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NWT OPEN REPORT 2019-012

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Introduction

Construction of the Inuvik to Tuktoyaktuk Highway (ITH) was initiated in the winter of 2014 following the completion of long-term environmental, socioeconomic, and engineering studies by the Government of Northwest Territories (GNWT; Department of Infrastructure [GNWT – INF] 2017, previously known as the Department of Transportation) and other agencies. The ITH traverses the Anderson Plain and Tuktoyaktuk Coastlands between Inuvik and Tuktoyaktuk, as shown in Figure 1. Terrain suitability for the ITH was assessed using published local surficial geology (Rampton 1987, 1988) and through the analysis of sediment cores from a series of geotechnical boreholes advanced along the proposed route before construction in 2013, including anticipated bridge piling locations. Additional boreholes were obtained in the winter of 2017 along the ITH embankment and at undisturbed "Sentinel" sites representing distinct regional terrain types. The objectives of this NWT Open Report are to compile geotechnical and supporting data obtained through these projects for inclusion in the Northwest Territories Geotechnical Database and to describe spatial variation in substrate characteristics. Ground temperature monitoring is ongoing and is the subject of related NWT Open Reports by Rudy *et al.* (2020a; b) and Ensom *et al*. (2020a; b). Approximately 700 additional boreholes were also advanced in the region between 2012 and 2014 to characterise potential aggregate sources; however these data are not incorporated in the present report.

Physical setting

The western extents of the Anderson Plain and Tuktoyaktuk Coastlands physiographic regions of the western Canadian Arctic shown in Figure 1 overlie continuous ice-rich permafrost (Burn and Kokelj 2009). Permafrost thickness ranges from approximately 100 m near Inuvik to over 500 m near Tuktoyaktuk (Mackay 1967, Judge *et al.* 1979). Rolling ice-rich Pleistocene morainal, glaciofluvial, lacustrine, and deltaic deposits characterise the western Tuktoyaktuk Coastlands (Mackay 1963; Aylsworth *et al.* 2000). Vegetation transitions from irregular open woodland around Sitidgi Lake to low-shrub tundra further north and to tundra along the coast (Mackay 1963; Kokelj *et al.* 2017).

The regional climate is represented by conditions at Inuvik and Tuktoyaktuk, where from 1981 to 2010 mean annual air temperatures were -8.2 °C and -10.1 °C (Environment and Climate Change Canada [ECCC] 2018). Winters are long and cold, summers are short and cool, and precipitation is greater inland than along the coast. Annual mean air temperature increased by more than 2.5 °C between 1970 and 2006 (Burn and Kokelj 2009; Burn and Zhang 2010). Climate normal precipitation for 1981 to 2010 was 240.6 mm at Inuvik and 160.7 mm at Tuktoyaktuk, and annual snowfall for this period was 158.6 cm and 103.1 cm (ECCC 2018). The majority of annual precipitation is snow.

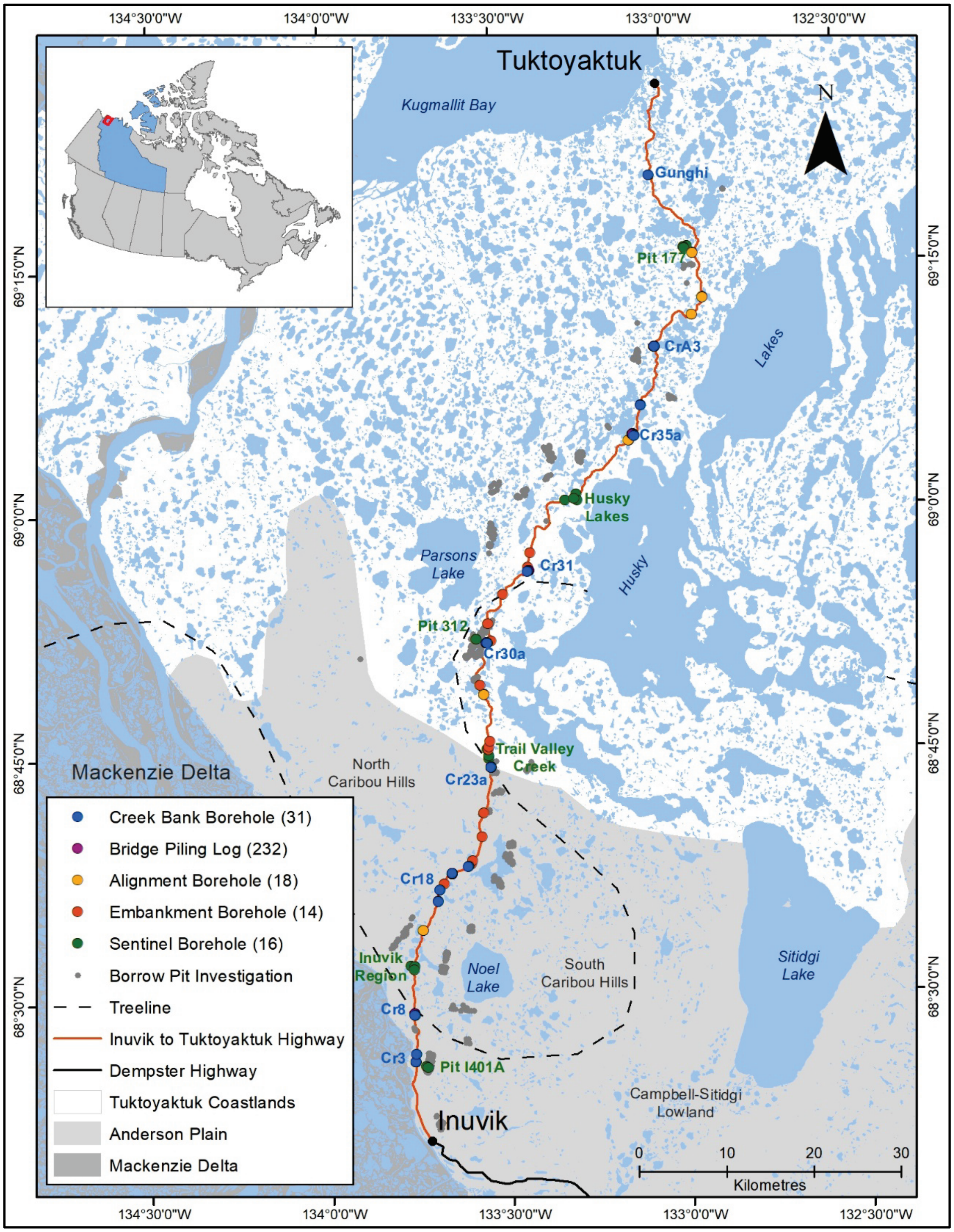


Figure 1. Geotechnical boreholes advanced since 2013 along the Inuvik to Tuktoyaktuk Highway corridor. The number of boreholes of each type is shown in parentheses in the legend. Datum is North American Datum (NAD) 83. Projections are Universal Transverse Mercator (UTM) Zone 8 North for the mainframe and Canada Albers Equal Area Conic for the inset map. Tuktoyaktuk Coastlands and Anderson Plain extents correspond with Rampton (1988). Polygons representing the extents of water bodes are from CanVec (Natural Resources Canada 2017).

Creek bank investigations

The geotechnical investigations of creek banks were conducted in 2013 at stream crossing sites being considered for bridges along the proposed ITH alignment (Kiggiak-EBA 2013a). Thirteen crossing sites were assessed with 29 boreholes. Undisturbed frozen soil samples were collected using a 10 cm inside-diameter Cold Regions Research and Engineering Laboratory (CRREL) core barrel. Borehole logs were prepared on-site from cuttings retrieved from auger flights and sections of core extruded from the CRREL barrel.

Figure 2a shows the geotechnical investigation at the banks of Creek A3, approximately 35 km south of Tuktoyaktuk, in April 2013. As shown in Figures 2b, c, and d, boreholes were located on creek banks at a range of distances from the edge of the water at bankfull elevation. The two boreholes at Gunghi Creek were drilled under a separate scope of work in February 2017 (Kiggiak-EBA 2017a). These boreholes and those described in the following sections are shown in Figure 1 and detailed in Appendix A.

Bridge piling investigations

The eight bridges along the ITH were constructed between February 2014 and March 2017. Up to 32 additional geotechnical logs (auger only) were produced at each bridge site from the preparation of holes for bridge piling installation. Bridge characteristics are summarised in Table 1, and Figure 3 shows the northern pier and abutment rows at the Bridge 23a site following installation.

Table 1. Inuvik to Tuktoyaktuk Highway bridges.

Name	ID	Location (Figure 1)	Kilometre Post	Creek Name[1]	Drainage Basin[2] Area (km^2)
Bridge 3	Br3	Cr3	2.5	(Creek 3)	22.5
Bridge 8	Br8	Cr8	8.4	(Creek 8)	12.1
Bridge 18	Br18	Cr18	26.1	(Creek 18)	27.8
Bridge 23a	Br23a	Cr23a	40.4	Trail Valley Creek	57.6
Bridge 30a	Br30a	Cr30a	57.3	Hans Creek	310.5
Bridge 31	Br31	Cr31	69.1	Zed Creek	411.5
Bridge 35a	Br35a	Cr35a	92.6	Diamond Creek	127.5
Bridge A3	B3A3	CrA3	104.1	(Creek A3)	8.0

[1] Names in parentheses used in lieu of official names; “Diamond Creek” suggested by M. Dillon (personal communication 2019);

[2] Drainage basin areas are presented by Kavik-Stantec (2012a) and refer to the catchment at the crossing site.

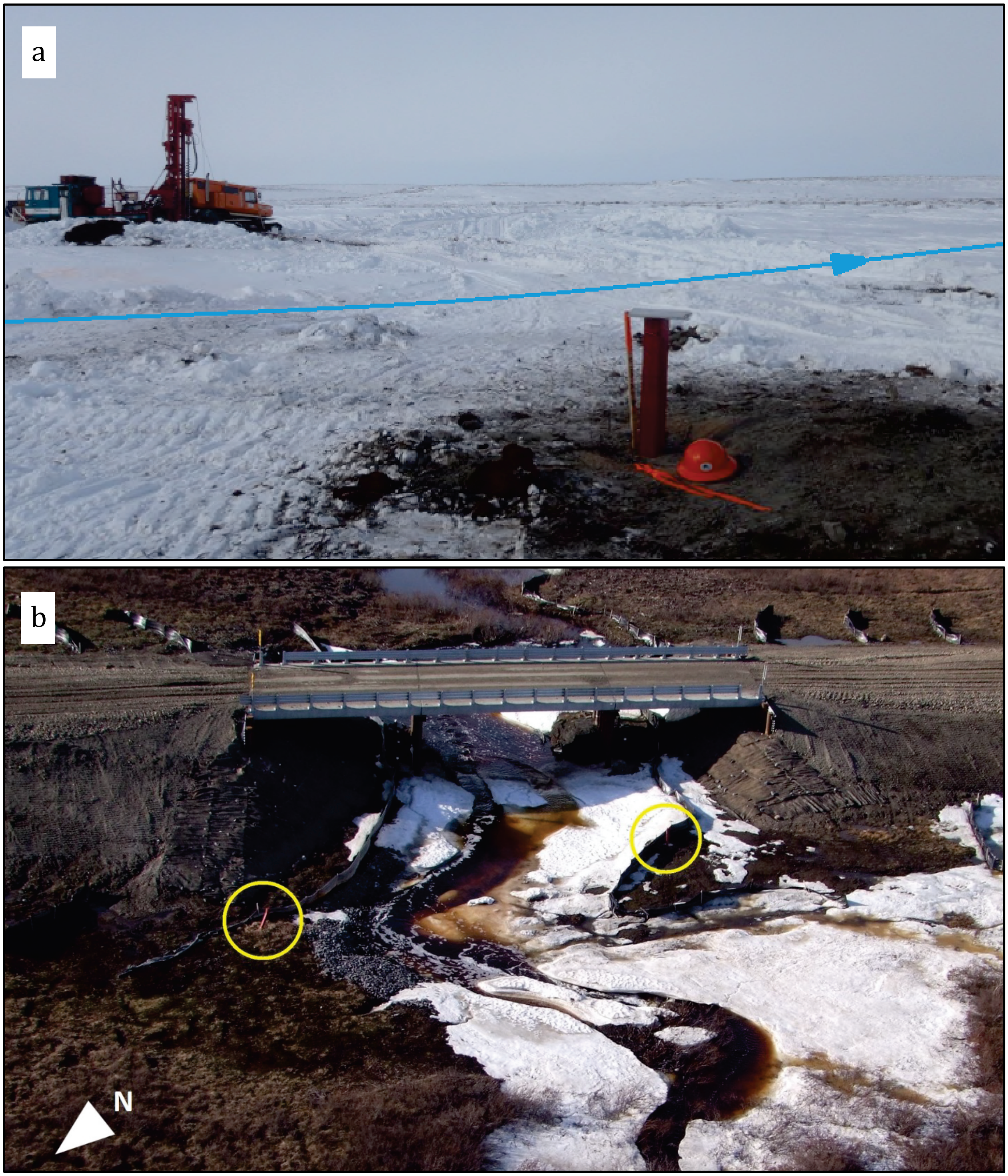


Figure 2. (a) North-facing view of geotechnical drilling at CrA3-N, with a casing of completed CrA3-S borehole in the foreground, on 20 April 2013. Image modified from Kiggiak-EBA. (2013a), with streamflow direction and approximate centreline indicated in blue. (b) Southeast-facing (downstream-facing) view of Bridge 18 on 25 May 2017, with creek bank borehole casings indicated by yellow circles.

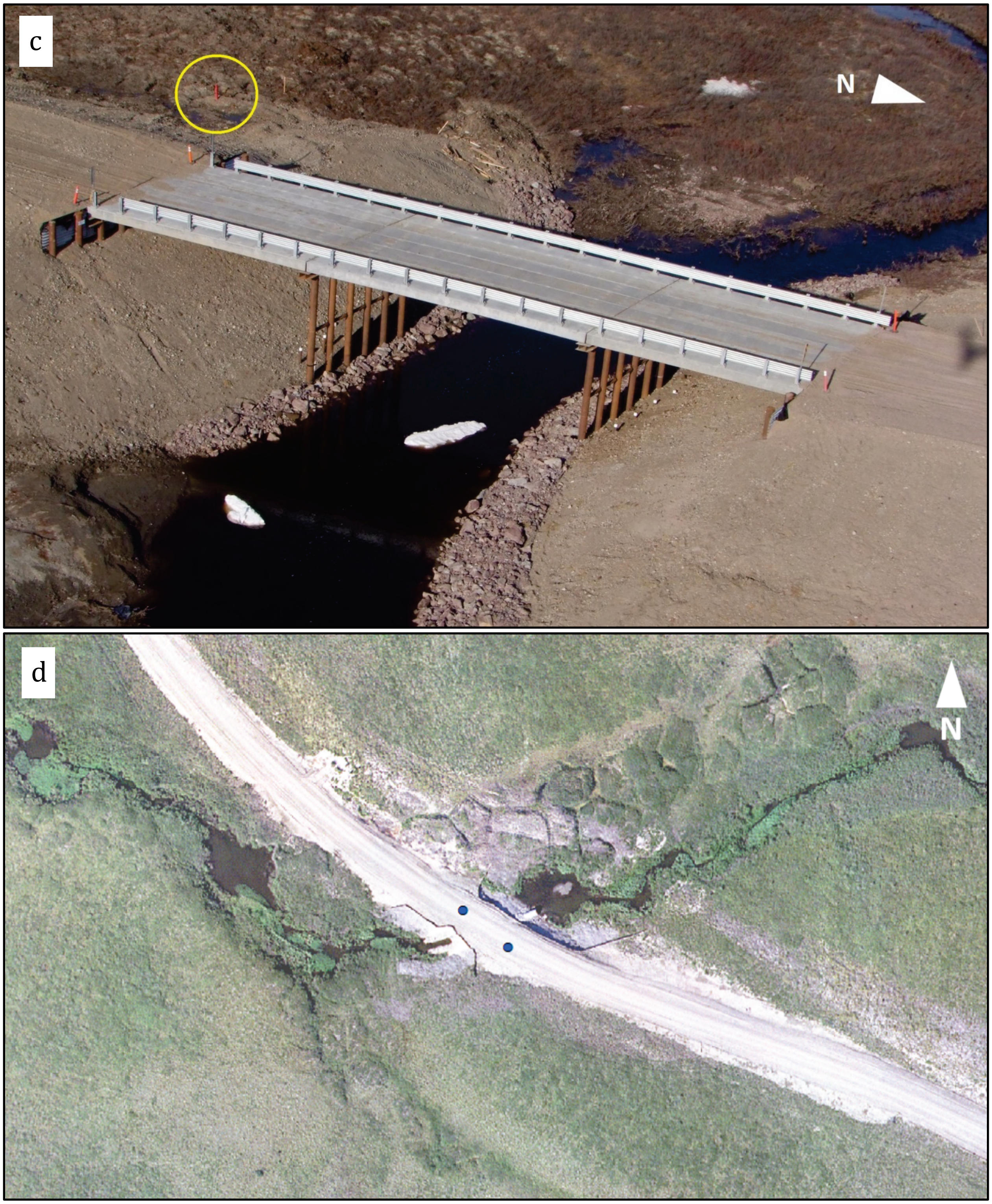


Figure 2. (c) Southwest-facing (upstream-facing) view of Bridge 23a (Trail Valley Creek) on 25 May 2017, with Cr23a-S borehole casing indicated by a yellow circle; (d) Gunghi Creek 2011 orthophoto with 2017 borehole sites superimposed.

Figure 3. Northwest-facing view of the north half of the Bridge 23a site on 20 April 2016 during the NWT Permafrost Summit. The temporary road was built across the ice-covered stream.

Highway alignment and embankment sites

In addition to the investigations at creek bank sites before the ITH construction, 18 boreholes were advanced at six representative terrain sites along the proposed ITH alignment in winter 2013 to characterise geotechnical conditions (Kiggiak-EBA 2013b). Following highway construction, an additional 14 boreholes were advanced through the embankment centre and into the underlying substrate in March 2017 to install ground temperature cables to permit the monitoring of ground and embankment thermal regime (Kiggiak-EBA 2017b). Alignment and embankment borehole sites are shown in Figure 4a and b.

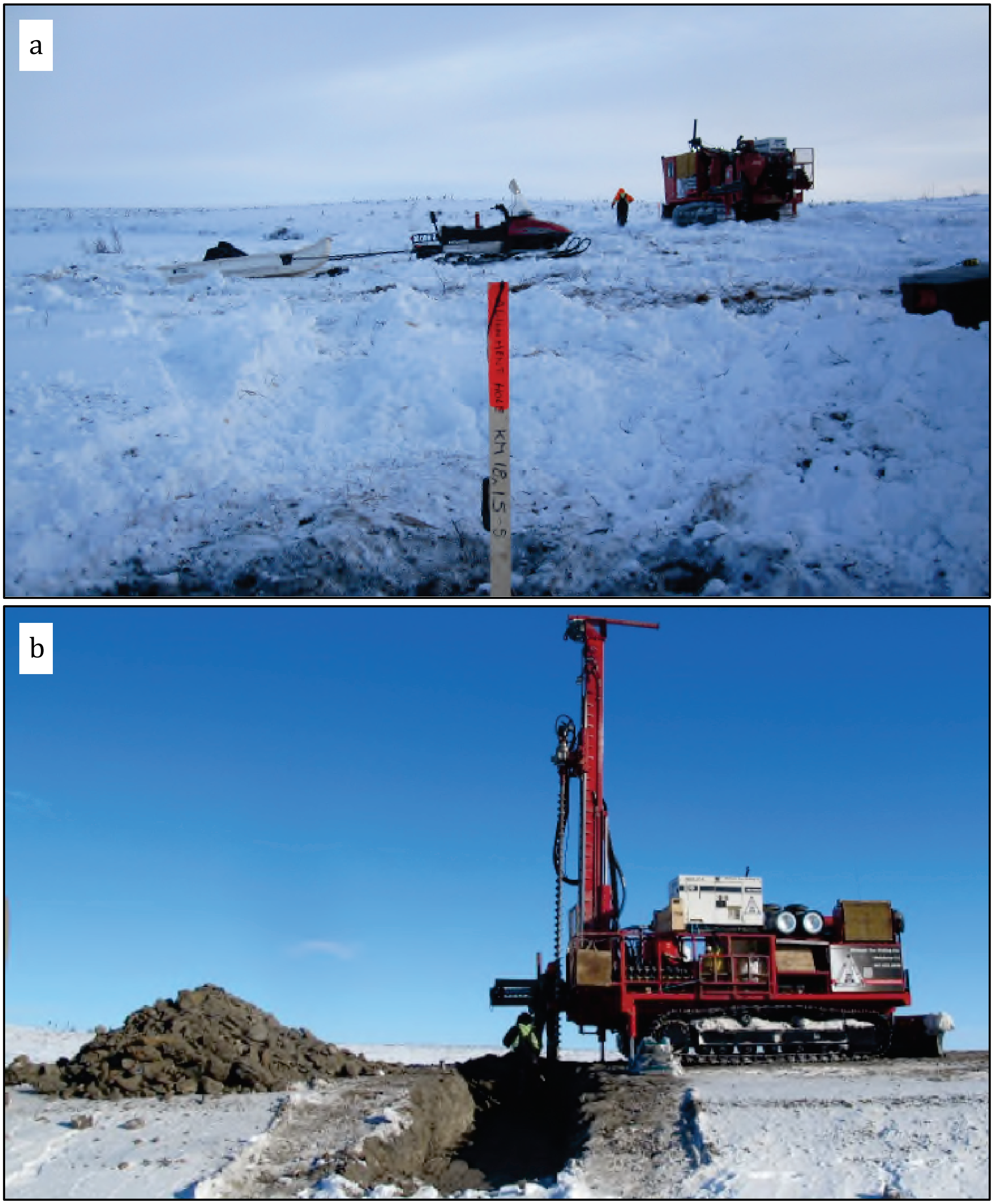


Figure 4. (a) Alignment borehole site AH18.15-S on 30 March 2013. Photo from Kiggiak-EBA (2013b). (b) Borehole drilling at ITH-4 following embankment excavation between foreground and embankment centre line. Photo from Kiggiak-EBA (2017b).

