Bijaya Adhikari

From:	Dean Ahmet <Dean_Ahmet@gov.nt.ca>
Sent:	Monday, October 17, 2016 6:07 PM
To:	Philippe Thibert-Leduc
Cc:	Stephen Charlie; Bijaya Adhikari; Mardy Semmler; doug@egrubens.com; Alexis Campbell; fbailey@northwindltd.ca; Kevin McLeod; Freda Wilson; ITH; 'Russell Newmark'; Mohammad Hossain; Patrice Ngu Ndiangang; Binay Yadav
Subject:	RE: Industrial Water Licence N7L1-1835 Inspection - August 31, 2016
Attachments:	N7L1-1835 ITH Borrow Source 174 31-08-2016.pdf; rpt_Source174_recommendations_8Sept2016_fnl_red.pdf

Hi Philippe,

Please find attached report as requested in response to your inspection observations below:

MATTERS FOR FOLLOW UP

- Before the next ITH Monthly Meeting scheduled for **October 19, 2016, provide an update the Inspector and the Board** in an email, letter or report on the following matters:

1. Findings of the permafrost scientist retained by DOT early September 2016;
2. Summary of the work that has been done between the time the sinkhole was first reported and the time of this inspection report; and
3. Action plan moving forward on how to mitigate the sinkhole from further degrading and how to protect the water body downhill from a significant sediment discharge event.

Thank you,

Dean Ahmet, RET, PL(Eng.), BSc(Eng.), MPM, PMP
Senior Program Manager, Major Projects
Inuvik to Tuktoyaktuk Highway (ITH)

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Government of Northwest Territories Gouvernement des Territoires du Nord-Ouest

KAVIK-STANTEC

Technical Memo

To:	Russell Newmark, CEO EGT Northwind Ltd.	From:	Erica Bonhomme, P.Geo. 4910 53rd St. Yellowknife, NT
File:	123511255	Date:	September 8, 2016

Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

EXECUTIVE SUMMARY

On September 1, 2016 field observations and active layer measurements were completed by KAVIK-STANTEC Inc. at Borrow Source 174 with assistance by EGT Northwind Ltd. The purpose of the site observations was to determine: the origin of a "sinkhole" located approximately 30 m downslope of the edge of the borrow source; to determine if further slumping at this location can be prevented; and, to advise on any mitigations recommended to protect the environment.

Field measurements suggest that the "sinkhole" observed downslope of Borrow Source 174 is a result of ice wedge erosion; however, the cause of the ice wedge slumping cannot be attributed solely to the development of the borrow source. It is possible that additional meltwater contribution from Source 174 has accelerated the erosion since, prior to 2015 development, surface and active layer meltwater was channeled through a different area.

Mass failure of the slope may or may not occur, though morphology of the general area and corresponding active layer depths suggest that the area may be prone to slope movement. Such movement is not preventable.

Existing mitigations to protect the environment, including silt fencing installed at the top of the slope and trenching to divert water away from the affected area is effective for its purpose. These existing mitigations should be checked on an occasional basis to conduct and repairs or modifications as may be required. Additional mitigation measures are not recommended, as any impacts to the environment – particularly the adjacent lake – from ice wedge erosion or downslope movement are likely to be negligible.

1 PROBLEM SCOPE

Borrow Source 174 is located partly on Inuvialuit Private Lands and partly on Government of Northwest Territories Crown Land (Figure 1- Figure 3-2 from the PDP). Operations at the source are authorized under Quarry Permit issued by the Department of Lands (DOL) and Quarry Licence issued by the Inuvialuit Land Administration (ILA). Both authorizations include a Pit Development Plan, specifying the areas to be developed, methods, quantities, erosion control measures and reclamation (KAVIK-STANTEC, 2014a). Approximately 800,000 m^3 of borrow material from the southernmost polygon of the source was extracted in winter 2014/15 and 2015/2016.

In April of 2015, April 2016, July 2016 and August 2016, the DOL and ILA conducted inspections of the borrow source. During 2016, conditions pertaining to erosion control at Borrow Source 174 were deemed "unacceptable", specifically pertaining to a "sinkhole" located approximately 20 m south, and downhill of silt fencing located at the southernmost edge of the borrow source, and an uphill area of saturated ground

Reference: Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

(Figure 2). The area of concern is on Crown land under jurisdiction of DOL.

DOL has requested that an assessment of the area be undertaken and that a plan of action be developed to mitigate further subsidence in the area. In response to the request, EGT Northwind requested KAVIK-STANTEC to provide an expert assessment of the area to:

1) advise on the cause for the sinkhole;
2) advise on mitigation to prevent possible slumping; and,
3) in the event that slumping cannot be prevented, actions that may be taken to mitigate impacts to the environment.

