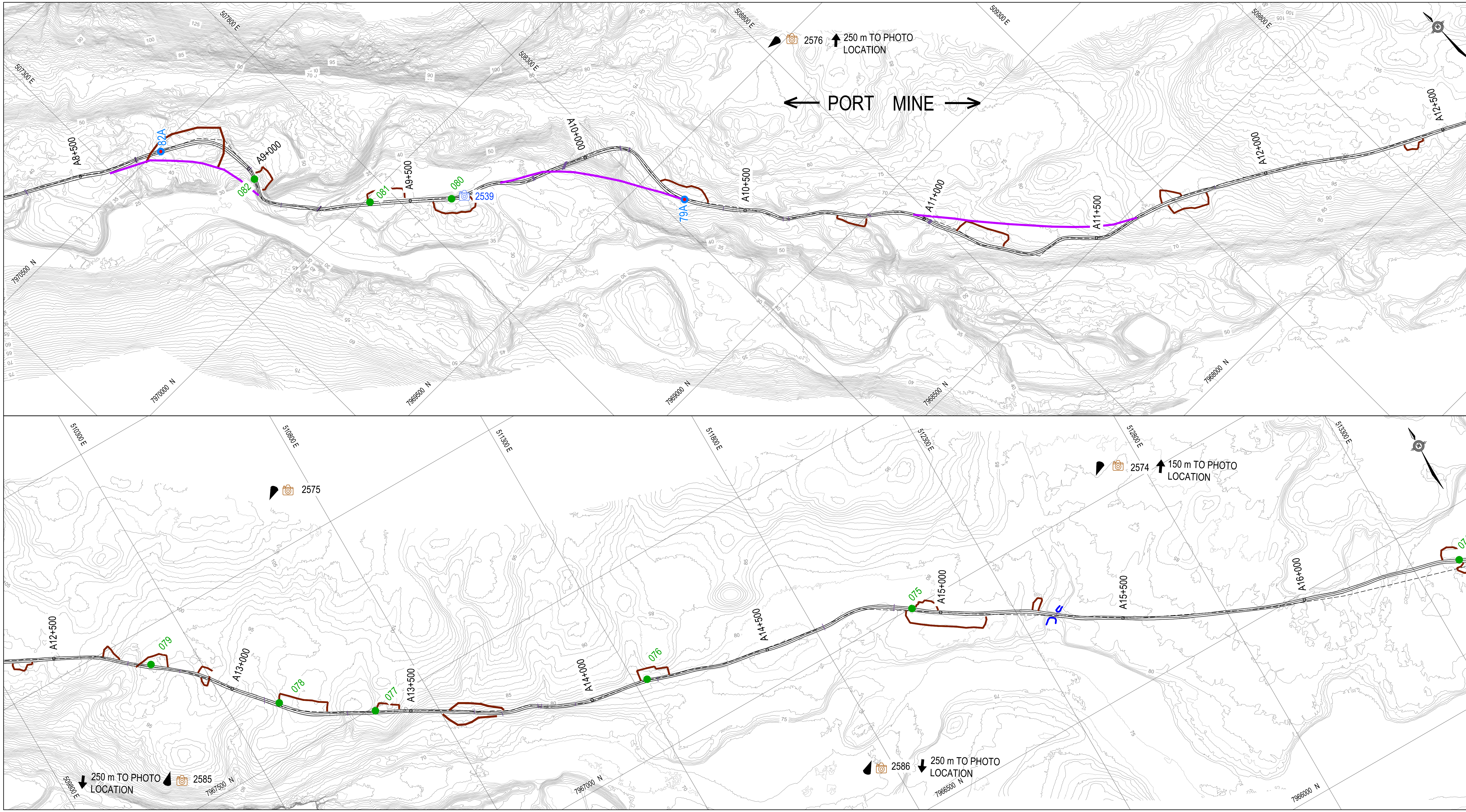
EDM	December 2019		

Figure 1

Q:\Edmonton\Engineering\E141\Projects\E14103210-01 Tote Road Evaluation\E14103210-01_Figure 1 thru 13_OCT2019new_IFU.dwg [FIGURE 1] December 17, 2019 - 1:54:04 pm (BY: PALCZEWSKI, ERNEST)



Q:\Edmonton\Engineering\E141\Projects\E14103210-01 Tote Road Evaluation\E14103210-01_Figure 1 thru 13_OCT2019new_IFU.dwg [FIGURE 2] December 17, 2019 - 1:55:07 pm (BY: PALCZEWSKI, ERNEST)

LEGEND:

- 2591 - 2019 AERIAL PHOTOGRAPH LOCATION WITH DIRECTION OF VIEW AND REPORT PHOTO NUMBER(S)
- 100 m - DIRECTION AND DISTANCE TO AERIAL PHOTOGRAPH LOCATION WHEN TAKEN OFF THE FIGURE WINDOW
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PLAN PHOTO LOCATIONS
SHEET 2 OF 13

PROJECT NO.	DWN	CKD	REV
ENG.EARC03171-01	BR/EP	KJ	0

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Figure 2