Permafrost Sentinel research program

Overview

The construction of the ITH created an unprecedented opportunity in Canada to study permafrost conditions across the treeline, to develop baseline monitoring datasets to inform highway management and maintenance, and to create a hub for collaboration between researchers, practitioners, and northern communities. In winter 2017 the GNWT Northwest Territories Geological Survey (NTGS) and INF, and collaborators from the Geological Survey of Canada (GSC), the Aurora Research Institute (ARI), academic institutions, and northern contractors initiated a program to investigate regional geotechnical and sedimentological conditions, monitor and compare the ground thermal regime and thermal evolution of undisturbed terrain offset from the ITH with ITH alignment and embankment sites, and to monitor the thermal evolution of ground exposed by quarrying. Initial geotechnical results from this program were reported by Kiggiak-EBA (2018).

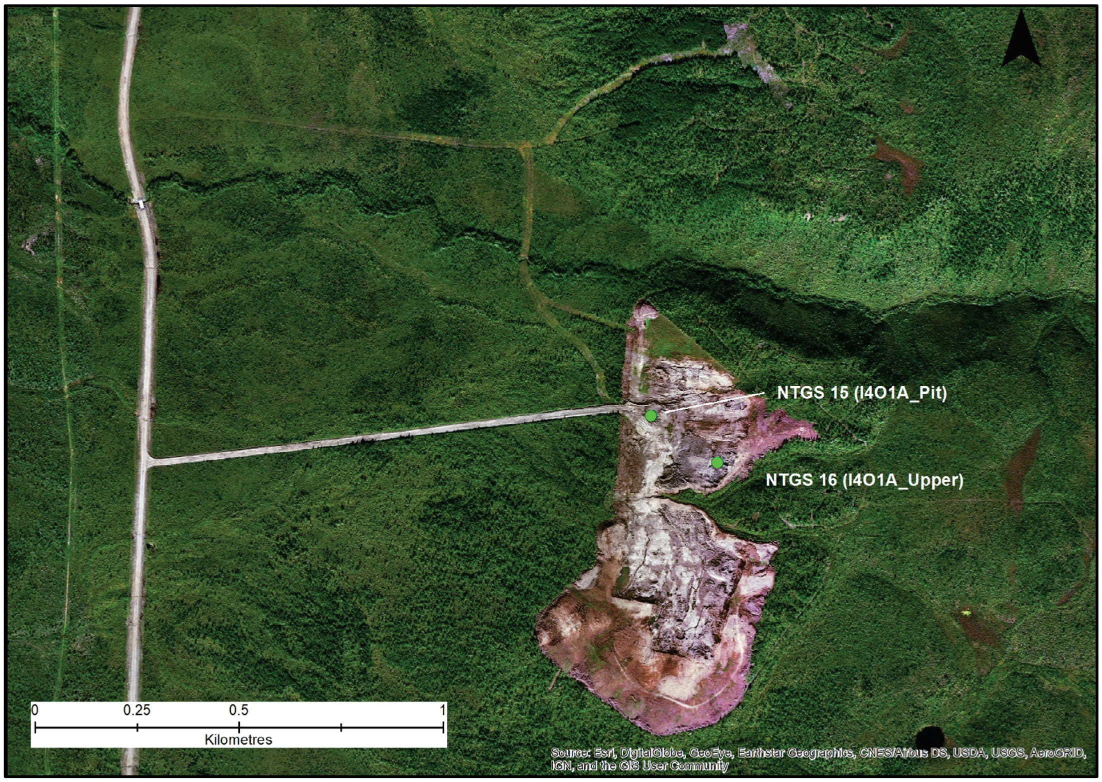
Sentinel sites were selected to represent the main terrain types and surfaces disturbed by quarrying across the forest-tundra transition between Inuvik and Tuktoyaktuk. Sites include four natural hilltop sites, three natural riparian sites, three natural peatland sites, five sites disturbed by quarrying for aggregate used in ITH construction, and one site to assess conditions in undisturbed tundra upslope of a small retrogressive thaw slump. These sites are grouped in six clusters (Pit I401A, Inuvik Region, Trail Valley Creek, Pit 312, Husky Lakes, and Pit 177) between Inuvik and Tuktoyaktuk (Figure 1). The positions of individual boreholes within each cluster are shown in the Figure 5 series. These figures provide the alphanumeric site ID (*e.g.,* NTGS 1) and the abbreviations (*e.g.,* INU_P for Inuvik Region peatland) used during the field program for easy recognition. To aid in the interpretation of this report, Table 2 provides the name, abbreviated name, alphanumeric site ID, and two similar GSC/ARI laboratory IDs for each Sentinel site. The prefix "ENG.YARC03097-01/" also appears occasionally as a prefix for a Sentinel alphanumeric site ID, as this is the project code used by Tetra Tech Inc.

The hilltop, riparian, and peatland terrain types are common in the study region between Inuvik and Tuktoyaktuk, and generally analogous to Terrain Types 2, 3, and 4 in the ITH Terrain Classification (EGT Northwind Ltd. *et al.* 2013). The hilltop and peatland sites are located a minimum distance of 150 m from the ITH, whereas the riparian sites are typically within 100 m of the ITH, upstream of the culvert locations. Sentinel site locations were also guided by the descriptions of regional Quaternary geomorphology, including permafrost and ground ice distribution, by Rampton (1988) and by an interest in advancing this knowledge. A series of Sentinel site photographs are presented in Figure 6.

Table 2. Permafrost Sentinel Program site identifiers used in data processing.

Name	Abbreviated Name	Alphanumeric ID	Geological Survey of Canada and Aurora Research Institute Laboratory Processing
Inuvik Peatland	INU_P	NTGS 1	NTGS-BH01 or NTGS17-BH01
Inuvik Hilltop	INU_H	NTGS 2	NTGS-BH02 or NTGS17-BH02
Inuvik Riparian	INU_R	NTGS 3	NTGS-BH03 or NTGS17-BH03
Trail Valley Peatland	TVC_P	NTGS 4	NTGS-BH04 or NTGS17-BH04
Trail Valley Hilltop	TVC_H	NTGS 5	NTGS-BH05 or NTGS17-BH05
Trail Valley Riparian	TVC_R	NTGS 6	NTGS-BH06 or NTGS17-BH06
Husky Hilltop	HUS_H	NTGS 7	NTGS-BH07 or NTGS17-BH07
Husky Peatland	HUS_P	NTGS 8	NTGS-BH08 or NTGS17-BH08
Husky Riparian	HUS_R	NTGS 9	NTGS-BH09 or NTGS17-BH09
Tuktoyaktuk Hilltop	TUK_H	NTGS 10	NTGS-BH10 or NTGS17-BH10
Pit 177 Pit Floor	177_Pit	NTGS 11	NTGS-BH11 or NTGS17-BH11
Pit 177 Margin	177_Margin[1]	NTGS 12	NTGS-BH12 or NTGS17-BH12
Pit 312 Pit Floor	312_Pit	NTGS 13	NTGS-BH13 or NTGS17-BH13
Pit I401 Pit Floor	I401A_Pit	NTGS 15	NTGS-BH15 or NTGS17-BH15
Pit I401A Hill	I401A_Upper	NTGS 16	NTGS-BH16 or NTGS17-BH16
Husky Slump	HUS_Slump	NTGS 17	NTGS-BH17 or NTGS17-BH17

[1] Due to an update in the site plan, some records and the drill log for the Pit 177 Margin site provide the abbreviated name as "177_Pond".



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 5a. Pit I401A Sentinel permafrost monitoring site cluster. Image acquired 8 August 2015 by DigitalGlobe (ESRI 2020).

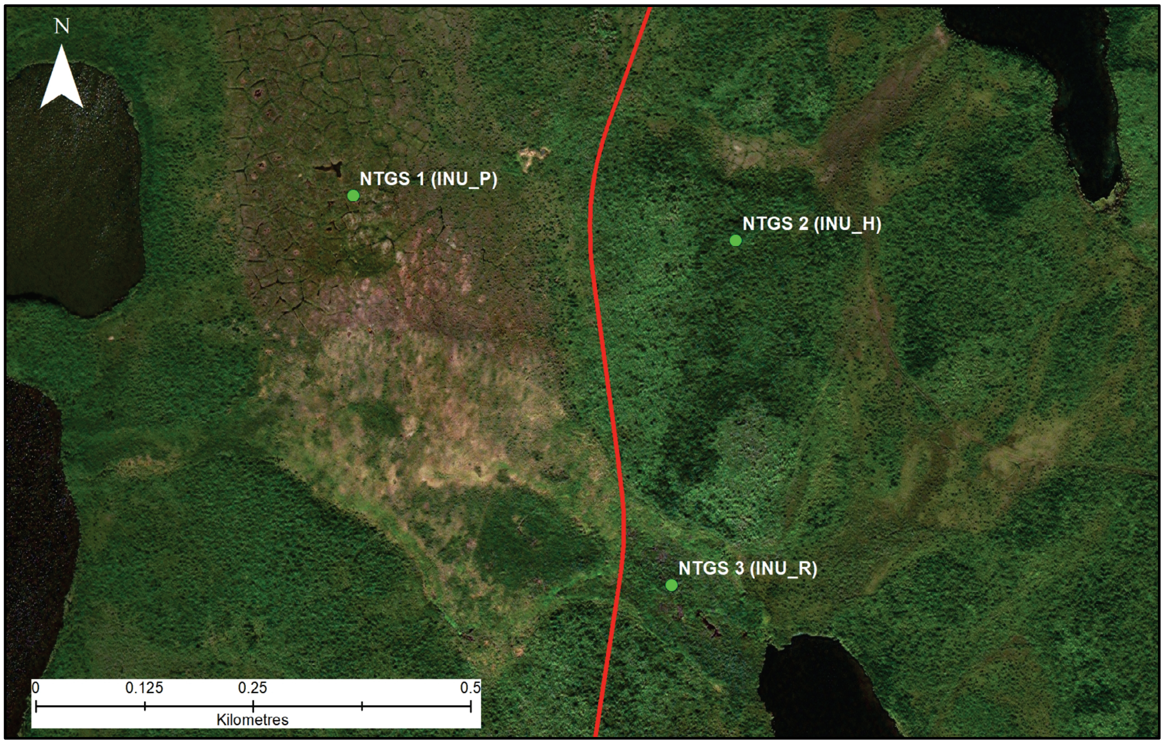


Figure 5b. Inuvik Region (INU) Sentinel permafrost monitoring site cluster. Image acquired 12 July 2012 by DigitalGlobe (ESRI 2020).

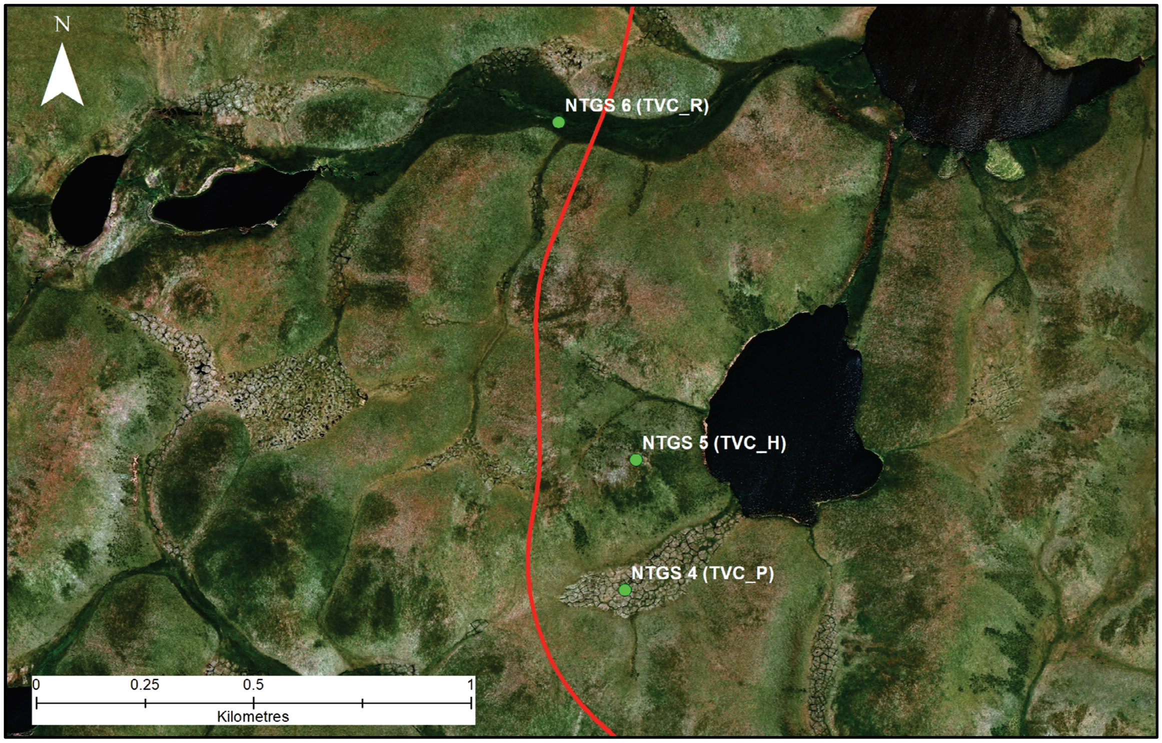


Figure 5c. Trail Valley Creek (TVC) Sentinel permafrost monitoring site cluster. Image acquired 30 June 2010 by DigitalGlobe (ESRI 2020).

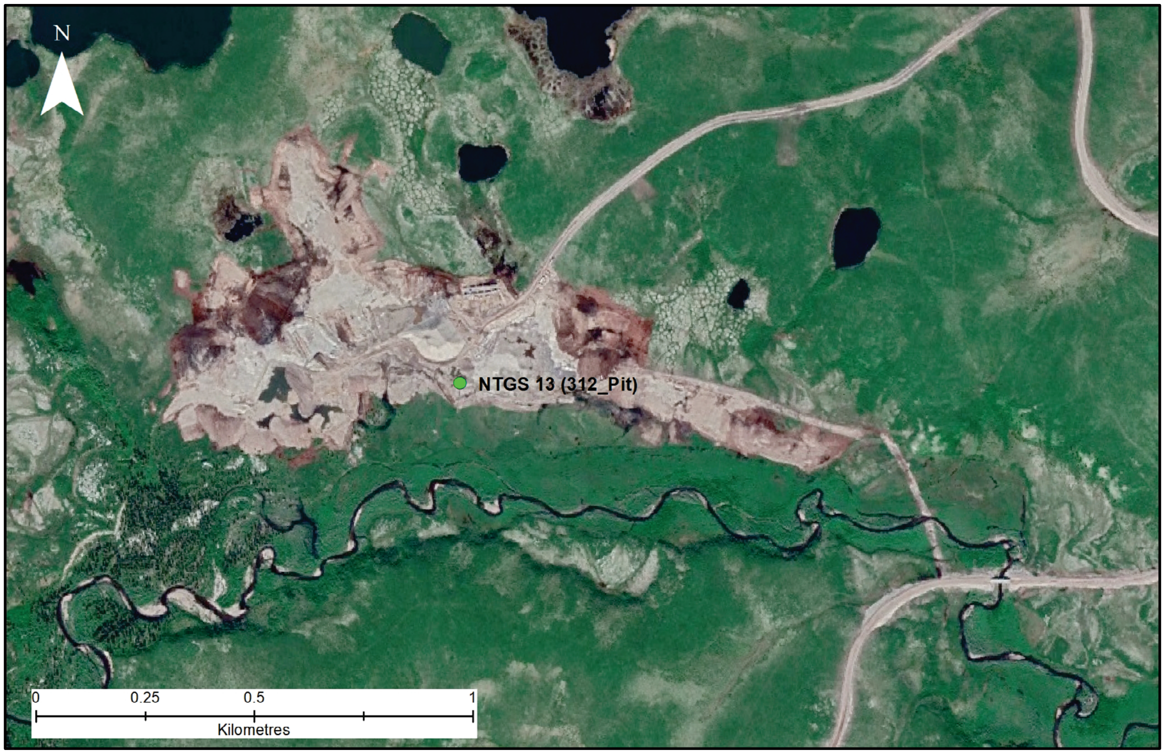


Figure 5d. Pit 312 Sentinel permafrost monitoring site. Image acquired 28 June 2017 (Maxar Technologies and Google Earth).

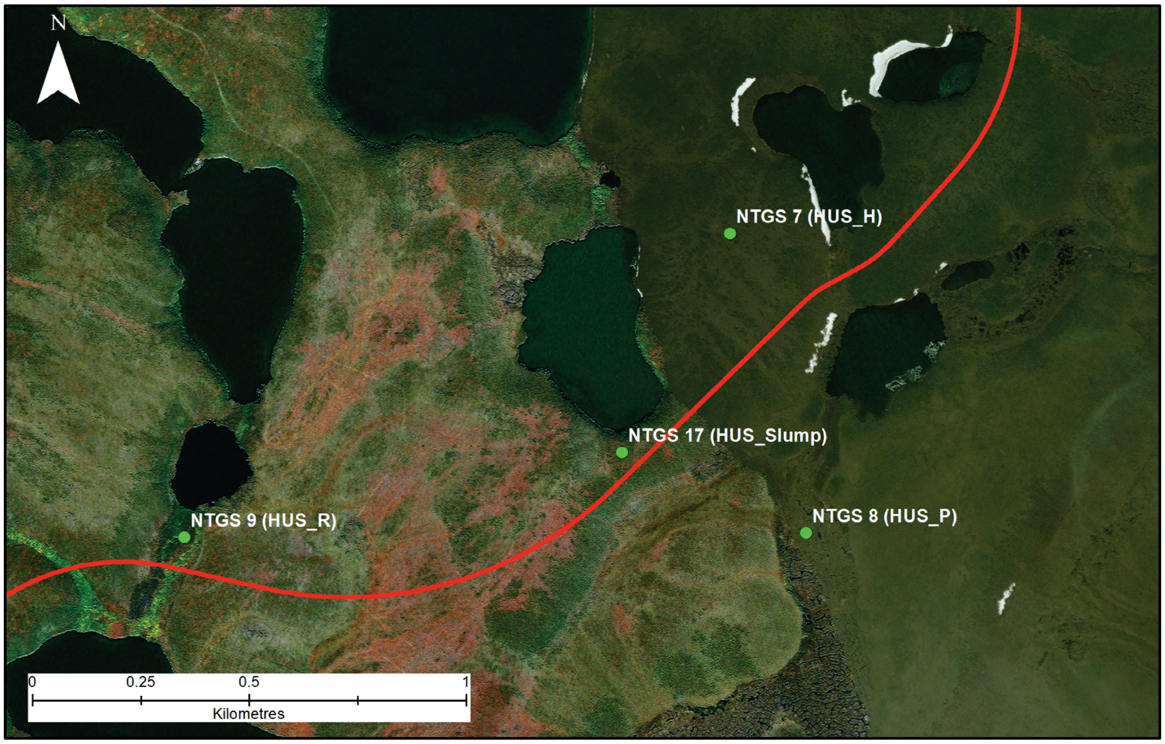


Figure 5e. Husky Lakes (HUS) Sentinel permafrost monitoring site cluster. Image acquired 25 August 2009 (left side) and 14 June 2011 (right side) by DigitalGlobe (ESRI 2020).

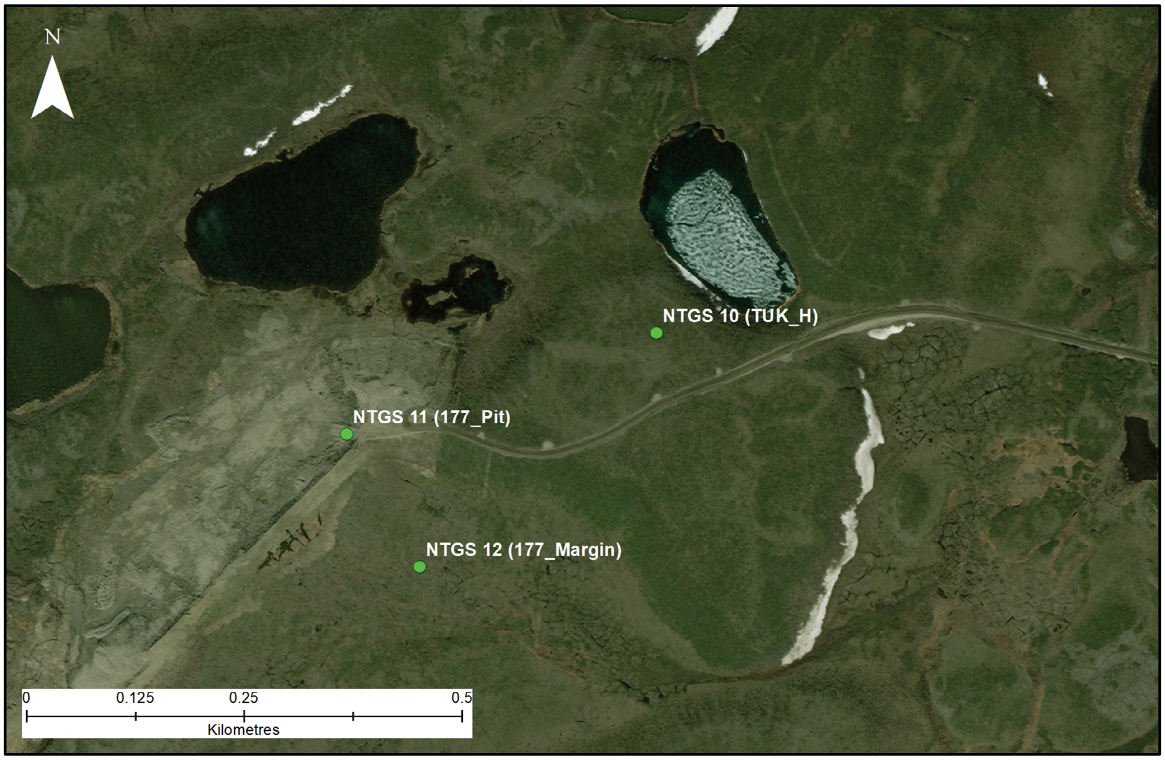


Figure 5f. Pit 177 and Tuktoyaktuk Hilltop (TUK) Sentinel permafrost monitoring site cluster. Image acquired 14 June 2011 by DigitalGlobe (ESRI 2020).

Figure 6a. Northwest-facing view of NTGS 15 (I401A_Pit) Sentinel site, 27 July 2017.