This memo provides the methods and results of this investigation.

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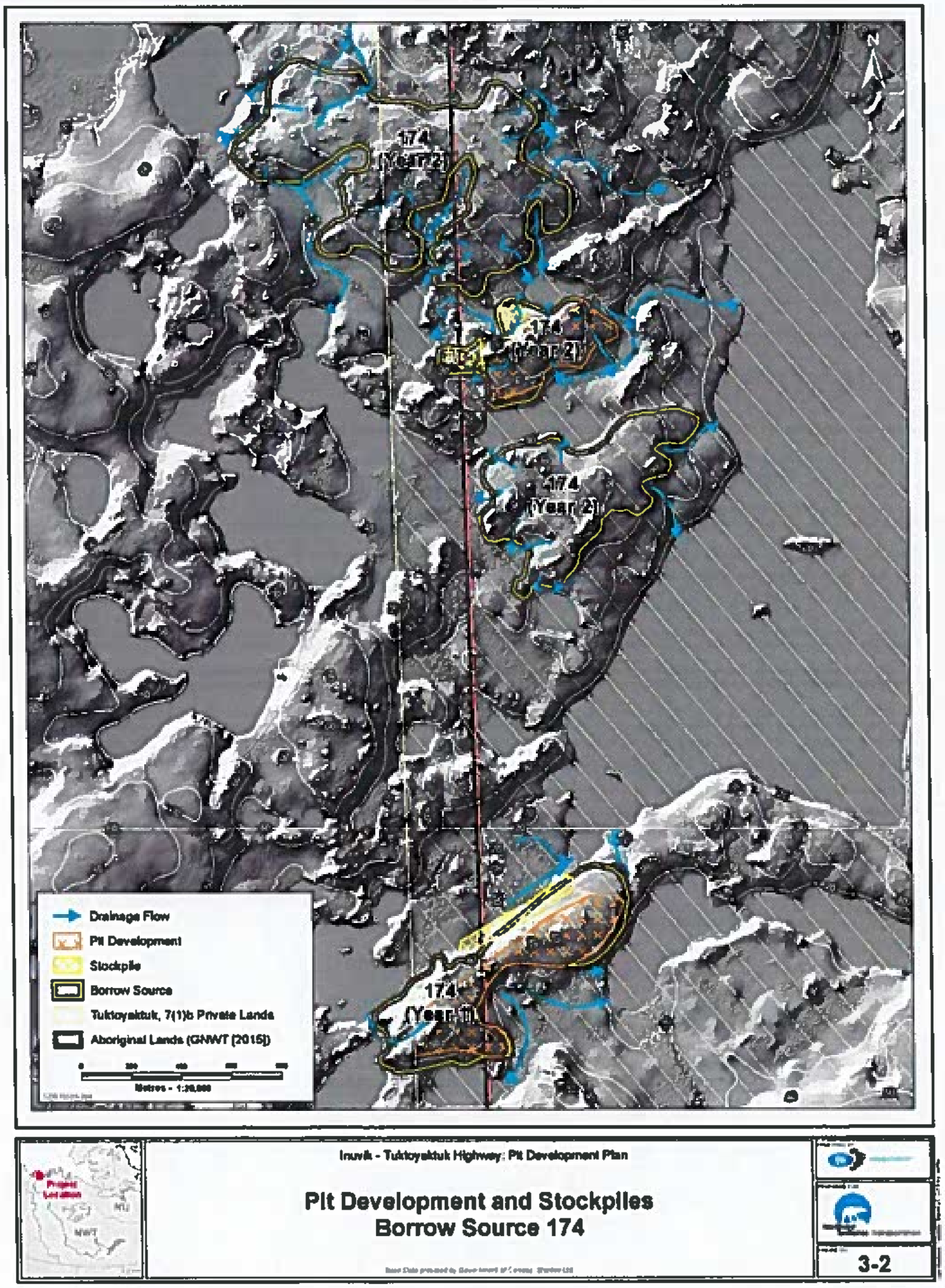
Reference: **Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174**

Figure 1: Borrow Source 174 Pit Development Plan – Figure 3-2



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Reference: **Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174**

Figure 2: Area noted in DOL inspection report of August 18, 2016 noting a sinkhole and cracking. Inset image shows area noted on pre-development LiDAR image (KAVIK-STANTEC 2014a)

ENVIRONMENTAL INSPECTION REPORT

Inspection Images:

Figure 1

Aerial edited to indicate area of concern

2 METHODS

The assessment methodology was based on a review of the project information, including:

- DOL and ILA Inspection reports (2015 and 2016);
- Borrow Source 174 Pit Development Plan (2014a);
- Surveyed as-built imagery from 2014 and 2015;
- Pre-development geotechnical borehole results (KAVIK-STANTEC 2014b)

Based on examination of the photos, the area of subsidence is due to thermo-erosion: possibly due to borrow

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source development activities directly; possibly facilitated by borrow source development activities; or, possibly unrelated to borrow source development activities. The photos indicated presence of visible ice within the slumped area, and subsidence adjacent to the hole. The area is also directly downgradient of an area where silt fencing has been installed to prevent sediment from moving downhill.

The methods to identify the cause of the sinkhole were based on a review of published literature pertaining to the behavior of the active-layer and permafrost in the area, the morphology and dynamics of retrogressive thaw slumps, the degradation or melting of ice-wedges, as well as on professional experience.

Published studies of retrogressive thaw slumps, active layer failures and active layer characteristics in the Mackenzie Delta and Beaufort coastal areas (e.g., Wolfe et. al, 2000, Wolfe et. al. 2001, Lantuit and Pollard 2005), indicates that generally, the exposure and degradation of permafrost is attributable to erosion or deepening of the active layer overlying permafrost. Godin and Fortier (2010) attribute the thermo-erosion of the upper portion of ice-wedges to the rapid heat transfer that can occur between flowing water and frozen ground or ice. As such, the methodology chosen for investigating the cause of the sinkhole at Source 174 involves determining what may have led to the thermo-erosion and deepening of the active layer, specifically. To do this, the following information was recorded:

- Depth of the active layer at, adjacent and away from the sinkhole along a 100 m transect;
- Observations of water flow characteristics and quantity at the exposed area;
- Observation of ice and sediment within permafrost, including size, type and quantity; and,
- Geomorphological observations of the general area.

On September 1, 2016, Erica Bonhomme, P.Geo., accompanied Douglas Saunders and Fred Bailey of EGT Northwind Ltd. Observations were taken between 1540h-1745h under clear skies, light wind and temperature 12°C.