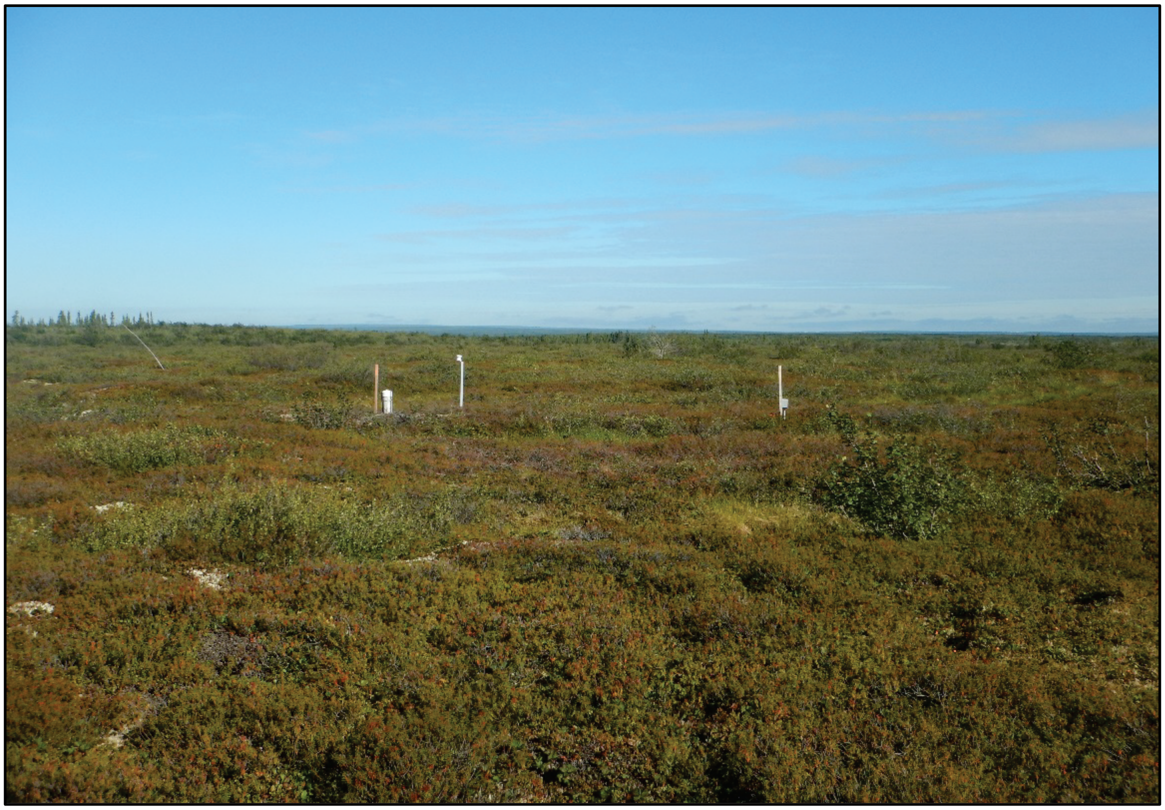


Figure 6b. Northwest-facing view of NTGS 1 (INU_P) Sentinel site, borehole at left, 27 July 2017.

Figure 6c. Shallow ground temperature apparatus near NTGS 2 (INU_H) Sentinel site, 27 July 2017.

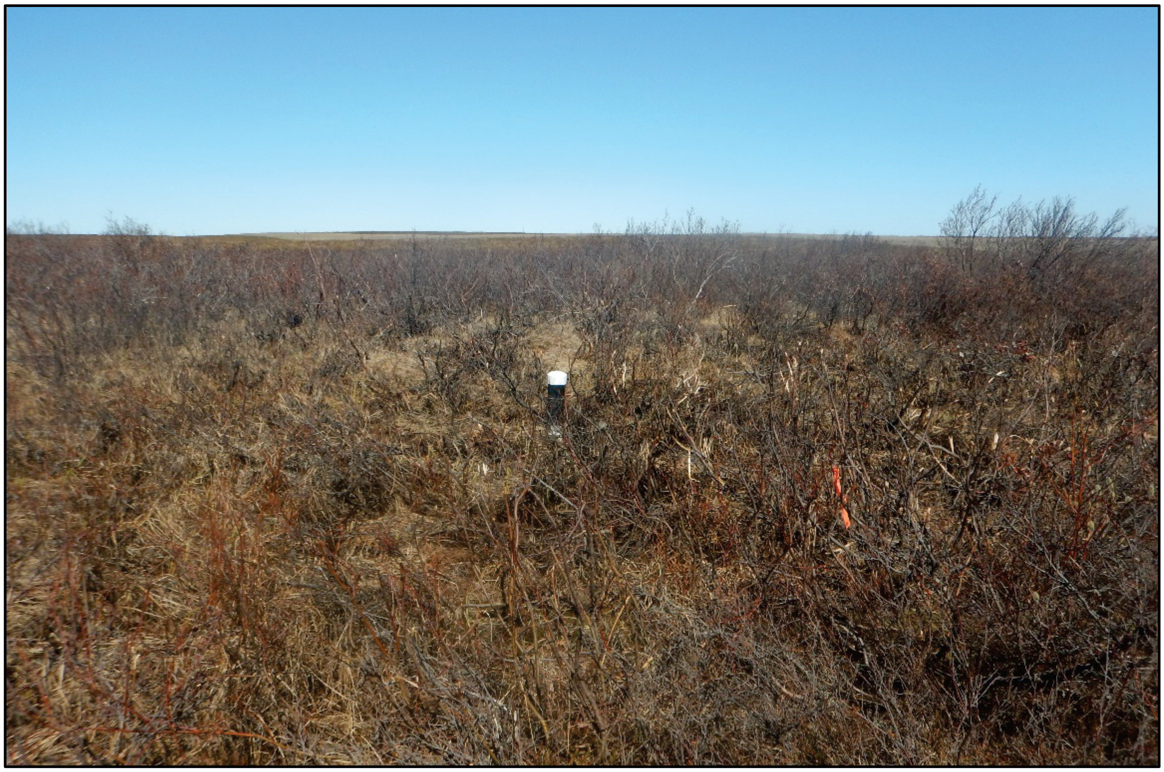


Figure 6d. Northeast-facing view of NTGS 6 (TVC_R) Sentinel site, 8 June 2017.

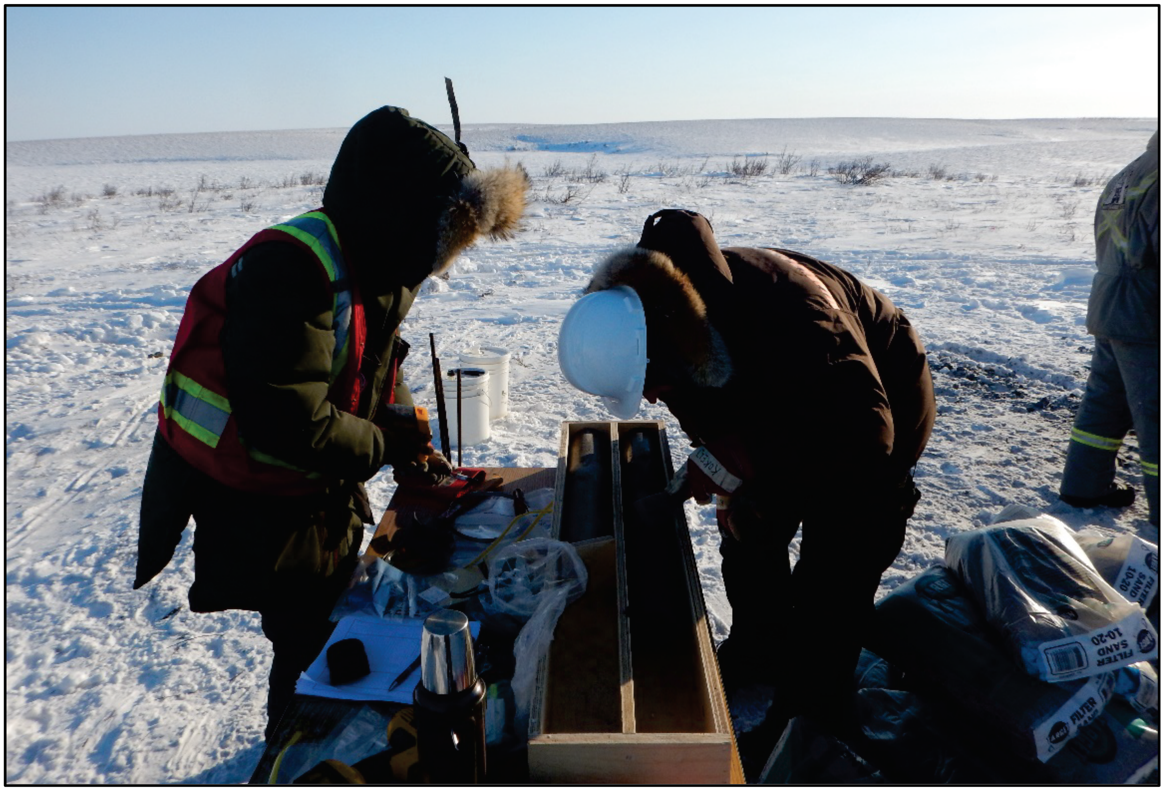


Figure 6e. East-facing view of NTGS 5 (TVC_H) Sentinel site during core logging, 11 March 2017.

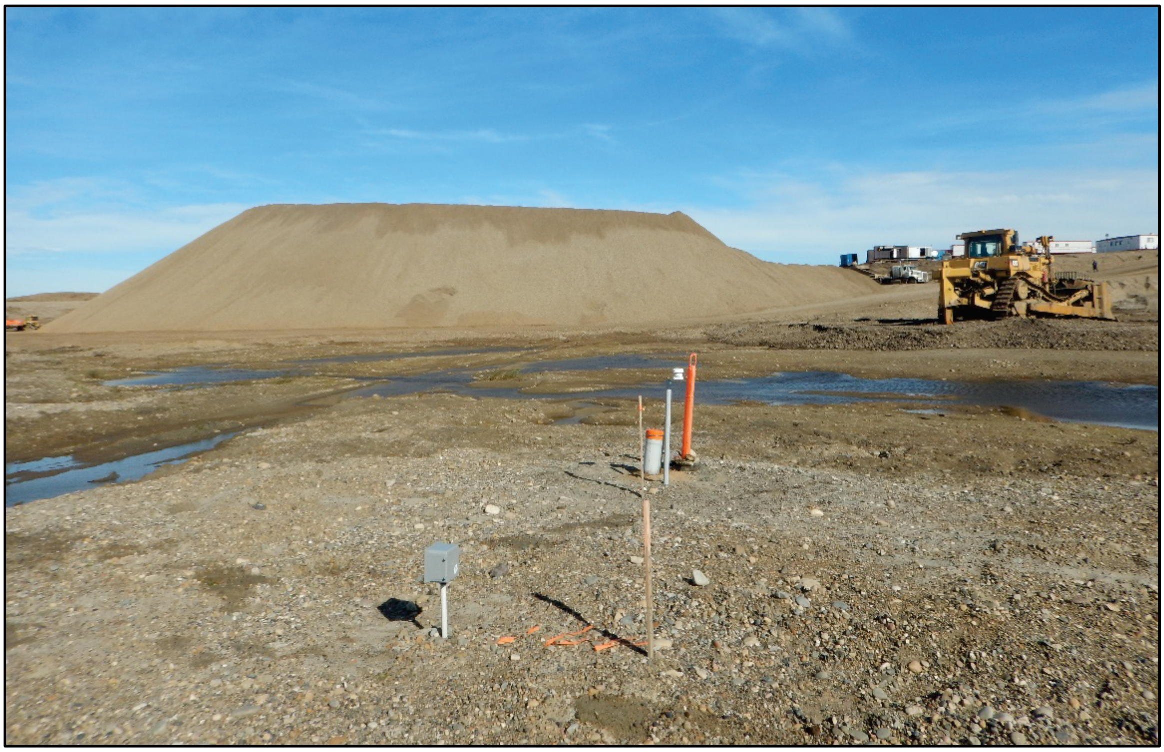


Figure 6f. North-facing view of NTGS 13 (Pit 312) Sentinel site, 1 August 2017.

Figure 6g. Southwest-facing view of material sampling near NTGS 17 (HUS_Slump) Sentinel site, 20 July 2017.

Figure 6h. Northeast-facing view of NTGS 11 (177_Pit) Sentinel site, 7 June 2017.

Field data collection

A mobile 2012 Prospector P1 RC/DD drilling rig from Midnight Sun Drilling Inc. was used to drill and recover permafrost boreholes to a depth of 20 m. Two separate drilling heads were utilised for borehole drilling and permafrost recovery. A CRREL drilling barrel (10 cm x 80 cm) with diamond-coated cutting teeth was the preferred method of extraction as it allowed for continuous recovery of *in situ* permafrost material. All core segments were recovered using the CRREL barrel. Core samples were placed in prefabricated wooden core boxes following the extraction and documented based on borehole number and sample recovery depth. A 25 cm diameter earth auger drill bit was used in place of the CRREL coring system in instances where the cutting teeth repeatedly broke, likely due to encountering an abundance of isolated hard rock clasts (*e.g.,* quartzite, granite) in the permafrost material. In such instances, bulk sediment samples (~ 3 kg) were taken from the auger flighting conveyor at 50 cm intervals. The extracted core and auger samples were immediately subject to a temperature measurement with a hand-held infrared thermometer. Initial on-site geotechnical soil descriptions were made for all extracted samples, including soil type, colour, organic abundance, and percent ice volume (Appendix B-1).

All samples were kept frozen and transported from the drilling location to Inuvik for further processing and analyses at ARI. In the unheated GSC warehouse in the ARI compound, core samples were cut in half lengthwise using a tile saw. Split cores were cleaned using a razor blade scraper and photographed (Appendix B-2). Detailed borehole logs were created for each borehole using established sedimentological and cryostratigraphic techniques (Appendix B-3) including grain size, colour, sedimentary structures, percent visible ice, and cryostructures. Cryostructures are the geometric distribution of ice in permafrost and can aid the interpretation of permafrost origin, freezing/thawing history, and susceptibility to thaw. Cryostructures were documented based on the classification and nomenclature of Murton and French (1994), where seven principal cryostructures are defined: structureless (Sl), lenticular (Le), Layered (La), regular reticulate (Rr), irregular reticulate (Ri), crustal (Cr), and suspended (Su). Bulk sediment auger samples and corresponding depths were also denoted on the borehole logs. A split of each core sample and half the weight of each bulk sediment sample obtained by auger were allocated to laboratory testing. The corresponding splits were encased in 6 mil plastic bags and transported frozen to the University of Alberta for archival purposes. In total, 58 splits and 159 bulk sediment samples were preserved for future analysis.

Materials allocated for laboratory testing were divided in half (each representing a quarter of the original core material) to conduct analyses of geochemical and sedimentological properties. The splits were further partitioned according to depth and were arranged to represent discrete 0.5-m depth intervals. A further 5 g to10 g of sample was retained for each depth interval for the purposes of conducting an aqueous isotopic analysis. In total, 409 sub-samples were processed at the ARI laboratory to determine moisture content and to extract and prepare water samples for geochemical analysis. Geochemical analyses were conducted at the Taiga Environmental Laboratory in Yellowknife. Three hundred ninety sub-samples were sent to the GSC for sedimentological analysis (Table 3).

Laboratory procedure

Augured and cored samples were processed at the ARI Inuvik lab to determine the percent gravimetric water content (GWC), percent excess ice content, and for the extraction of pore and supernatant water. Samples were thawed and homogenised, poured into beakers, weighed, and allowed to settle for twelve hours. Volumes of sediment and supernatant water were recorded from both augured and cored samples to estimate excess ice content Ic (%) as follows:

$$Ic = \{[W\mathrm{v} *1.09] / [S\mathrm{v} + (W\mathrm{v} *1.09]\}*100 \qquad [1]$$

where Ic (%) is the excess ice content expressed on a volumetric basis, Wv is the volume of supernatant water, Sv is the volume of saturated sediment, and 1.09 represents the density of water divided by that of ice. The supernatant water was then collected with a syringe and filtered through 0.45 µm cellulose filter paper for geochemical analysis. Samples were then dried for twelve hours at 105°C and reweighed to determine GWC.

Table 3. Summary of samples processed by the Aurora Research Institute (ARI) and Geological Survey of Canada (GSC) laboratories.

Borehole	ARI (n)	Not processed at ARI	Note	GSC (n)	Not processed at GSC	Note
NTGS-BH01	23			23	-8C to -13C	Pure ice
NTGS-BH02	42			41		
NTGS-BH03	22			22		
NTGS-BH04	23			20	-03A to -05A	Incorrect depths (see Sentinel borehole Sample Processing Log, Appendix B-3) not submitted to the lab.
NTGS-BH05	40			40		
NTGS-BH06	19	BH06 – 5.5-6m	Not processed	20		
NTGS-BH07	40			40		
NTGS-BH08	37			23	-24C to -34C	Duplicates – not submitted to the lab.
NTGS-BH09	21			20	-12C	Missing from submission to lab.
NTGS-BH10	26			27	-04C	Missing from submission to lab.
NTGS-BH11	19			19		
NTGS-BH12	19			19		
NTGS-BH13	20			20		
NTGS-BH15	20			20		
NTGS-BH16	20			19	-07A	Missing from submission to lab.
NTGS-BH17	17			17		

Following soil sample drying and GWC determination, distilled and deionised water was added to each sample in the extraction ratio (1:1 soil:water). Samples were then homogenised and allowed to settle for twelve hours. The pore water was then collected with a syringe and filtered through 0.45 μm cellulose filter paper for geochemical analysis. Pore and supernatant water contents were labelled as follows:

Supernatant water content - NTGS17-BH#-Sample#-A/C-S

Example:

NTGS17-BH10-01-A-S (supernatant water collected from Augured samples)
NTGS17-BH10-01-C-S (supernatant water collected from Cored samples)

Pore water content – NTGS17-BH#-Sample#-A/C-P

Example:

NTGS17-BH10-01-A-P (pore water collected from Augured samples)
NTGS17-BH10-01-C-P (pore water collected from Cored samples)

*A detailed description of the laboratory procedure and data recorded is provided in Appendix C.

Geochemical analysis procedure

The geochemical analyses were completed for water and soil samples from the Sentinel boreholes at the Taiga Environmental Laboratory in Yellowknife. Water samples were analysed following standard methods (Creed *et al.* 1994; ISO 1997; Bernard *et al.* 2014; APHA 2018) at the Canadian Association for Laboratory Accreditation (CALA 2018)-accredited lab. Water chemistry parameters, conductivity, and pH were measured via titration (modified from APHA methods SM2510:B and SM4500-H:A/B) using an automated titrator system (Mantech PC Titrator, Mantech Inc.). Dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were analysed using a Shimadzu TOC-L analyser with a TNM-L attachment (modified from APHA method SM5310:B and ISO method 11905, Shimadzu Corporation). Major ions were analysed via ion chromatography (Dionex ICS-3000, Dionex Corporation), with calcium and sulphate concentrations described here (modified from APHA method SM4110:B). A suite of trace metal concentrations was analysed via Inductively Coupled Plasma Mass Spectroscopy (ICP-MS; Agilent 7900, Agilent Technologies Inc.), with arsenic and iron results presented (modified from EPA200.8; Creed *et al.* 1994).

The results were synthesised and input into R version 3.5.2 (R Core Team 2018). Within R, packages 'ggplot2' (Wickham 2016) and 'gridExtra' (Auguie 2017) were used to create stratigraphic plots to assess variability by depth.

Soil sedimentological analysis procedure

Soil samples were submitted to the GSC Sedimentology Laboratory in Ottawa, Ontario to determine Atterberg limits, particle size distribution, carbon content (inorganic and organic), and Munsell Colour. Selected samples were further analysed by quantitative X-ray Diffraction Analysis (XRD) to determine the mineralogy of the clay-size fraction. Sample handling, preparation, and analysis are according to Girard *et al.* (2004).

Atterberg limits and liquidity and plasticity indices were determined following ASTM-D2487 (Standard Practice for Classification of Soils for Engineering Purposes), ASTM-D2216 (Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass), ASTM-D4318 (Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils), and referencing Lambe (1951) and Murthy (2003).

Atterberg limits are engineering type tests that determine the strength or load-bearing capacity of sediment, usually performed on 100 grams of <0.045 mm fraction. The liquid limit (W_L) is the water content (%, dry-basis), of soil at the arbitrarily defined boundary between the semiliquid and plastic states. A computational method is substituted for the graphical method for fitting a straight line to the data and determining the liquid limit. The plastic limit (W_P) is the water content (%, dry-basis) of soil at the boundary between the plastic and semi-solid states. The W_P and W_L data are determined using Casagrande cup or Fall Cone penetrometer. The natural water content (W_N) is the ratio of the mass of water contained in the pore spaces of soil or rock material, to the dry, solid mass of particles in that material, expressed as a percentage.

The liquidity index (I_L), expressed as a percentage, is the ratio of the water content W_N of the soil minus the plastic limit W_P, to its plasticity index (I_P):

$$I_L = \frac{(W_N - W_P)}{I_P} \qquad [2]$$

Plasticity index is the range of water content over which soil behaves plastically. Numerically, it is the difference between the liquid limit and the plastic limit:

$$I_P = W_L - W_P \qquad [3]$$

The I_L values are classified as either semi-solid/solid-state (negative), very stiff (0), very soft (1), or liquid when disturbed (>1), and the I_P values are classified as either non plastic (0), low plastic (<7), medium plastic (7 to 17), or highly plastic (>17). If the W_L or W_P tests could not be performed, or if $W_P >= W_L$, the soil is reported as non plastic. The W_L and I_P results are plotted on a Unified Soil Classification System (USCS) Plasticity Chart (Figures D.2.1 to D.2.16) to assess the behavioural characteristics of the sample (Table 4).

Table 4. Unified Soil Classification System (USCS) inorganic fine-grained soils component only.

Liquid Limit	Plasticity Index relative to A-line	Soil class and plasticity	Code
Liquid Limit <50% (L)	On or above	Lean Clay Inorganic clays, sandy clays, silty clays, lean clays. Low to medium plasticity, no or slow dilatancy.	CL
	Below	Silt Inorganic silts and very fine sands, rock flour, silty or clayey fine sands. Slight plasticity to non-plastic, slow to rapid dilatancy.	ML
Liquid Limit >50% (H)	On or above	Fat Clay Inorganic clays, fat clays. High plasticity, no dilatancy.	CH
	Below	Elastic Silt Micaceous or diatomaceous fine sandy and silty soils, elastic silts. Low to medium plasticity, no to slow dilatancy.	MH
Liquid Limit <30% (L) Plasticity Index 4% to 7%	Not applicable	Silty Clay A mixed zone where both CL and ML soils plot	CL-ML

Particle size distributions are reported either as sand-silt-clay percentages or as complete grain size. The procedure for grain size analysis includes sand-silt-clay, complete grain size analysis, and the procedure for low weight samples, typically lake sediments. The classes of sizes >0.063 mm are determined using wet sieving in a stack of sieves, and the classes of sizes <0.063 mm are determined using a Lecotrac LT-100® Particle Size Analyser in conjunction with digital image analysis instrumentation (Camsizer). Detailed grain size determination and statistics with multiple data sets in each of the sand/silt/clay categories are performed with GRADISTAT v8.0. The GSC Sedimentology Laboratory reports clay as <0.002 mm unless otherwise requested.