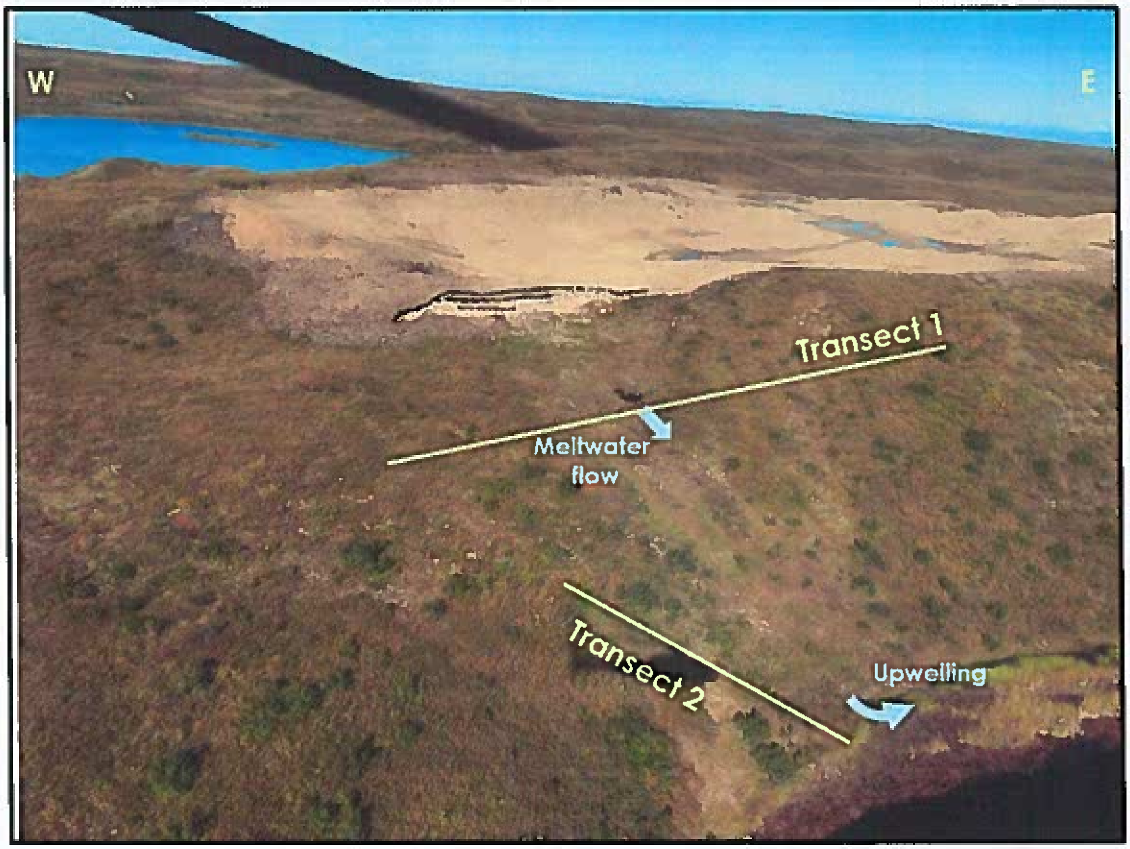
3 RESULTS

3.1 Active Layer Depths

Active Layer Transect 1 is located approximately 50 m from the lake shore, is 100 m long, and is centered on a natural depression between small ridges on either side of the sinkhole area (Figure 3). Two separate active layer depths were recorded every 5 m approximately, using 1 cm diameter steel probe graduated in 20 cm increments. Distance from the base of vegetation to base of active layer was recorded when substrate encountered was determined by feel to be top of permafrost. Detailed location information is included in Attachment A. Due to the coarse nature of the substrate visible at surface in the area (pebbles and cobbles), resistance at depth not due to permafrost was frequently encountered.

Reference: Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

Figure 3: Location of Active Layer Transects in Relation to Borrow Source and Sinkhole



Active Layer depths are plotted in Figures 4a and 4b. They indicate a high variability in active layer depth, but show deeper active layer depths on the hill sides as compared to the middle of the valley. The exception is an isolated area at the location of the sinkhole, where active layer was not encountered – possibly because it was > 2 m (length of probe), or because the probe encountered a crack in the ground. From the top of the ridge to the lake, active layer depth did not change substantively until the lake level was reached, with permafrost present almost all the way to the lake.

3.2 Observations of Water Flow

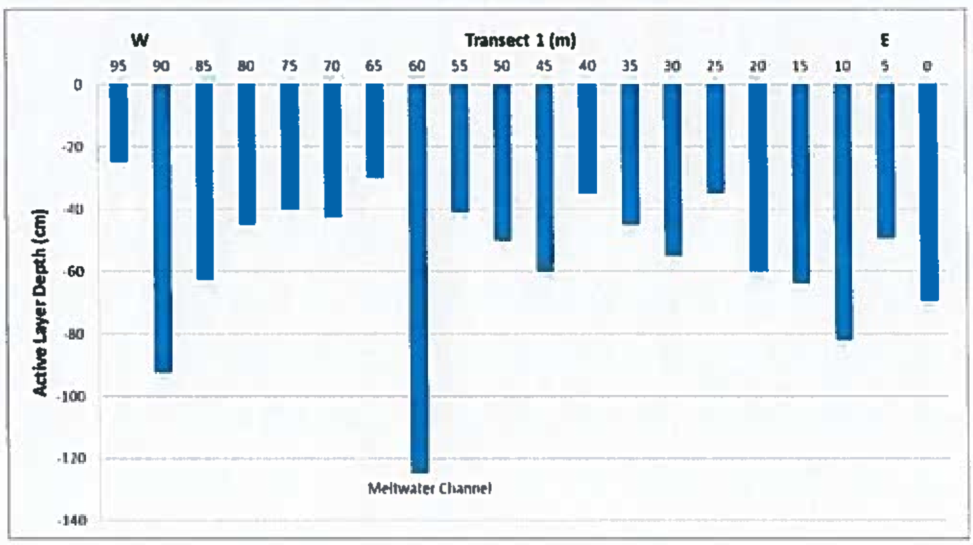
No water was visible at the surface downgradient of the silt fence. There remains a small pool of water (25 m^2) within the borrow source area, and it is undetermined in which direction it may be draining. At the sinkhole, water was observed seeping from the active layer where it overhangs void space. Meltwater is collecting within natural low points in the active layer and is channeling into cracks that have formed within the ground. It is estimated that flow is approximately 1 m^3/h. The active layer between the silt fence and sinkhole was saturated but firm.

Reference: Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

At the base of the slope, upwelling is occurring at lake level, as demonstrated by several areas of bubbling and flow. Sediment content within the upwelling material is low and there is no observable sediment plume or discoloration. Several types of benthic invertebrates were observed in the shallow near-shore zone. Aquatic vegetation extends 4 to 5 m away from the shoreline. The shoreline itself consists of sandy pebble-sized material.

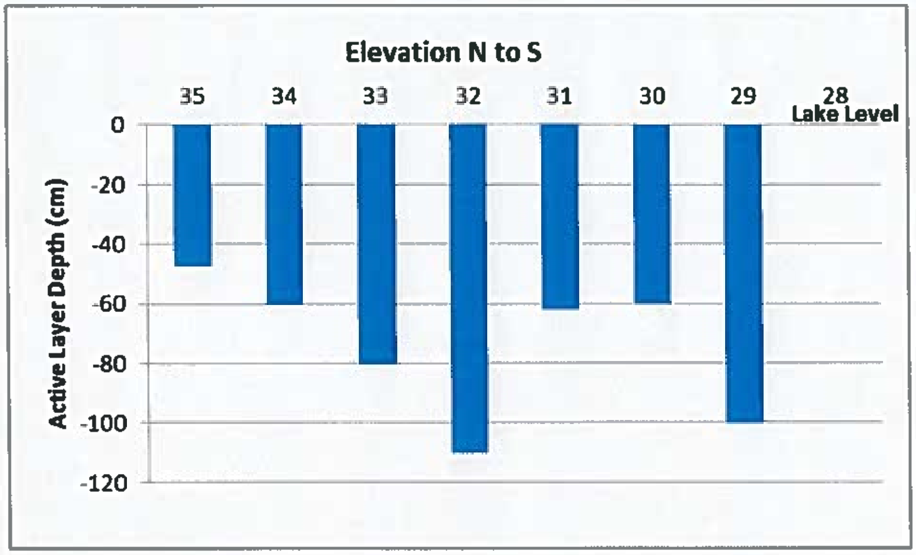
Measurements of pH of active layer water at the sinkhole and from upwelling material are neutral at 7.

Figure 4a: Active layer depths along Transect 1 showing deeper active layer at the edges of the valley and at the location of the sinkhole and meltwater channel.



Reference: **Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174**

Figure 4b: Active Layer depths along the axis of the valley towards the lake



3.3 Ice and Sediment Characteristics

The sinkhole is the only location where ice is visible. At this location, the active layer depth was observed to range from 30 to 50 cm. Material within the active layer consists of sand and cobbles. Multiple ice wedges are visible, as identified by their shape and vertical foliation within the ice. Frozen ground is melting preferentially, leaving overhanding organic mats. There is no obvious expression of ice wedges at the surface (Figure 5).

Vegetation in the center of the valley where the sinkhole is located, is short groundcover consisting of species characteristic of Dwarf Shrub Heath/Upland Shrub vegetation types, with a very thin root layer (<10 cm). Rounded pebbles and cobbles are present at surface.

Figure 5: Ice wedges and overhanging vegetation mat at the area of the sinkhole

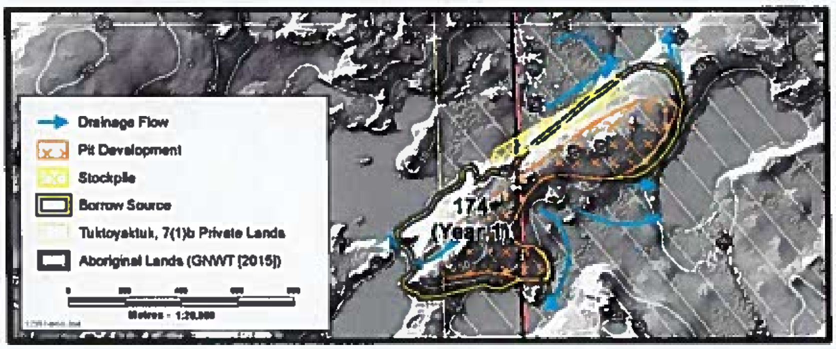
Reference: Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

A geotechnical drilling program was conducted in 2012 to identify borrow material sources for the Inuvik to Tuktoyaktuk Highway Project, included drilling within Borrow Source 174 (KAVIK-STANTEC 2014b). Four boreholes 174-52, 174-53, 174-54 and 174-55 indicate variable to low (< 30%) ice content at depth, with no massive ice encountered.

3.4 General Geomorphology of the Area

As indicated in the Pit Development Plan Figure 3-2, major drainage off of the high point of the borrow source was primarily identified towards the west (Figure 6).

Figure 6: Pre-disturbance drainage as identified from LiDAR (2014a)



During pit development in 2014/15 and 2015/16, approximately 5 m of elevation was removed from the hill. The drainage from the southwest portion of the pit now drains primarily to the south as shown in the sequence of Figures 7a-d.