Determination of the total carbon content by infrared spectrometry used a LECO RC-412 Carbon Analyser (Bernard et al. 2014; LECO Inc.). The weight-percent of "total" carbon content is first determined on a split, and the inorganic carbon determined on another split after low-temperature (<500°C) ashing to remove the organic carbon (i.e., loss on ignition residue). The organic carbon is deduced by subtracting the inorganic carbon from the total carbon. The results also include the loss on ignition (LOI) at 500°C. In addition to carbon (C), however, the weight loss associated with LOI also include volatile elements such as sulphur (S), nitrogen (N), hydrogen (H), oxygen (O), mercury (Hg), and moisture. Thus, the weight-percent organic carbon result is almost always less than the weight-percent LOI.

Munsell Colour is a standardised basis for describing soil colours using terminology and colour standards in the Munsell Soil Color Chart. The Munsell colour determination is reported as an alpha-numeric sequence that comprises three variables: hue, value, and chroma. Standard soil colour determination using an X-rite Spectrophotometer was performed on dry bulk samples, producing red, green, blue (RGB) and Munsell colour values. Standard soil colour determination using Soil Munsell Color Chart performed on moist bulk samples were also produced.

X-ray Diffraction Analysis provides qualitative and semi-quantitative determinations of silt and clay-sized (<0.063 mm) minerals, including illite/muscovite, chlorite, kaolinite, smectite, mixed-layer clay minerals, common rock-forming minerals (*e.g.,* quartz, plagioclase, K-feldspar, amphibole, pyroxene, calcite, dolomite), anhydrite, goethite/hematite, talc, jarosite, *etc*. X-ray Diffraction Analysis is most commonly applied to the analysis of clay-sized minerals. X-ray Diffraction Analysis analysis protocols comprise 1) sample preparation, 2) collection of X-ray diffraction spectra, and 3) X-ray diffraction pattern processing and interpretation. Part 1 is carried out by GSC Sedimentology Laboratory and Parts 2 and 3 in collaboration with scientists in the GSC Mineralogy and Microbeam Laboratory.

Results and discussion

Soil descriptions

Figure 7 presents the general substrate classes of all boreholes in latitudinal sequence from Inuvik to Tuktoyaktuk. Depths are relative to the ground surface. Figure 7 was prepared using SoilStats 0.7.1 (Yong Technology Inc. 2018). Figure 8 presents the same substrate classes for boreholes according to terrain type. Peatland sites (Figure 8a) include the three Sentinel sites selected for this terrain type, in addition to six ITH alignment boreholes and two ITH embankment boreholes. The latter eight boreholes were associated with peatland terrain through the review of 2011 aerial orthophotos (Northwest Territories Centre for Geomatics 2012). Near-surface materials typically include organics and peat, often in combination with ice. Silt, clay and sand generally occur at greater depths. Ice persists to a depth of at least 10 m at NTGS 1 (INU_P), and >6 m at NTGS 8 (HUS_P). The initial layer of sand and gravel in boreholes ITH 05 and ITH 13 is the ITH embankment.

Clay and sand characterise the top 20 m of the substrate at hilltop sites NTGS 7 (HUS_H) and NTGS 5 (TVC_H) (Figure 8b). Sand is ice-rich at NTGS 10 (TUK_H) and pure ice occurs at depths >13 m at NTGS 2 (INU_H). As shown in Figure 8c, substrate beneath broad riparian sites (HUS_R, INU_R, TVC_R) is predominantly clay at depths >4 m. Peat is common near the surface, often with a subjacent layer of pure ice or ice-rich silt or clay. Stream channel bank substrate is primarily silt and organics overlying clay or sand (Figure 8d). Sedimentary bedrock mudstone was encountered at three locations along the ITH alignment, at stream crossings CR3, CR4 and CR21 between the depths of 6 m and 14 m. Bedrock was not encountered in any boreholes north of stream crossing CR21. An important distinction between the Sentinel riparian sites and the other borehole sites near the stream channels is that the former typically represent low-order streams that are not fluvially incised. Some of the largest channels, including Hans Creek, occupy relict valleys of large floodways that were high-energy systems and have left behind a legacy of gravel.

Figures 9a to 9h present substrate data from auger logs at each bridge piling (pile) site (Kiggiak-EBA 2014a-c, 2015, 2016a-d). The eight bridges along the ITH include two single-span structures supported by abutment pilings and six three-span structures supported by abutment and pier pilings. The bridges are founded on adfreeze steel pipe piling foundations. The pipe pilings were installed in piling holes predrilled 100 mm larger in diameter than the piling. Following piling installation, saturated granular backfill was placed into the hole between the soil and the steel piling, as well as inside the pipe, to create the frozen adfreeze bond between the piling and soil. All auger drilled piling holes were logged in the field before piling installation. Each pier and abutment foundation comprised 6 and 10 adfreeze steel pipe pilings, respectively. While elevation, latitude and longitude are not indicated in Figures 9a to 9h, auger hole northing/easting coordinates and surface elevations were used to prepare the figures to eliminate distortion of substrate strata. The bridge pier and abutment pilings extend several metres above the top of each auger hole (Figure 3) and most abutment pilings are now mostly hidden (buried) by the highway embankment. The top of each borehole record in Figure 9a to Figure 9h is associated with the natural ground surface. Mineral surficial material is predominantly alluvial fluvial sand and gravel, with a general increase in fines in the underlying ground moraine till. To minimise the bridge span lengths the abutment pilings are near the stream channel, so the drill log data do not show a trend in substrate composition with increasing distance from stream channels. The grid at the base of each figure has 1 m x 1 m cells for scale. The piling installation forms containing the data used to prepare Figure 9a to Figure 9h, along with other information, are available as .xlsx spreadsheet files (Appendix H).

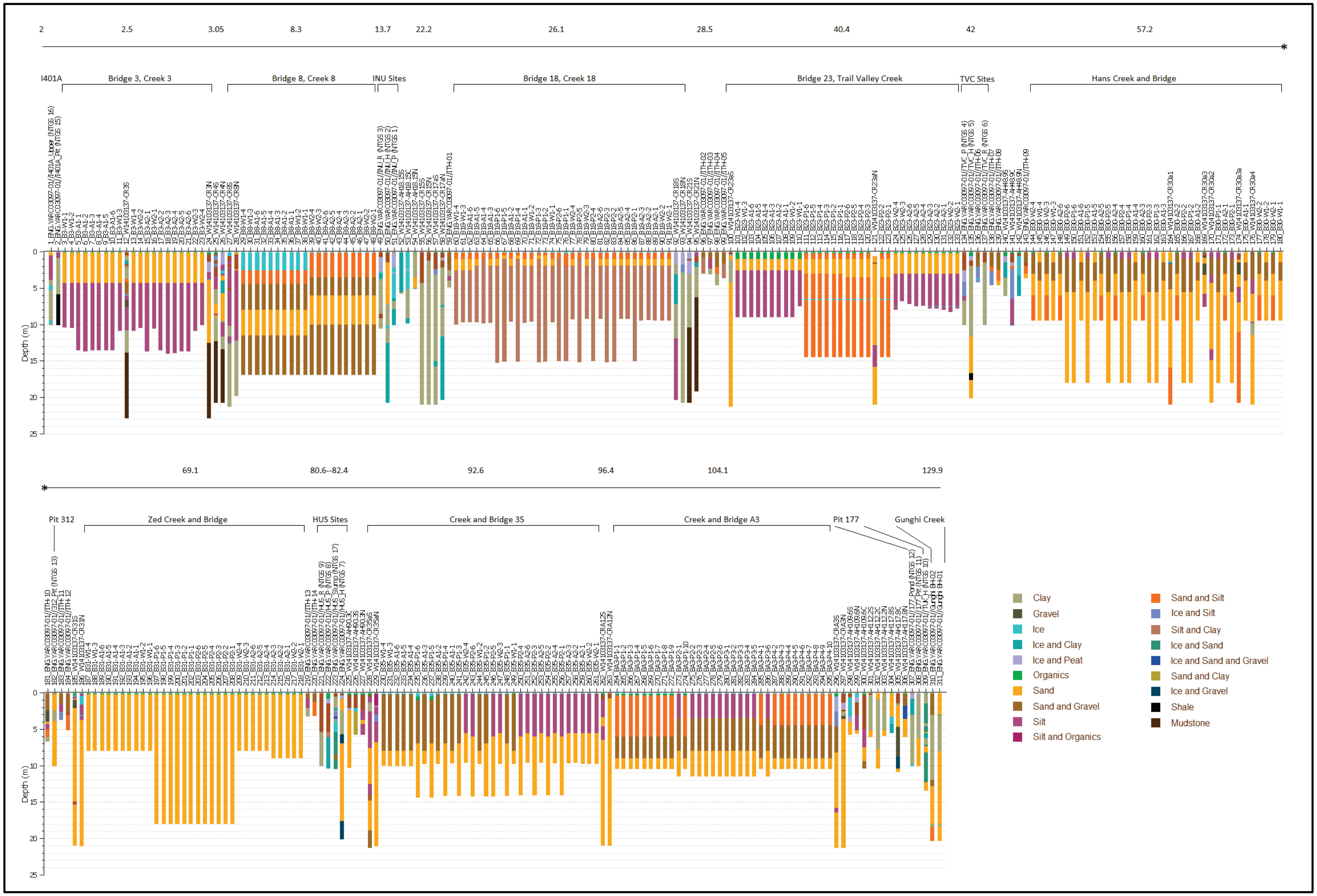


Figure 7. Substrate classes from a south to north sequence of geotechnical borehole logs at stream channel banks, highway alignment, highway embankment, bridge piling and Sentinel permafrost sites between Inuvik and Tuktoyaktuk, Northwest Territories. Boreholes are at irregular distances along the route, as shown in kilometres along the top. Individual borehole names are given vertically. Number prefixes on borehole names were applied for sequencing and do not indicate distance. This figure is reproduced in Appendix I as a single document in larger format for ease to facilitate printing and readability.

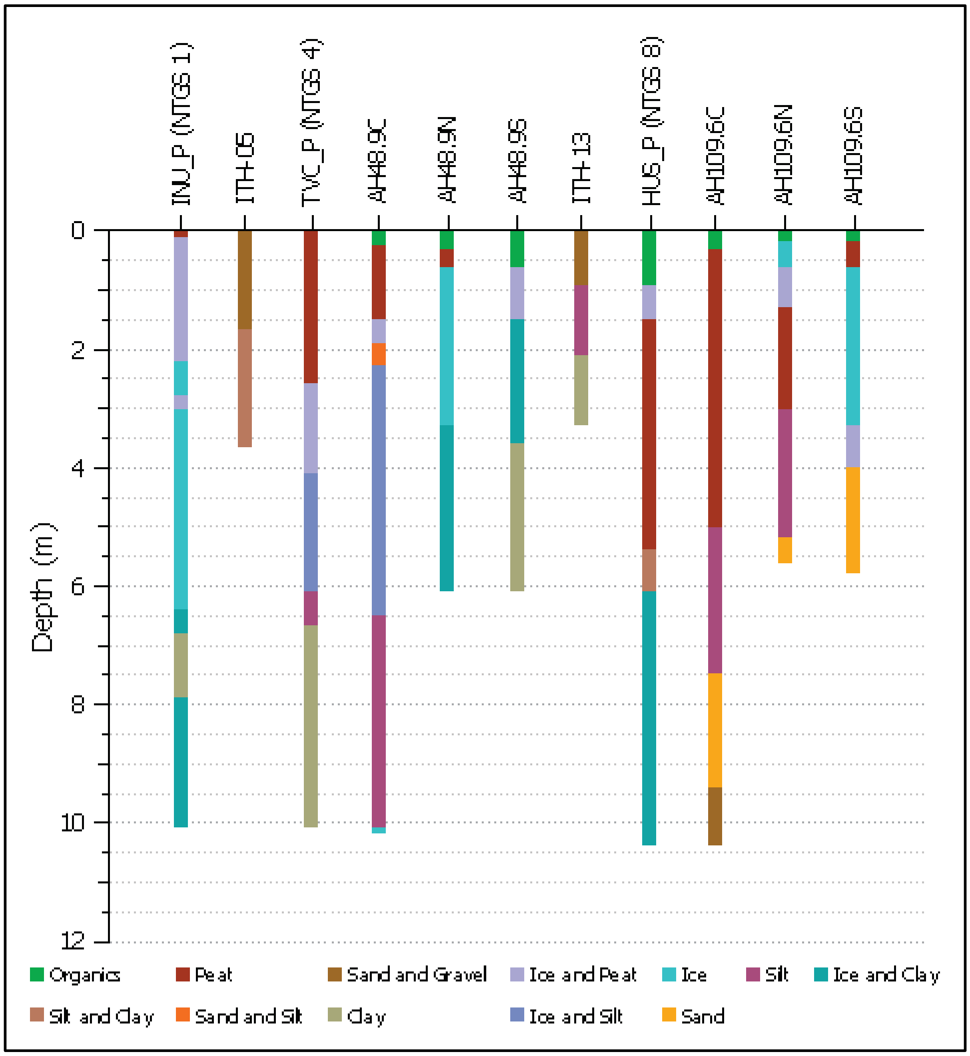


Figure 8a. Substrate classes for geotechnical boreholes in peatland terrain between Inuvik and Tuktoyaktuk.

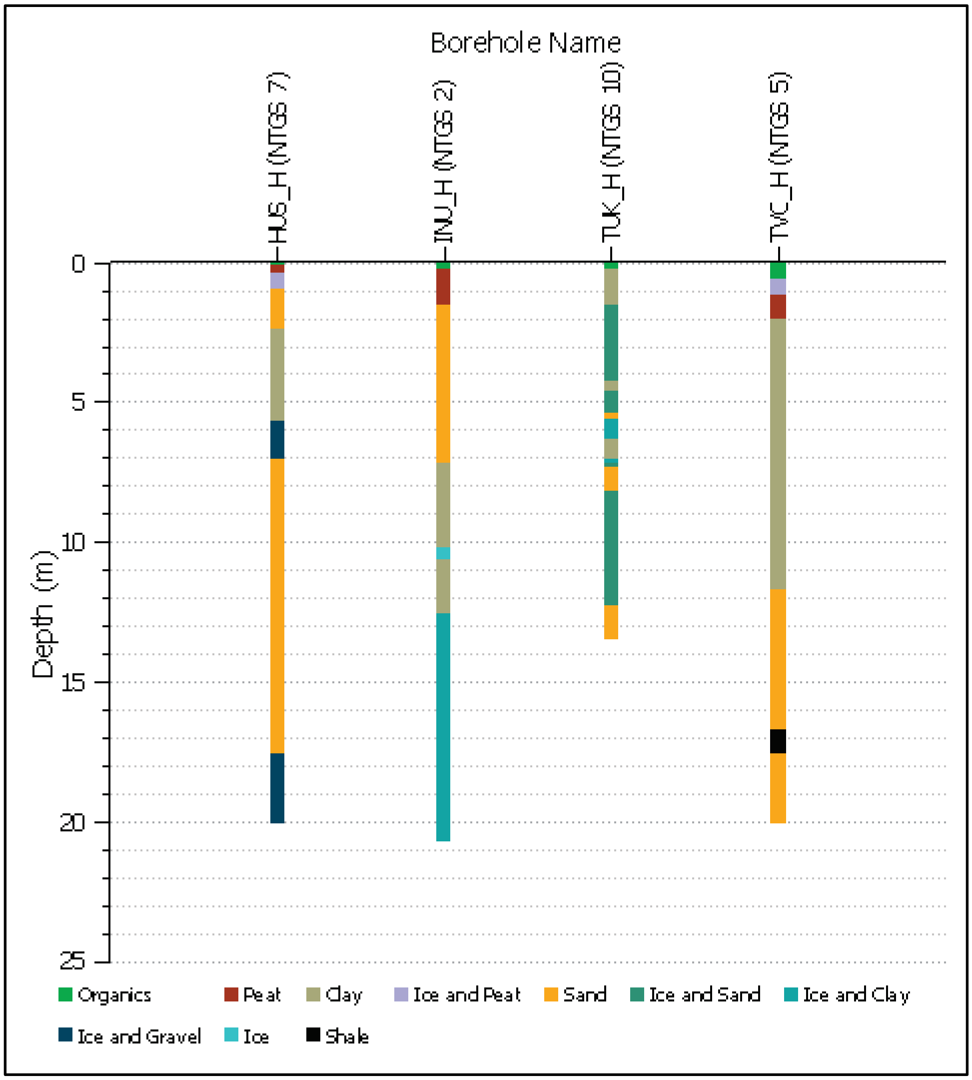


Figure 8b. Substrate classes for geotechnical boreholes at hilltop sites between Inuvik and Tuktoyaktuk.

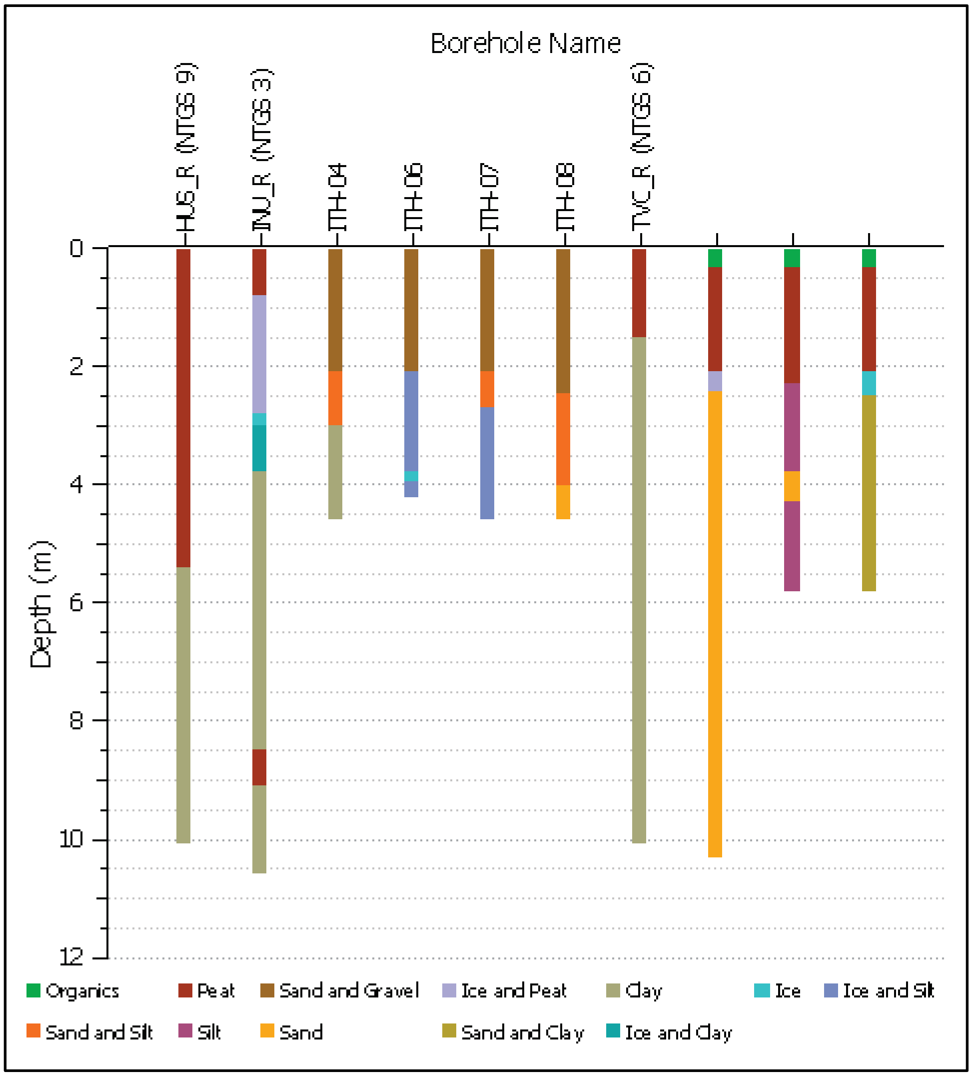


Figure 8c. Substrate classes for geotechnical boreholes in riparian terrain between Inuvik and Tuktoyaktuk.

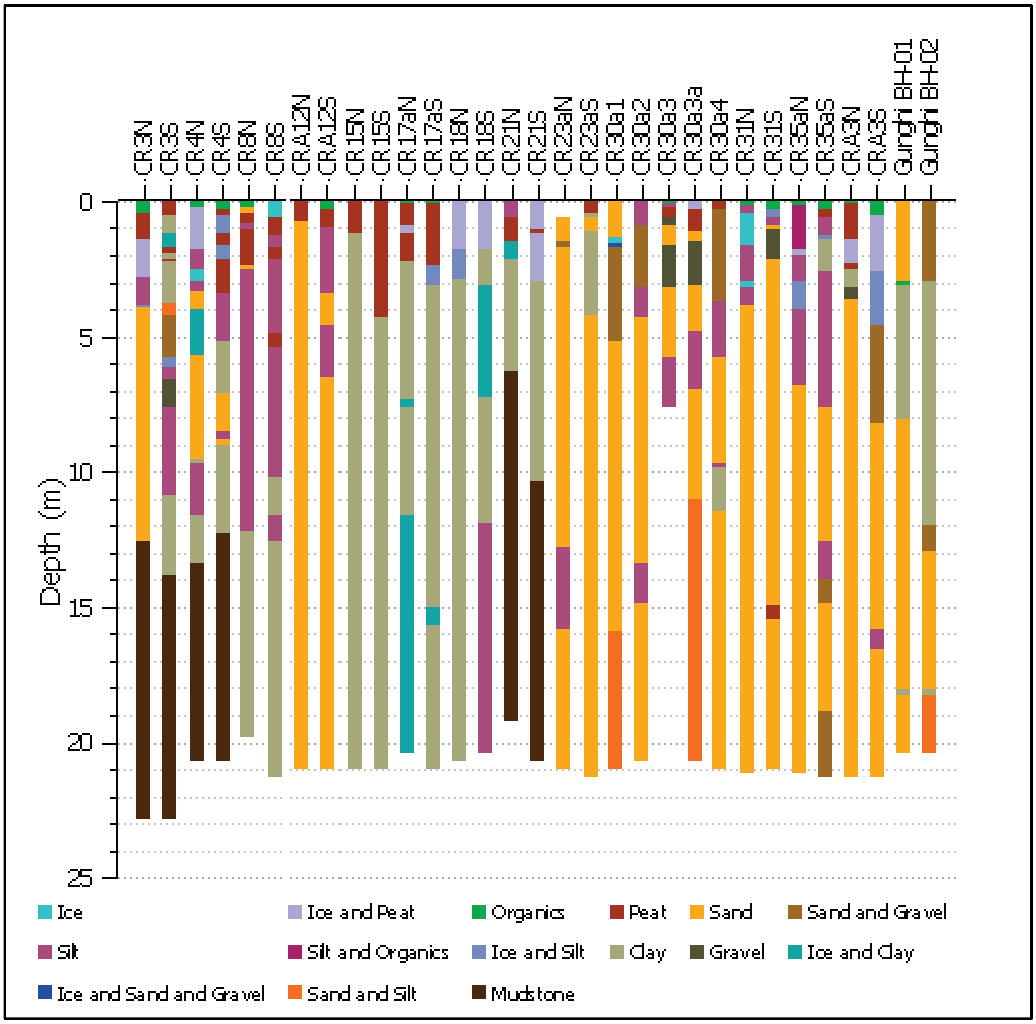


Figure 8d. Substrate classes for geotechnical boreholes at creek banks between Inuvik and Tuktoyaktuk.