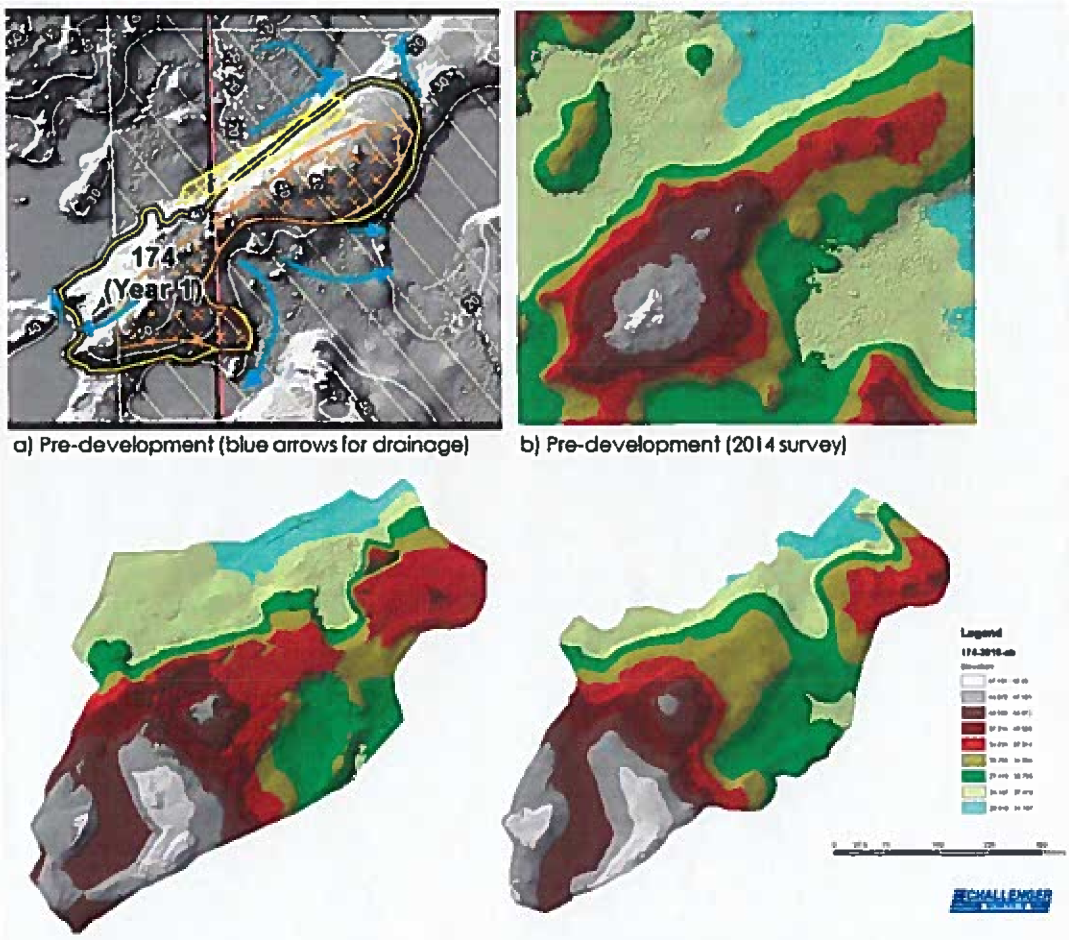
Drainage in the area; however, is poorly defined. No obvious channels are present, and surface drainage on and within the active layer is likely to be concentrated in natural swales in the landscape such as the one studied.

General observations of the area indicate that active layer detachments and thaw flowslides have likely occurred periodically in the past, as is evidenced by the general "bowl" shapes of many of the surrounding hillsides. On the south shore (north-facing) of the small lake to the south of the borrow source, a small (10 m wide) detachment is recent and unrelated to the development activity (Figure 8).

The depth of the lake immediately to the south of the borrow source is unknown, but the general morphology of the area suggests that it may be 5-10 m deep. It is not perennially connected to lakes downstream (northeast) and it is unknown whether it is fish-bearing.