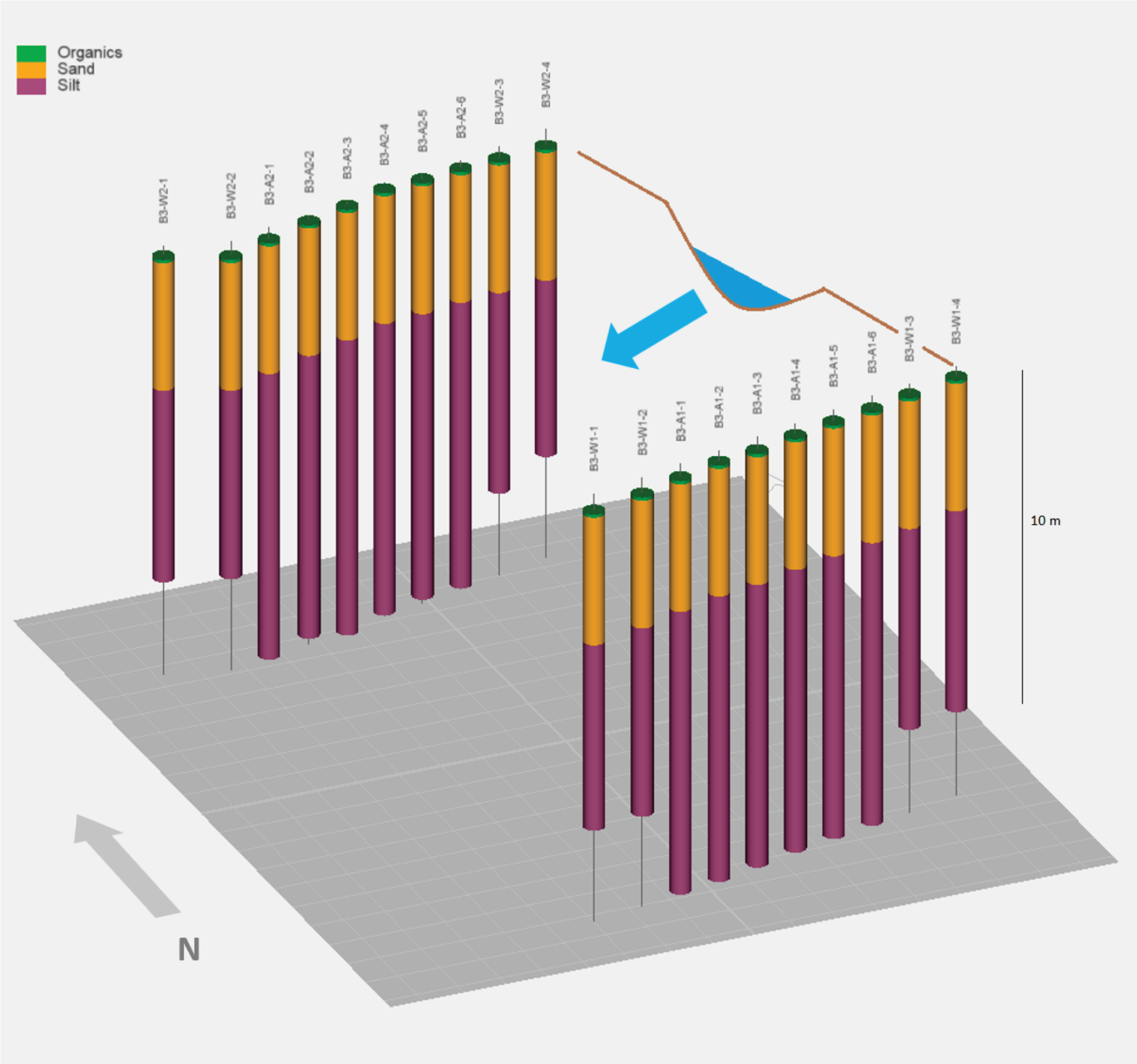


Figure 9a. Bridge 3 - general substrate classes from piling installation auger records. The view is to the northeast of ITH kilometre 2.5.

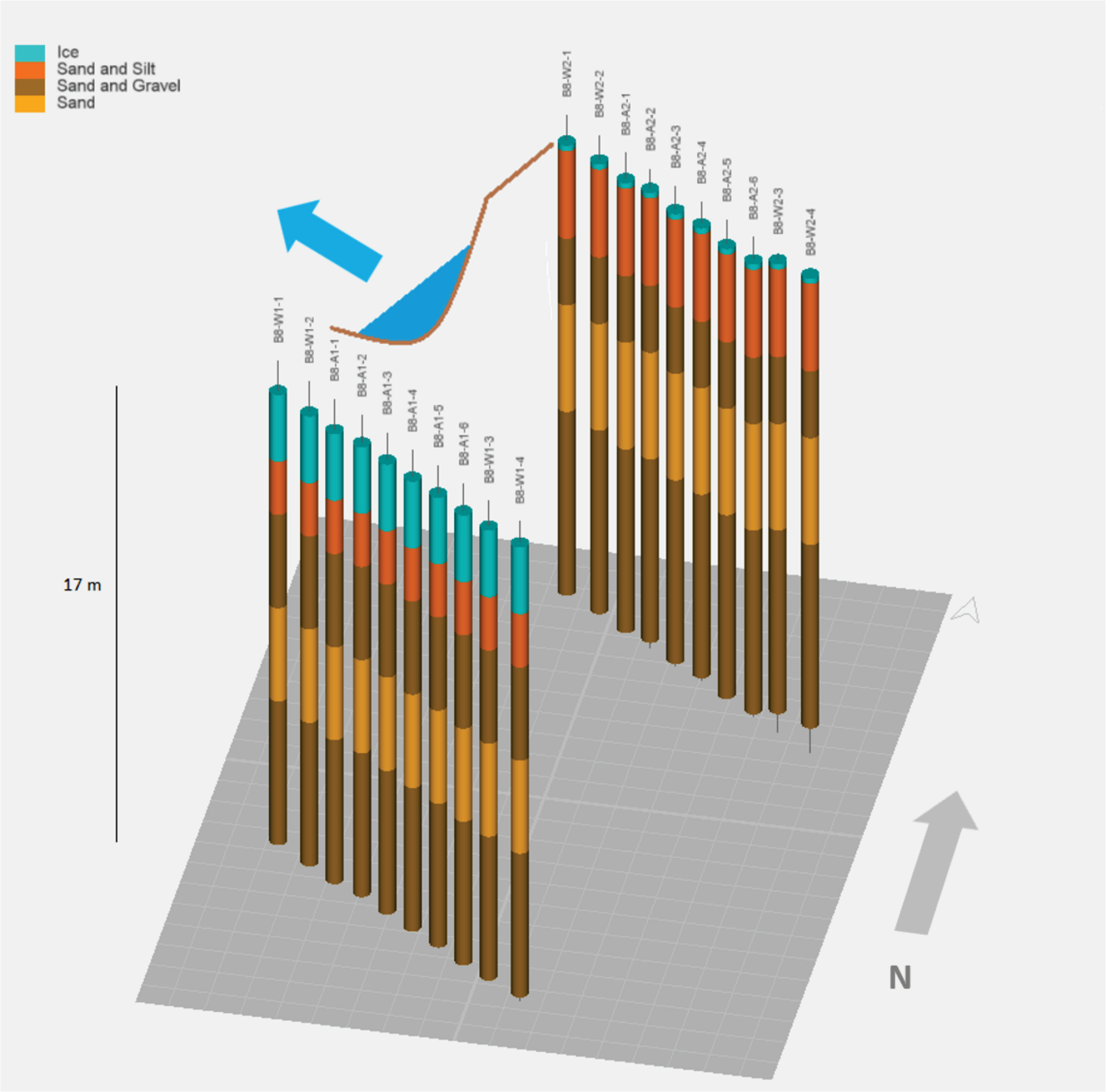


Figure 9b. Bridge 8 - general substrate classes from piling installation records. The view is to the northwest of ITH kilometre 8.3. Piling log notes refer to the ice substrate class as “glaciated creek flow”.

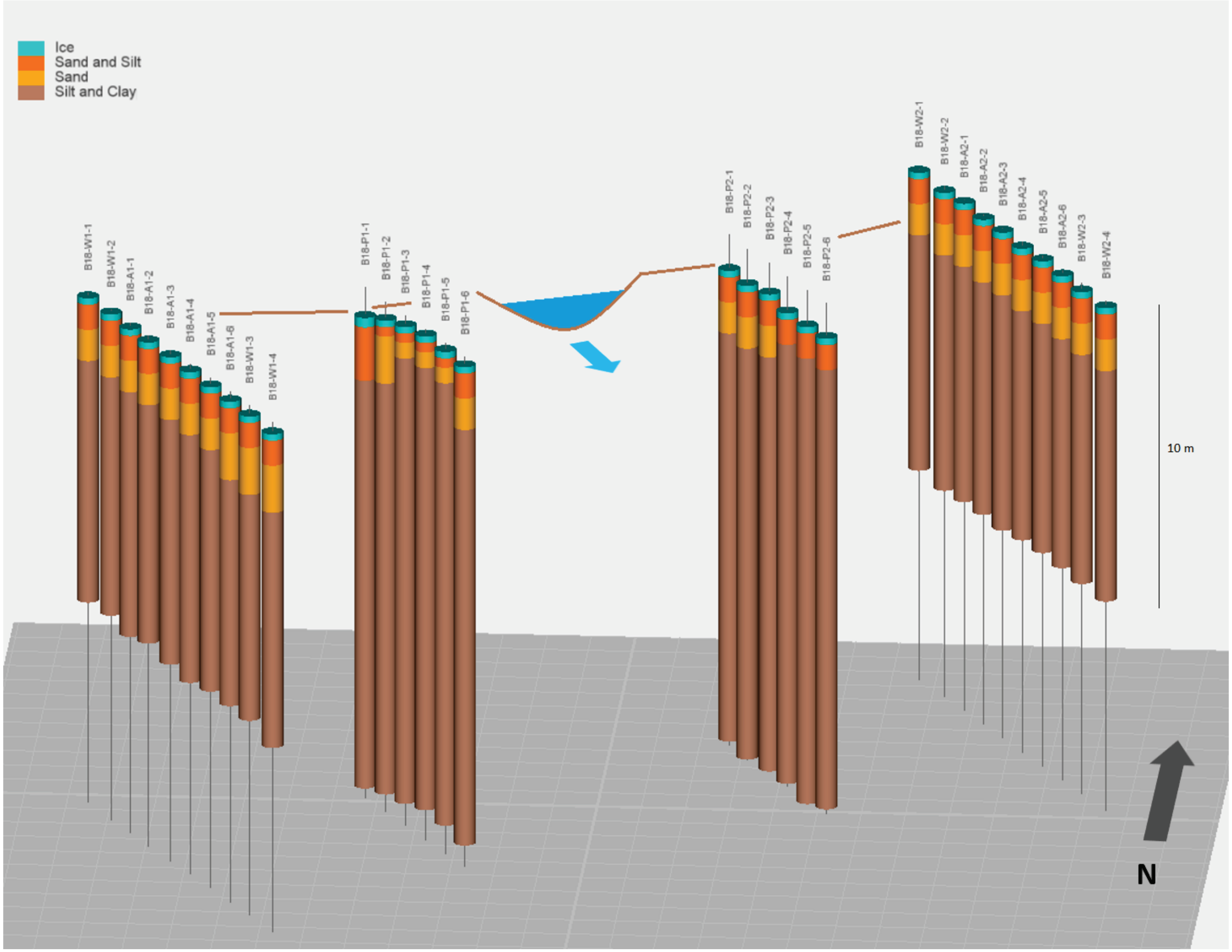


Figure 9c. Bridge 18 - general substrate classes from piling installation records. The view is to the northwest of ITH kilometre 26.

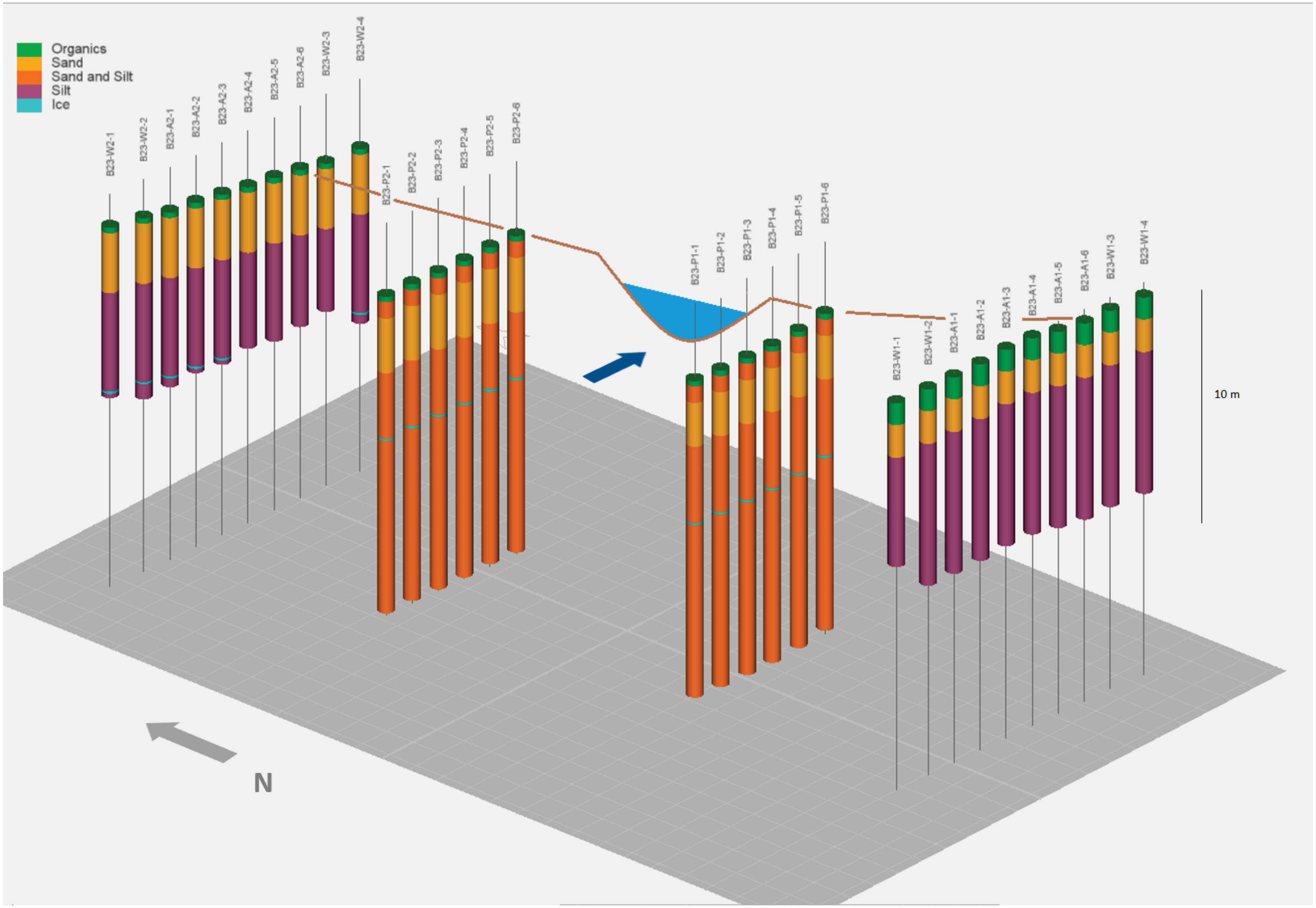


Figure 9d. Bridge 23 (Trail Valley Creek) - general substrate classes from piling installation records. The view is to the northeast of ITH kilometre 40.4.

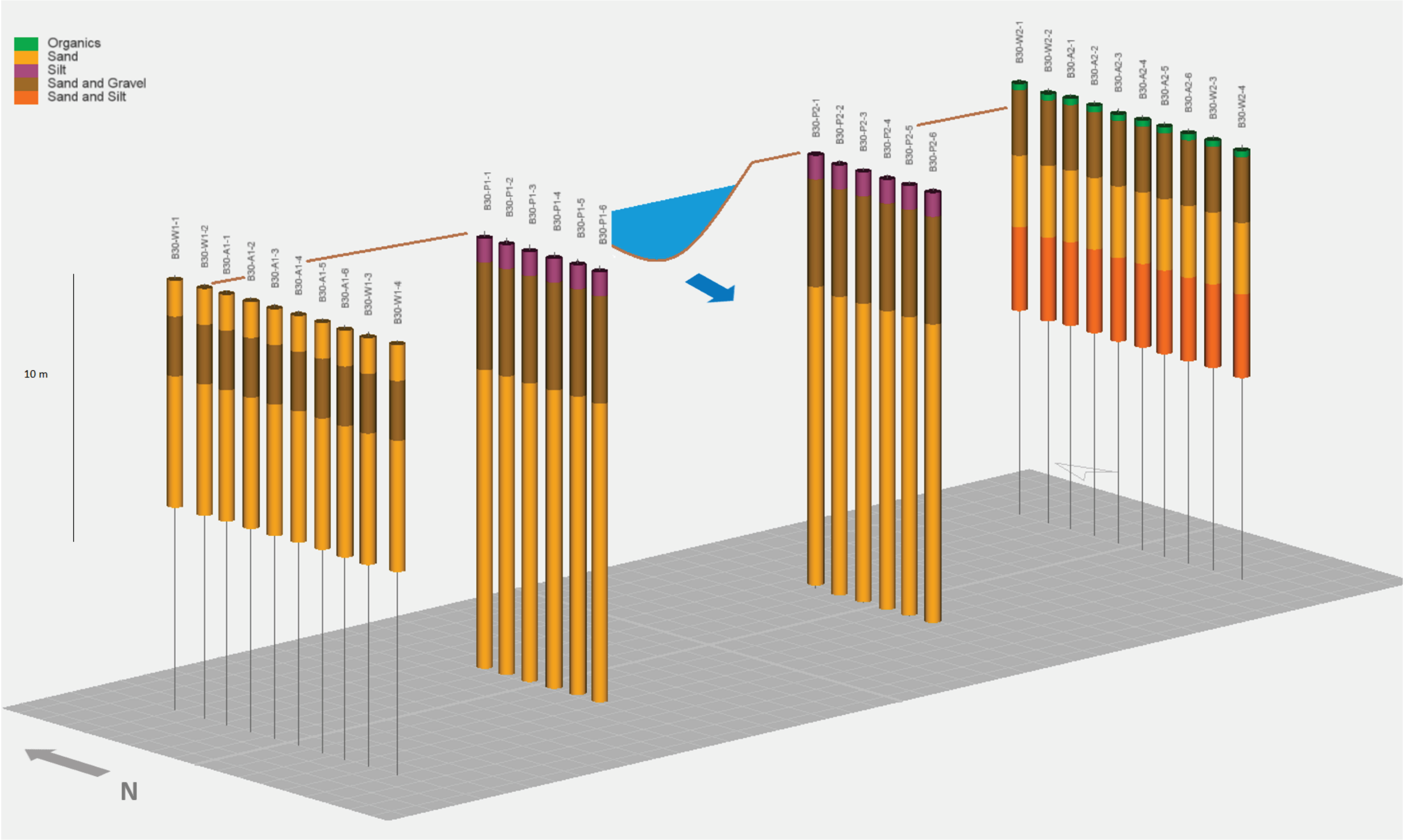


Figure 9e. Bridge 30a (Hans Creek) - general substrate classes from piling installation records. The view is to the northeast of ITH kilometre 57.3.

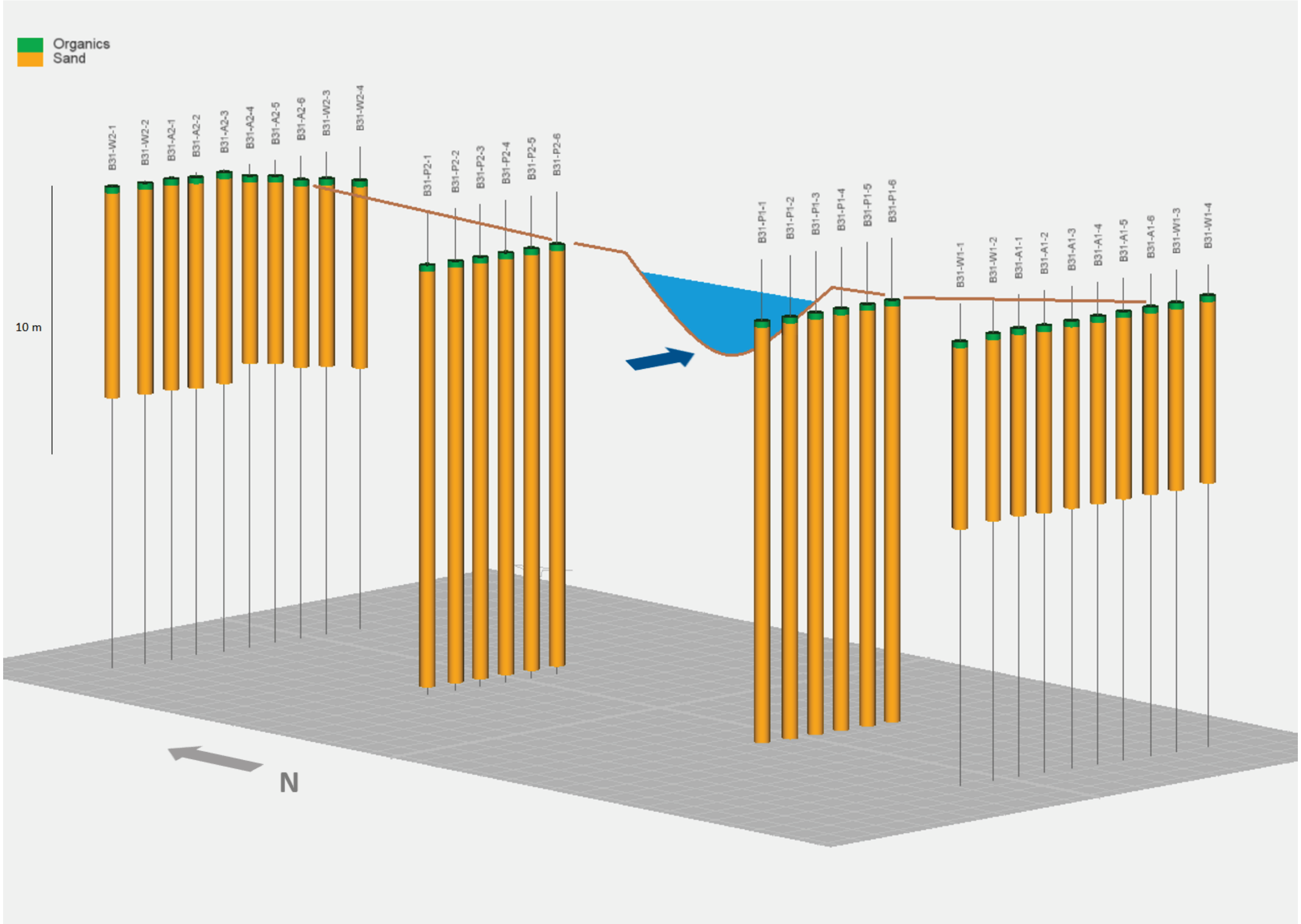


Figure 9f. Bridge 31 (Zed Creek) - general substrate classes from piling installation records. The view is to the northeast of ITH kilometre 69.1.

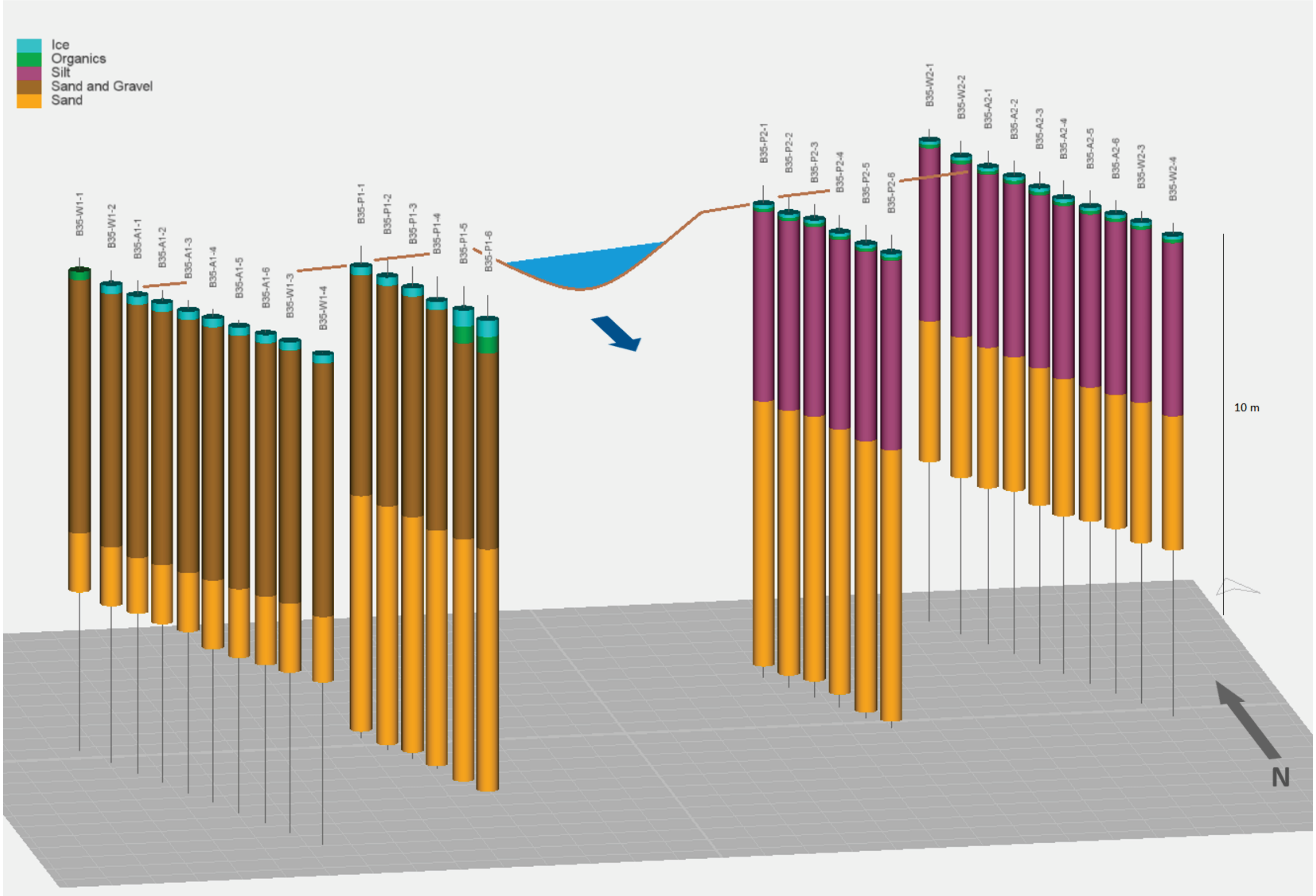


Figure 9g. Bridge 35 - general substrate classes from piling installation records. The view is to the northeast of ITH kilometre 92.6.

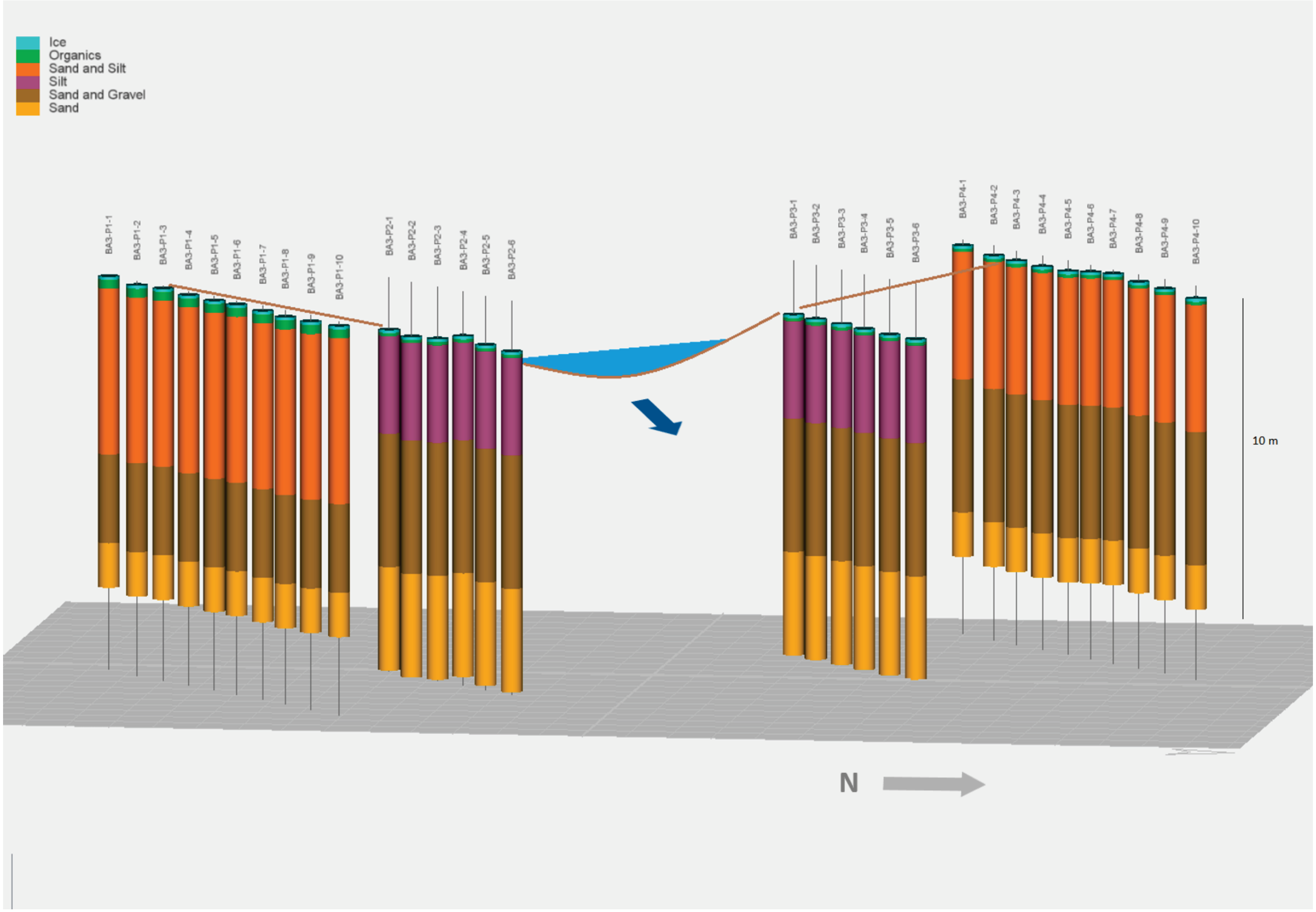


Figure 9h. Bridge A3 - general substrate classes from piling installation records. The view is to the west-southwest of ITH km 104.1.

Soil sedimentological and physical properties

Complete results for Atterberg limits, complete grain-size distribution, carbon content (inorganic and organic), and Munsell Colour are available in Appendix D. Complete XRD (clay-size) results are available in Appendix E. Figures 10a to 10p summarise the results with respect to depth (m) below the ground surface. The figures show sample depth intervals; instrumental results of grain-size fraction <0.063 mm as volume percent; gravel fraction as weight percent; I_P class; I_L class; properties of W_P, W_L, and W (%); USCS Plasticity Chart Classification; Munsell colour (RGB equivalent colour plotted); organic and inorganic carbon contents; and LOI. Unless a sample was not sent to the GSC Sedimentology Laboratory (Table 2), missing data represent cases where the analysis procedure was not performed either due to too little sample (too much ice/water), too much organic matter (peat), or too much sand.

Of the 390 samples, nearly 52% were either too organic (peat), sandy, icy, or small to determine a USCS classification (Figure 11). The behaviour of remaining samples is described primarily as lean clay (33.8%) and fat clay (7.4%). The clay-like behaviour contrasts with the <0.063 mm soil matrix descriptions that are dominated by silts, sandy silts and silty sands (Figures 10 and D.3.1 to D.3.16), and grain size data (Figure 10) that indicate silts and sands make up 49.5% and 38.1% of the average size distribution across samples.

Of the 187 samples processed to determine Atterberg limits, W_N is above the W_L in 43% of samples. With respect to the I_L, 22% of samples are very soft and 34% of samples are liquid when disturbed. The gravel content in samples was generally less than 25%, except in sand-rich samples. The very high gravel contents are usually associated with ice-rich samples; the relative proportion of the sample constituting mineral materials is low in these instances, so the relative contribution of gravel to the weight-percent of the bulk sample is high (*e.g.,* where depth >17 m depth at NTGS17_BH07 (HUS_H) (Figure 10g)).

On average, the total carbon content in a sample was 2.32%, ranging from 0.5% to 11.4%. The carbon in the samples was primarily organic in nature, constituting 75% of the total carbon, on average. The highest organic carbon contents in minerogenic materials occurred below 7 m in depth in NTGS17_BH15 (I401A_Pit) (Figure 10n). These values represent an analysis of samples retrieved from poorly consolidated mudstone, rather than sedimentary deposits.

Munsell colour, determined on 375 samples, reflects the array of sedimentary materials present, and ranges from black coloured peat to light brownish grey (Figure 10). Dominant colours are grey (27%), dark grey (26%), and greyish brown (23%).

X-ray Diffraction Analysis was conducted on 24 bulk samples (Table E1), and results are summarised in Table E2. Quartz dominated all samples (56% by weight on average), with mica as a secondary mineral (21% by weight on average). Minor minerals present in all samples are plagioclase feldspar (6% by weight on average) and chlorite (4% by weight on average), and minor to trace minerals present in all samples are dolomite (3.3% by weight on average) calcite (2.3% by weight on average) K-feldspar (2% by weight on average), and pyrite (1.8% by weight on average). Other minerals found in trace amounts in many samples include kaolinite, a mixed-layer clay mineral (probably illite/smectite) and gypsum and jarosite. Clinopyroxene and siderite were detected in a few samples. The results for clay–size samples (Table E3) are summarised in Table E4. Mica (illite, based on the <2 μm size; 29% by weight on average) and chlorite (26% by weight on average) dominate the samples, with subordinate quartz (20% by weight on average). Minor minerals include kaolinite (6.5% by weight on average), K-feldspar (4.5% by weight on average), and plagioclase feldspar (2.3% by weight on average). Smectite ranges from trace amounts to nearly 30% by weight, averaging about 7% by weight. Gypsum is present in 15 samples. While it represents a minor or trace proportion by mass of the clay fraction in most samples, it represents 88% of the clay fraction in sample BH03-06-A (Figure E8). Calcite and dolomite occur in a few samples in minor to trace amounts and pyrite is present in most samples as a trace mineral.

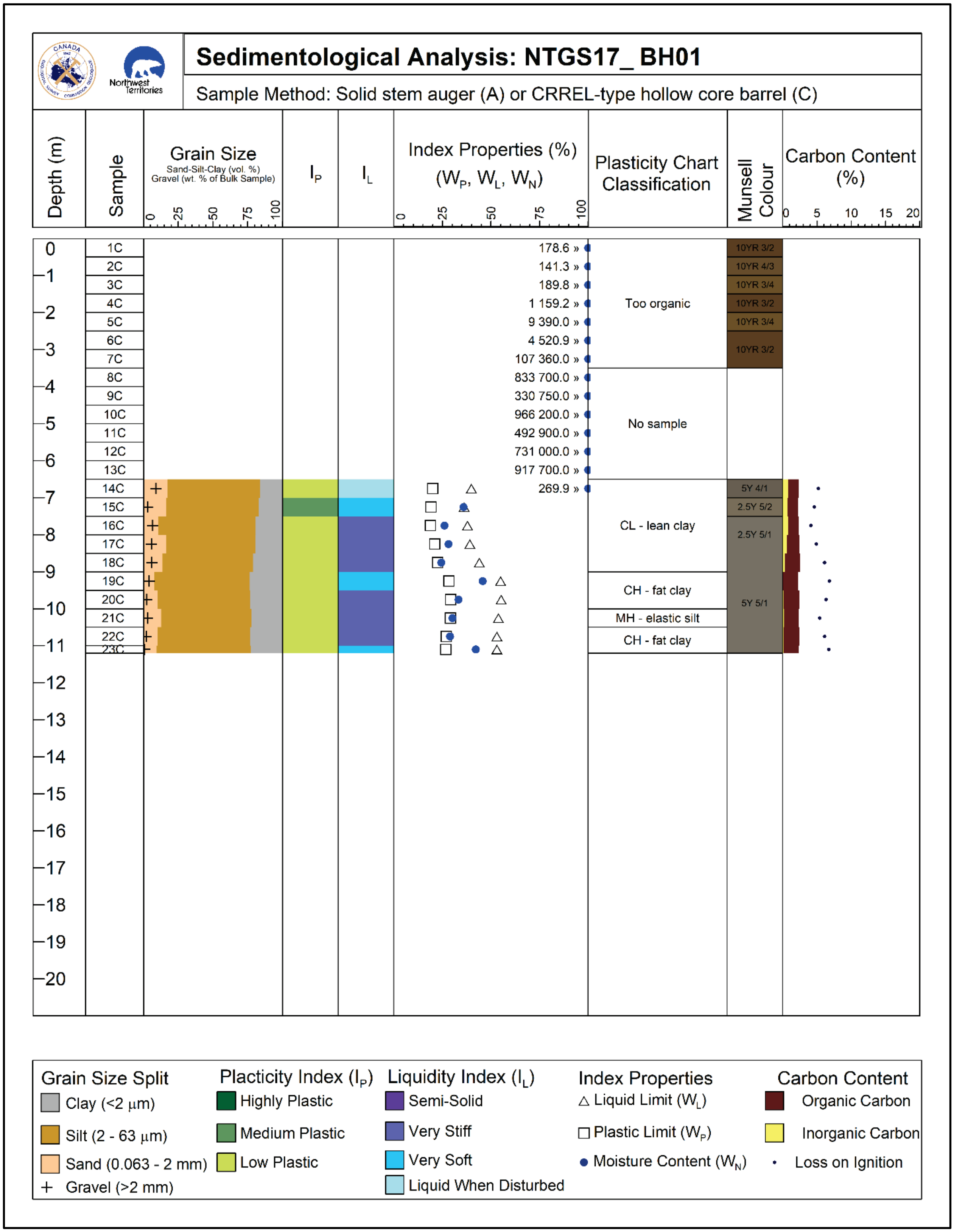


Figure 10a. Variation of sedimentological properties with depth at NTGS17-BH01 (INU_P).

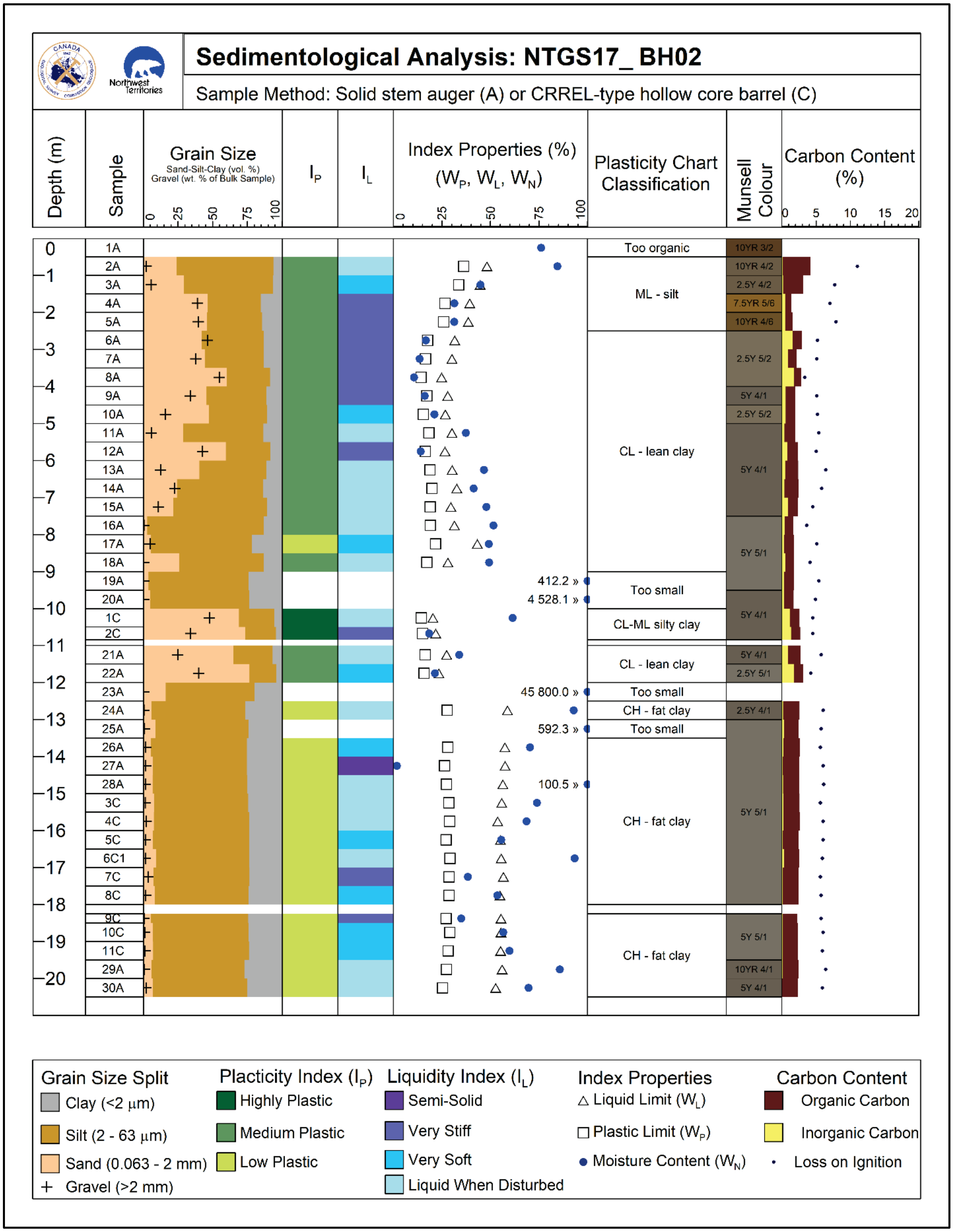


Figure 10b. Variation of sedimentological properties with depth at NTGS17-BH02 (INU_H).