Reference: **Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174**

Figure 7: Pit development topography pre-development to 2016

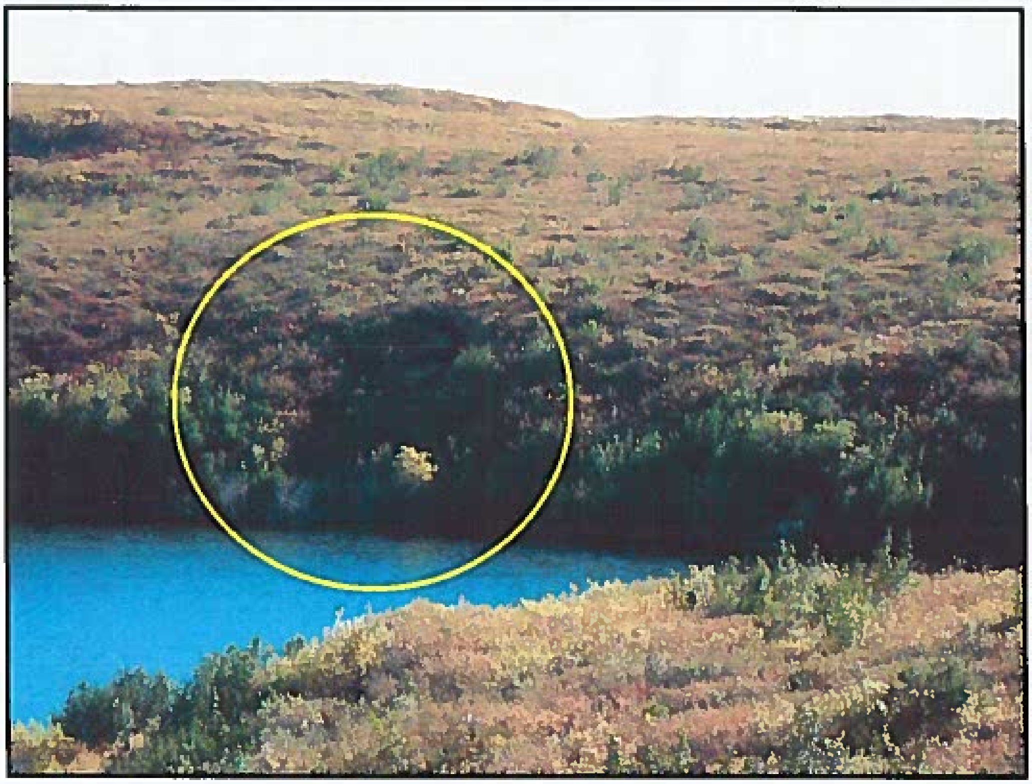


a) Pre-development (blue arrows for drainage) b) Pre-development (2014 survey)

c) First year development (2015 survey) d) Second year development (2016 survey)

Reference: **Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174**

Figure 8: Active Layer Detachment on shore of lake immediately south of Borrow Source 174. Photo taken from vantage of Transect 2.



4 DISCUSSION

Discussion related to the three primary questions is presented below.

1) What is the cause of the sinkhole downgradient of Borrow Source 174?

The "sinkhole" as identified in the inspection reports, is due to (thermal) erosion of ice wedges on the hillslope (an "ice wedge slump"). Meltwater moving down the hill slope is being channeled along ice wedges, causing localized detachment of blocks of ground and exposing underlying ground. This process is fairly common in the Beaufort Delta uplands and has been observed, in rare cases to result in widespread erosion and catastrophic drainage of lakes (e.g., Fortier et al. 2007). The general morphology of the area (bowl-shaped) suggests that there historically may have been a larger thaw failure in the area. The central part of the swale consists of grasses and low shrubs indicating that moisture likely continues to concentrate and move through this area more than on the surrounding ridges in the summer months, but that freezes back effectively in the fall, as evidenced by the shallow active layer depths. If a failure event has occurred in the past, it has likely been 30 years or more, since the ice wedges in the central part of the swale are well-developed.

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In 2016, additional surface melt contribution and thermo-erosion may be due to the development of Borrow Source 174. As shown in figure 7d, the surface drainage is now directed towards to south of the borrow source. It is possible that this additional surface contribution has facilitated the development of the ice wedge slump through thermo-erosion along ice wedge troughs, but it cannot conclusively be determined to be the cause of it. Similar activity on the opposite (north-facing) side of the lake, and general widespread similar occurrences allows for possibility that the slumping has been initiated naturally.

2) Measures to Prevent Slumping or Slope Failure

The ice wedge slumping observed is most likely naturally-occurring, possibly additionally facilitated by borrow source development. Such surface expressions and failures are common in the general area. Where ice wedges are not underlain by massive ice, as is suspected to be the case at this location, it cannot be predicted whether the slumping will continue, will accelerate, or may stop altogether as the vegetation mats recover the area.

Since water from Borrow Source 174 may have contributed to the slumping, continued propagation of slumping *might* be mitigated by diverting surface water from the borrow source away from this area and into an area of vegetation, such as to east of the borrow source; however, this is likely not to mitigate the slumping altogether, as meltwater from the surrounding undisturbed area will continue to channel into this area.

To eliminate excess meltwater and promote freezing, the southernmost area of Source 174 could be cleared of snow during mid and end of winter in order to promote freezing of the area post-development and minimize snowmelt. This is not suggested as a practical means, since it would require that equipment access the area overland.

3) Mitigation of Impacts to the Environment

The current ice wedge slumping may or may not lead to additional failure such as a mass movement. The failure mode is not predictable. If a mass movement-type failure such as a retrogressive thaw flowslide were to occur, sediment and vegetation would move into the small lake to the south of the borrow source. The full areal extent of such a failure is also not predictable, and would depend on the localized ice content of the subsurface material. It is possible that if a retrogressive that flowslide were to occur, the headwall could extend back into the area of the borrow source. The impact to the environment of such a failure, should it occur, would include change to lake chemistry (e.g., Kokelj et al. 2005), but is otherwise likely to be negligible for the following reasons:

- Mass movement on hillslopes in the form of active layer detachments, ice wedge block failures and retrogressive thaw flowslides is common in the general area, and has likely occurred at this location in the past;
- There is no deleterious material in the borrow source other than what occurs naturally. Material within the borrow source and on the affected slope consists of poorly-graded sand and gravel, though conductivity is unknown;

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- If material were to enter the adjacent lake, no fisheries would be impacted as it is not connected to any major fish-bearing lakes or watercourses;
- Meltwater originating in the borrow source is generally low in silt, and a currently installed silt fence is effective at capturing surface sediment.

Should it be desired to prevent impacts to the adjacent lake from a potential mass movement, a silt curtain could be installed in the area immediately downslope, however installation of this silt curtain in itself would result in localized impacts through unavoidable disturbance of vegetation and substrate.

Within the borrow source, a trench has been excavated to facilitate movement from the southernmost area of the borrow source northward away from the affected area. Such mitigation is considered best practice.

5 CONCLUSION AND RECOMMENDATIONS

Visual observations and active layer measurements suggest that the "sinkhole" observed downslope of Borrow Source 174 is a result of ice wedge erosion. The cause of the ice wedge slumping cannot be attributed solely to the development of the borrow source, since the area appears to have been subject to mass movement in the past and other ground failures such as active layer detachments, ice-wedge slumps and retrogressive thaw flowslides occur in the general area. It is possible that additional meltwater contribution from Source 174 has accelerated the erosion since prior to 2015 development, surface and active layer meltwater was channeled through a different area.

Mass failure of the slope may or may not occur, though morphology of the general area and corresponding active layer depths suggest that the area may be prone to natural slope movement. Such movement is not preventable.

The installed silt fencing at the top of the slope is effective at preventing sediment from surface meltwater from moving downslope. Trenching within the borrow source is directing ponded water away from the affected area and is also effective. Existing mitigations should be checked on an occasional basis to conduct and repairs or modifications as may be required. Additional mitigation measures are not recommended, as any impacts to the environment – particularly the adjacent lake – are likely to be negligible.

REFERENCES

Fortier, D., M. Allard, and Y. Shur. 2007. Observation of rapid drainage system development by thermal erosion of ice wedges on Bylot Island, Canadian Arctic Archipelago. Permafrost and Periglacial Processes 18: 229-243.

Godin E. and D. Fortier. 2010. Geomorphology of thermo-erosion gullies – Case study from Bylot Island, Nunavut, Canada. Proceeding of the 63rd Annual Canadian Geotechnical Conference and the 6th Canadian Permafrost Conference. Geo2010, Calgary, Alberta.

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Reference: Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

KAVIK-STANTEC Inc. 2014a. Construction of Inuvik to Tuktoyaktuk Highway: Pit Development Plan – Borrow Source 174. Prepared for the Government of the Northwest Territories Department of Transportation, Yellowknife, NT. November 2014.

KAVIK-STANTEC Inc. 2014b. Inuvik – Tuktoyaktuk Highway 2014 Geotechnical Investigation: Borrow Source 174 Summary Report. Prepared for the Government of the Northwest Territories Department of Transportation, Yellowknife, NT. June 2014.

Kokelj, S.V., Jenkins, R.E., Milburn, D., Burn, C.R., and Snow,N. 2005. The influence of thermokarst disturbance on the water quality of small upland lakes, Mackenzie Delta region, Northwest Territories, Canada. Permafrost and Periglacial Processes, 16: 343–353.

Lantuit, H. and Pollard, W.H. 2005. Temporal stereophotogrammetric analysis of retrogressive thaw slumps on Herschel Island, Yukon Territory Natural Hazards and Earth System Sciences, 5, 413–423.

Wolfe, S.A., Kotler, E., Nixon, F.M. 2000. Recent Warming Impacts in the Mackenzie Delta, Northwest Territories and northern Yukon Territory Coastal Regions. Geological Survey of Canada. Current Research 2000-1B, 9 pp.

Wolfe, S. A., Kotler, E., and Dallimore, S. R. 2001. Surficial characteristics and the distribution of thaw landforms (1970 to 1999), Shingle Point to Kay Point, Yukon Territory, Geological Survey of Canada, Open File 4088.

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Reference: Reference: Assessment of Downslope Permafrost Erosion at Borrow Source 174

SIGN-OFF

This document entitled *Assessment of Downslope Permafrost Erosion at Borrow Source 174* was prepared by KAVIK-STANTEC Ltd. ("KAVIK-STANTEC") for the account of EGT Northwind Ltd. (the "Client") and Government of Northwest Territories Department of Transportation (the "End Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects KAVIK-STANTEC's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between KAVIK-STANTEC and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, KAVIK-STANTEC did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that KAVIK-STANTEC shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

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Attachment A: Active Layer Measurements Detail

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Figure A-1: Active Layer Survey Points – Base image KAVIK-STANTEC (2014a)