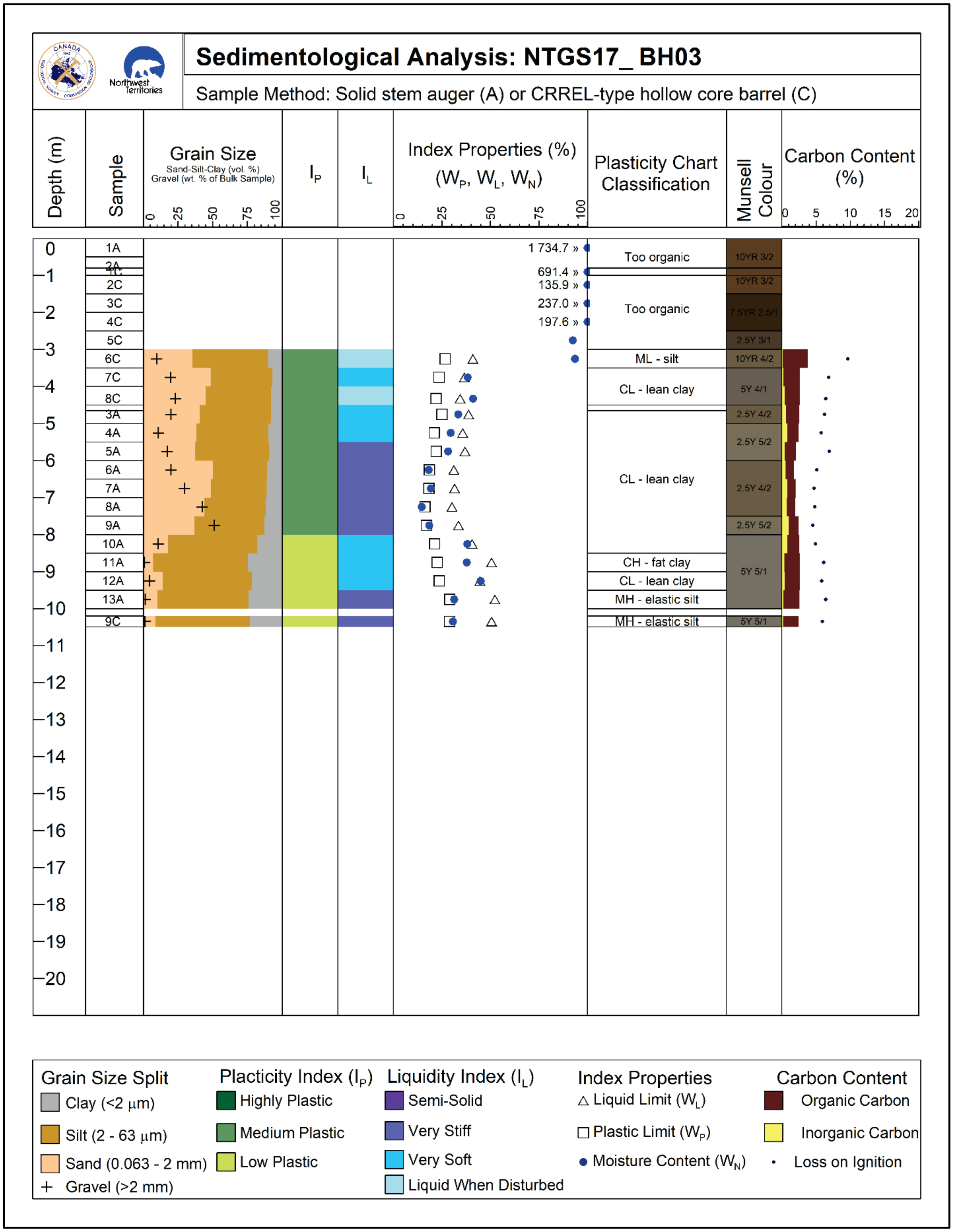


Figure 10c. Variation of sedimentological properties with depth at NTGS17-BH03 (INU_R).

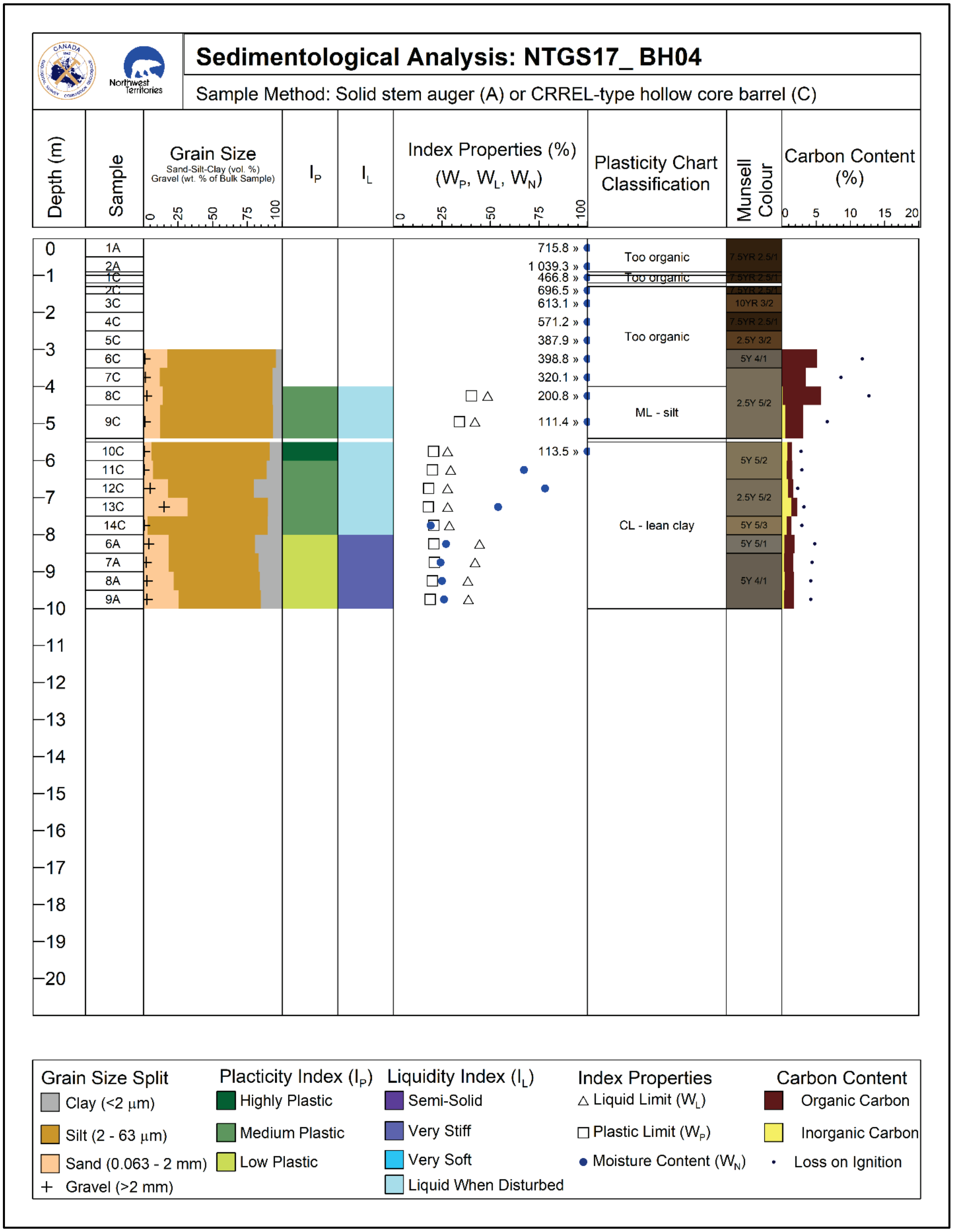


Figure 10d. Variation of sedimentological properties with depth at NTGS17-BH04 (TVC_P).

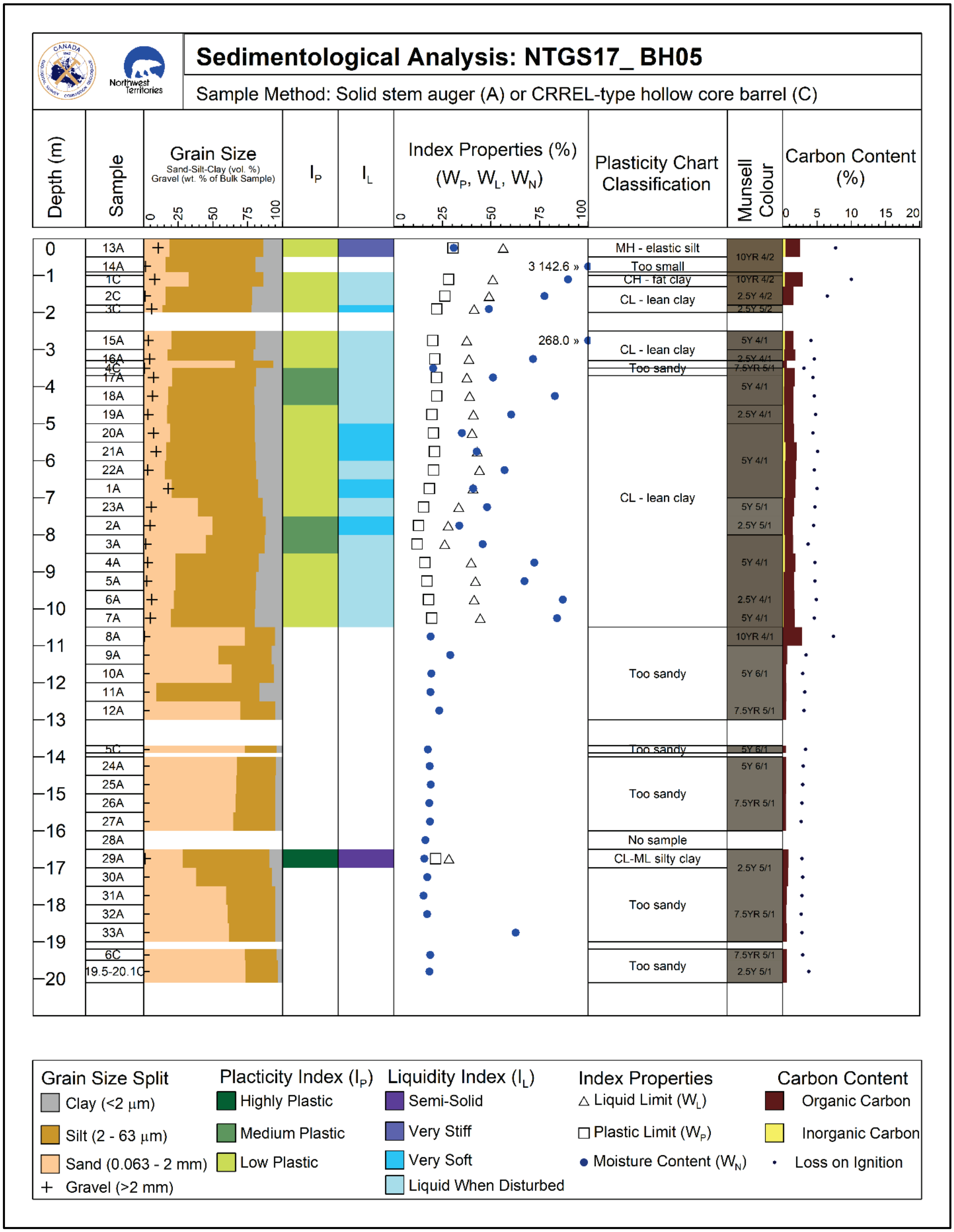


Figure 10e. Variation of sedimentological properties with depth at NTGS17-BH05 (TVC_H).

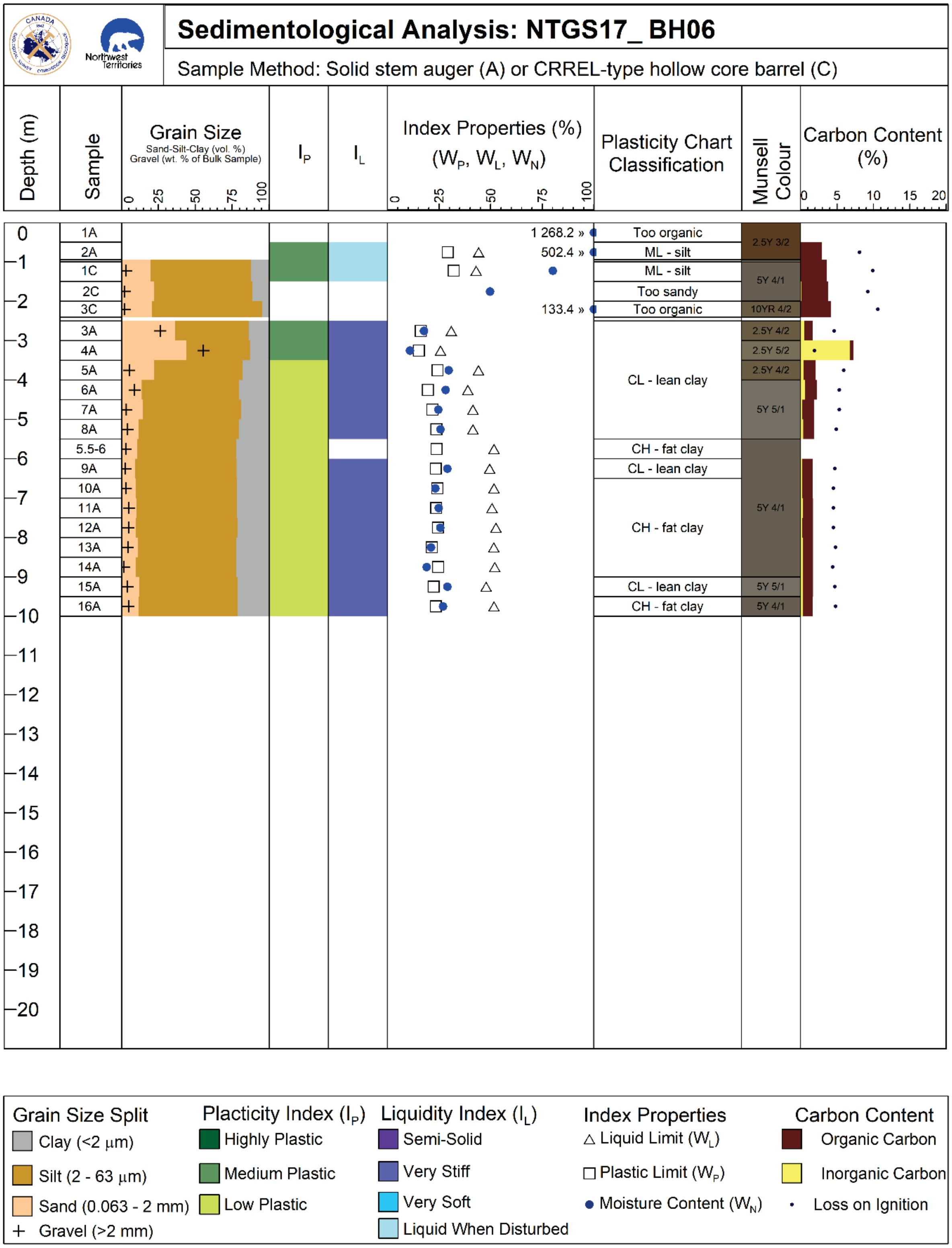


Figure 10f. Variation of sedimentological properties with depth at NTGS17-BH06 (TVC_R).

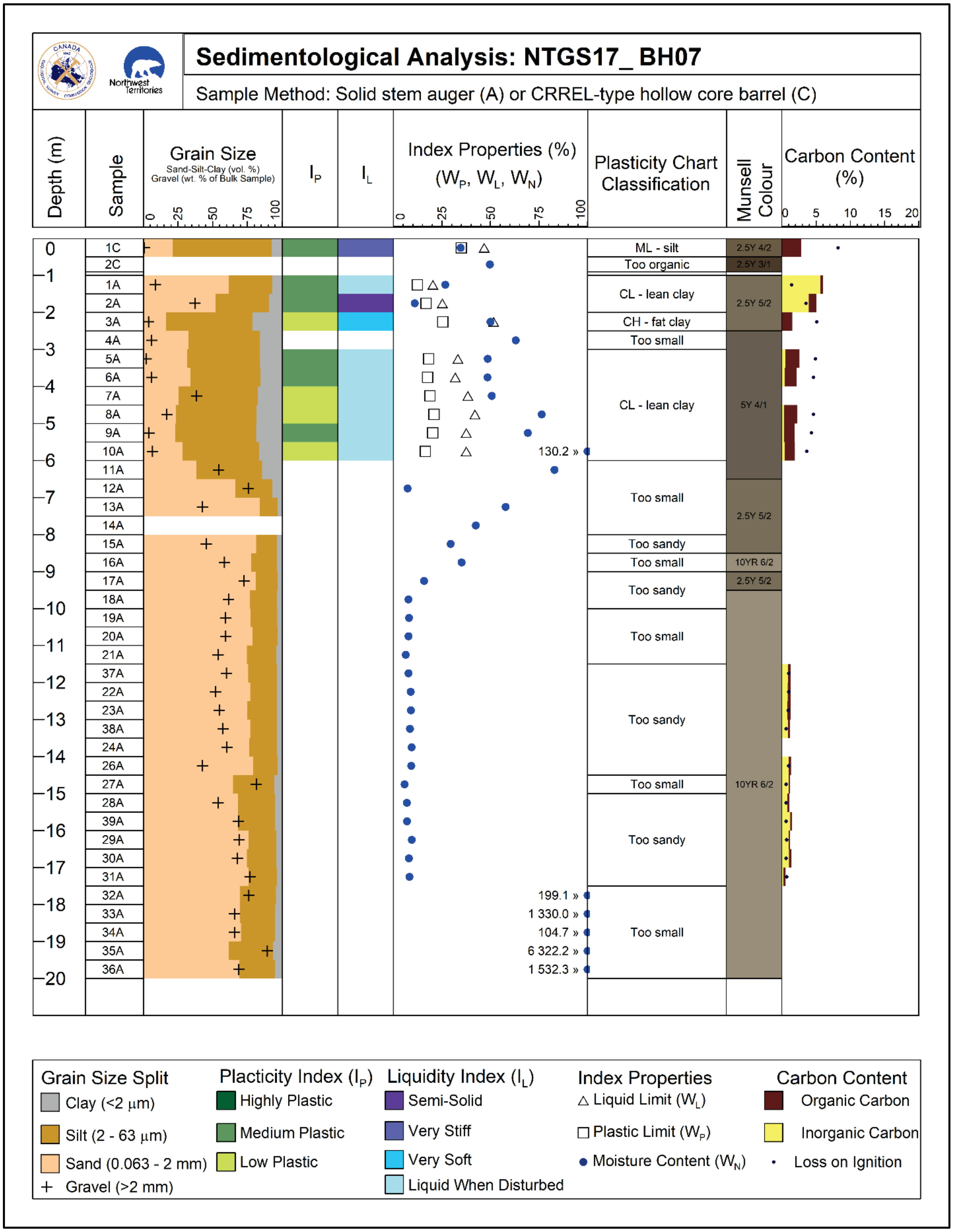


Figure 10g. Variation of sedimentological properties with depth at NTGS17-BH07 (HUS_H).

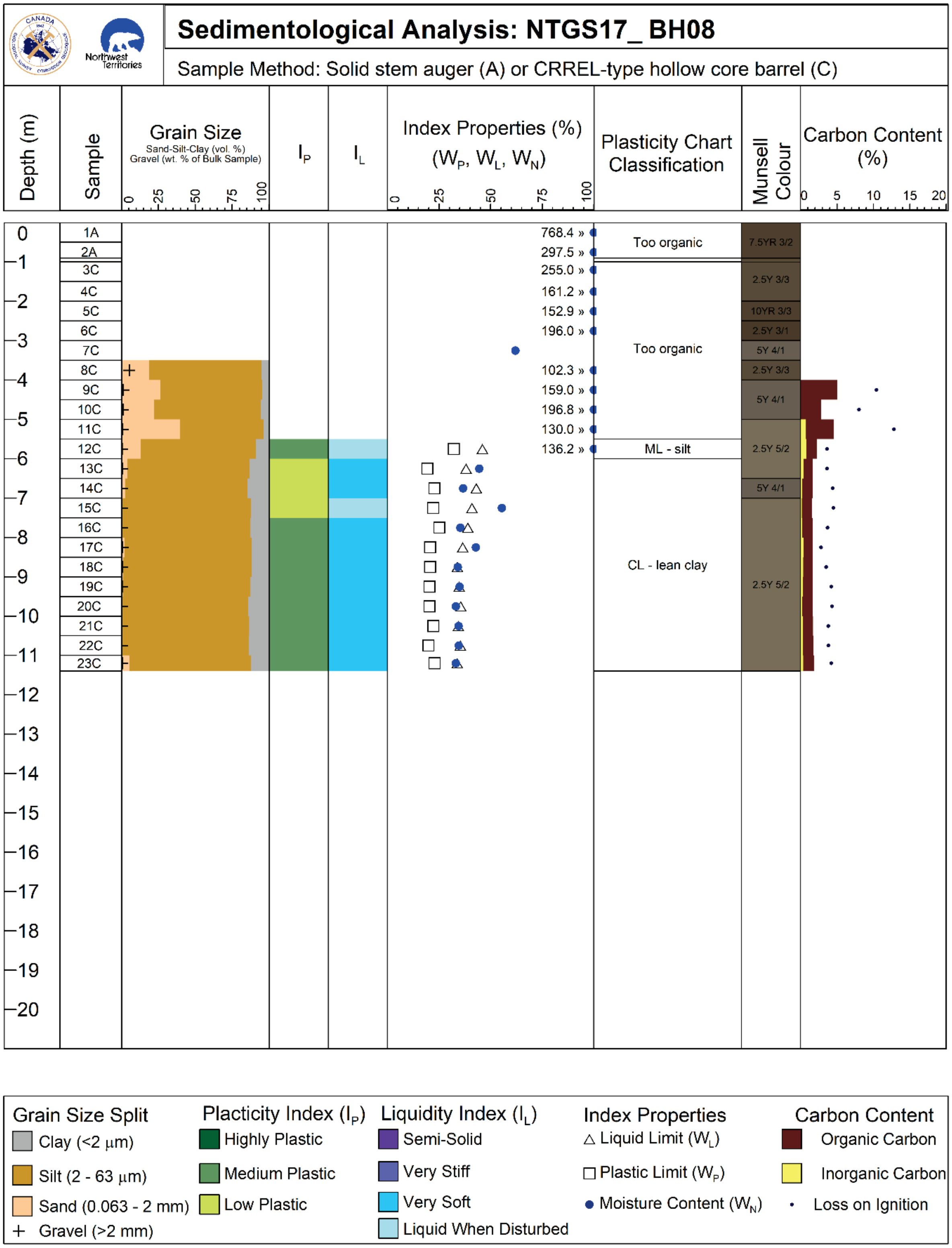


Figure 10h. Variation of sedimentological properties with depth at NTGS17-BH08 (HUS_P).

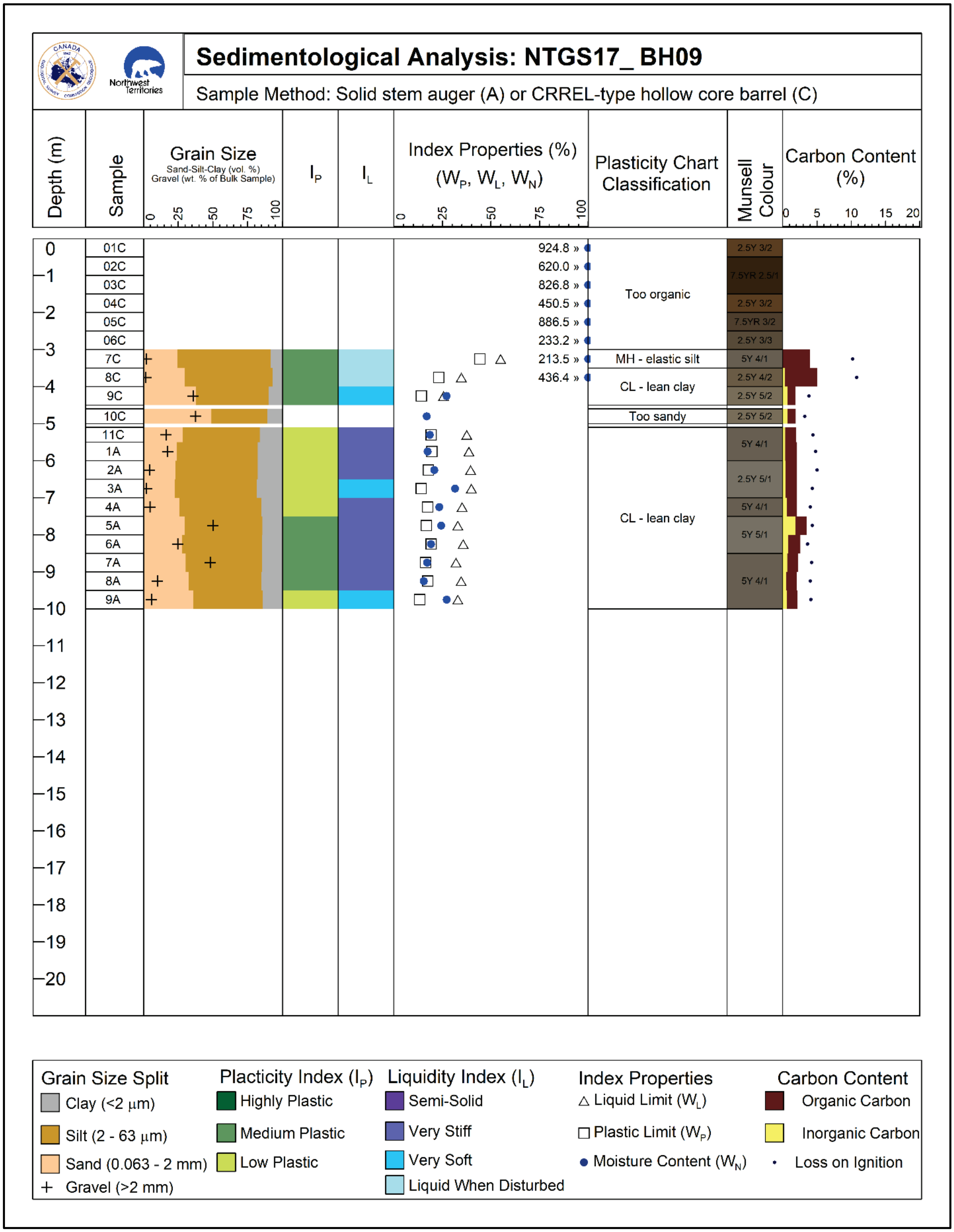


Figure 10i. Variation of sedimentological properties with depth at NTGS17-BH09 (HUS_R).

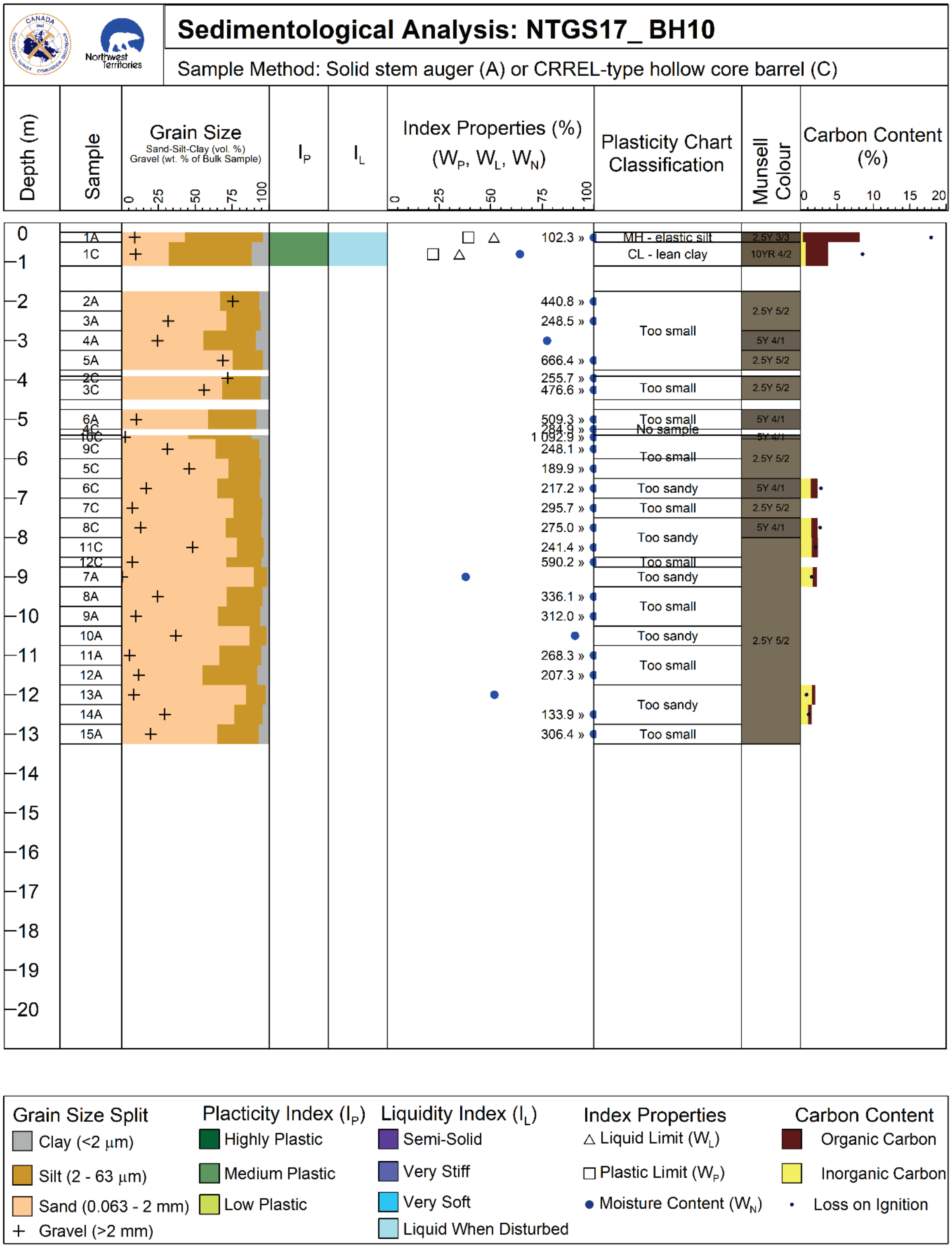


Figure 10j. Variation of sedimentological properties with depth at NTGS17-BH10 (TUK_H).

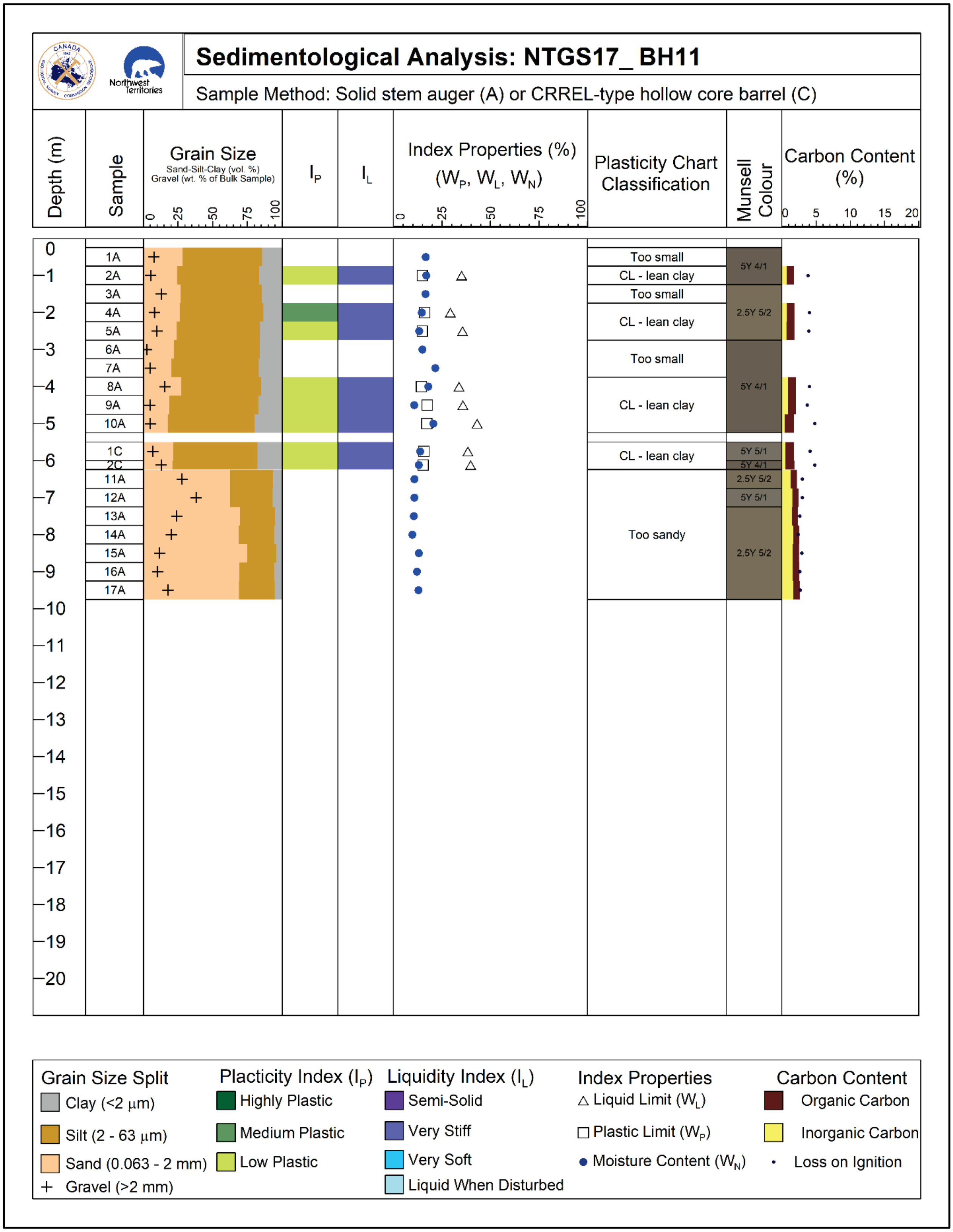


Figure 10k. Variation of sedimentological properties with depth at NTGS17-BH11 (177_Pit).

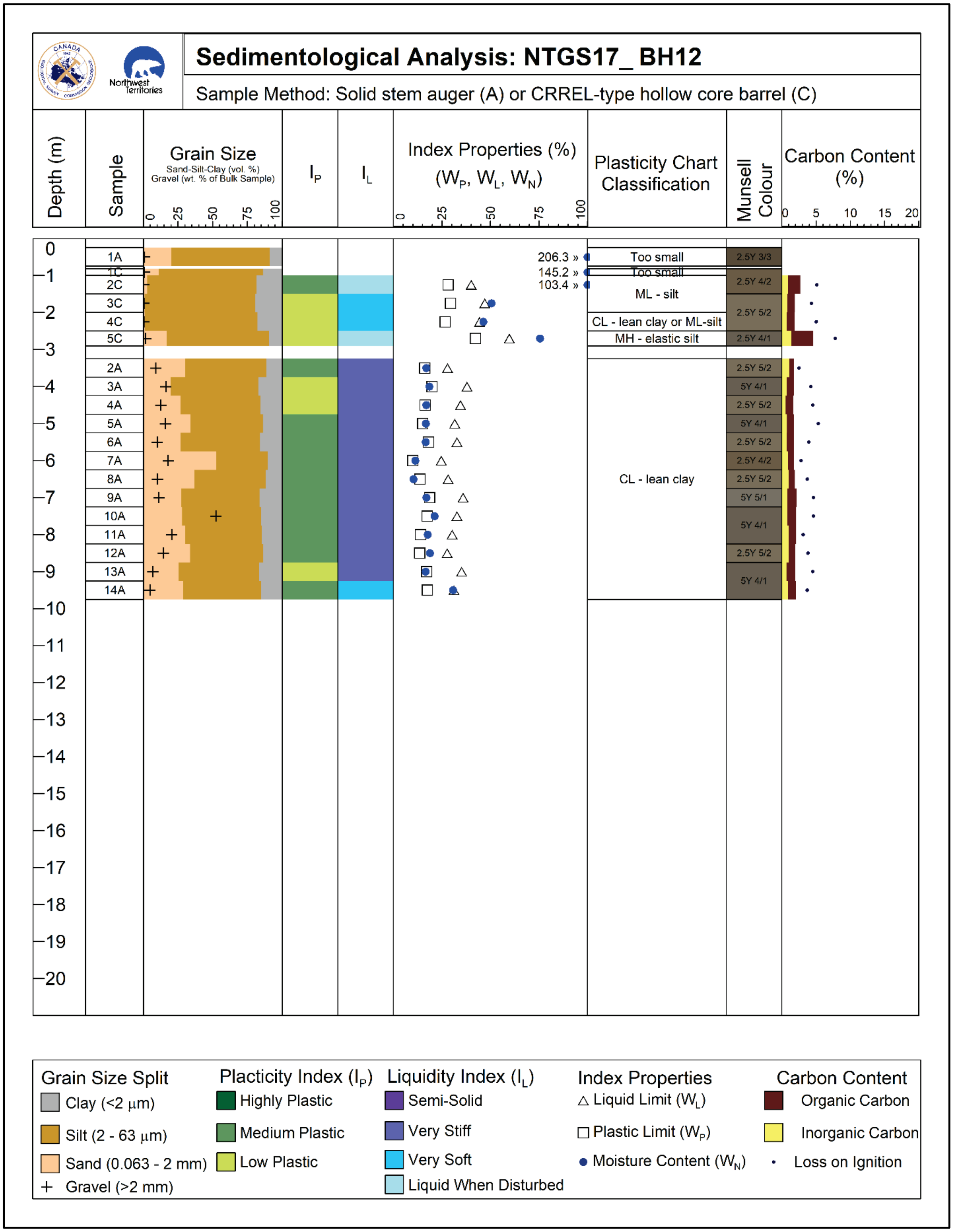


Figure 10l. Variation of sedimentological properties with depth at NTGS17-BH12 (177_Margin).

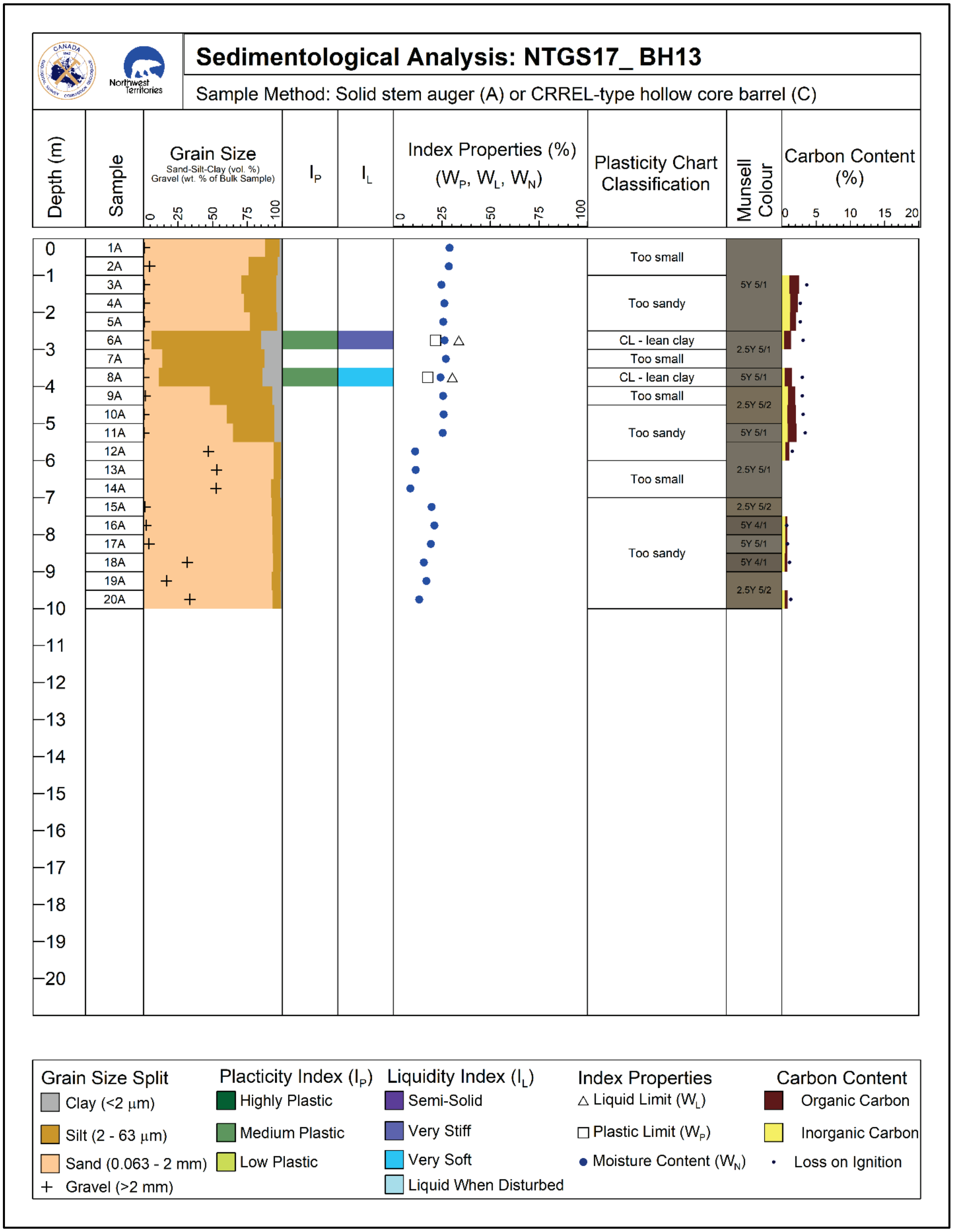


Figure 10m. Variation of sedimentological properties with depth at NTGS17-BH13 (312_Pit).

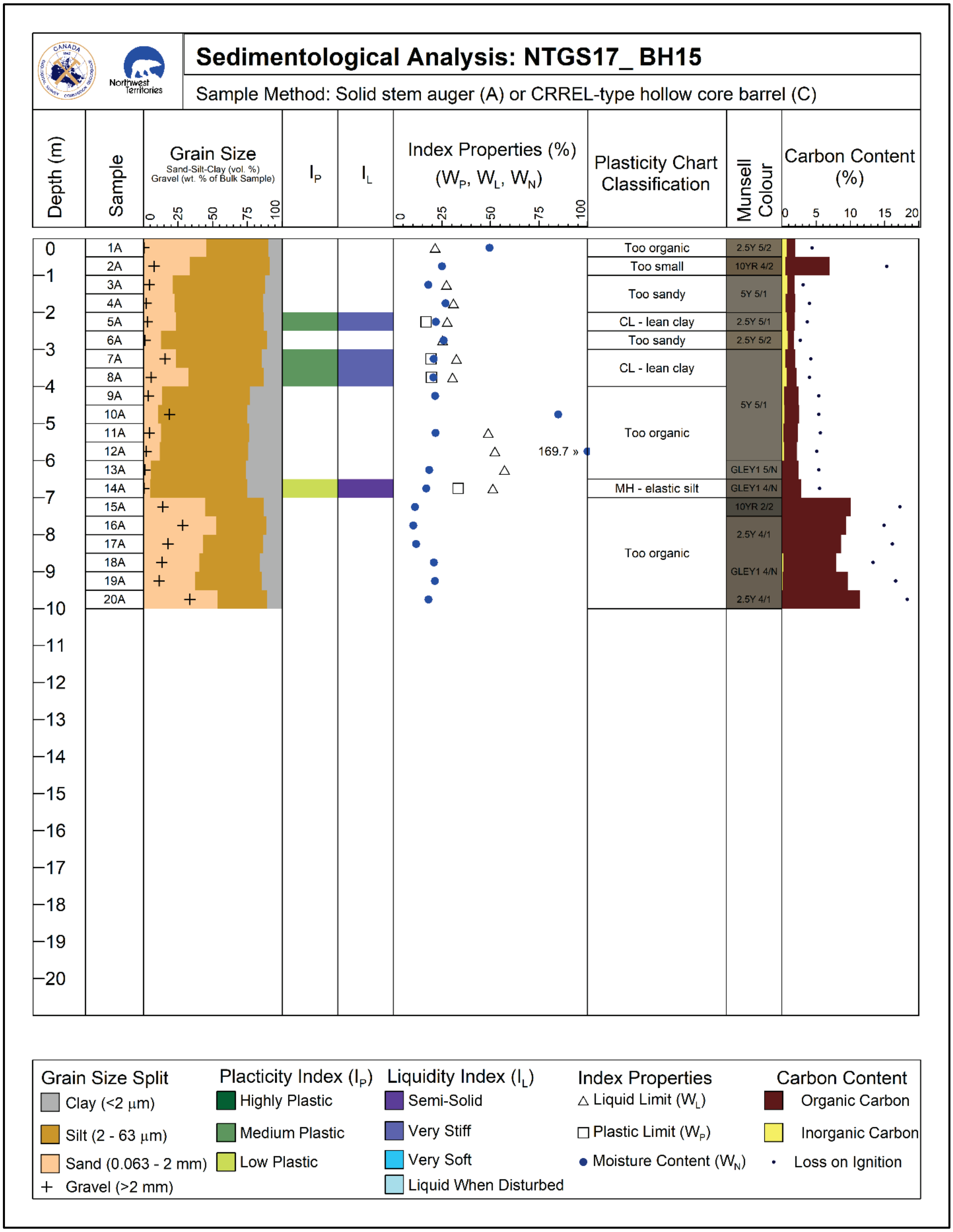


Figure 10n. Variation of sedimentological properties with depth at NTGS17-BH15 (I401A_Pit).

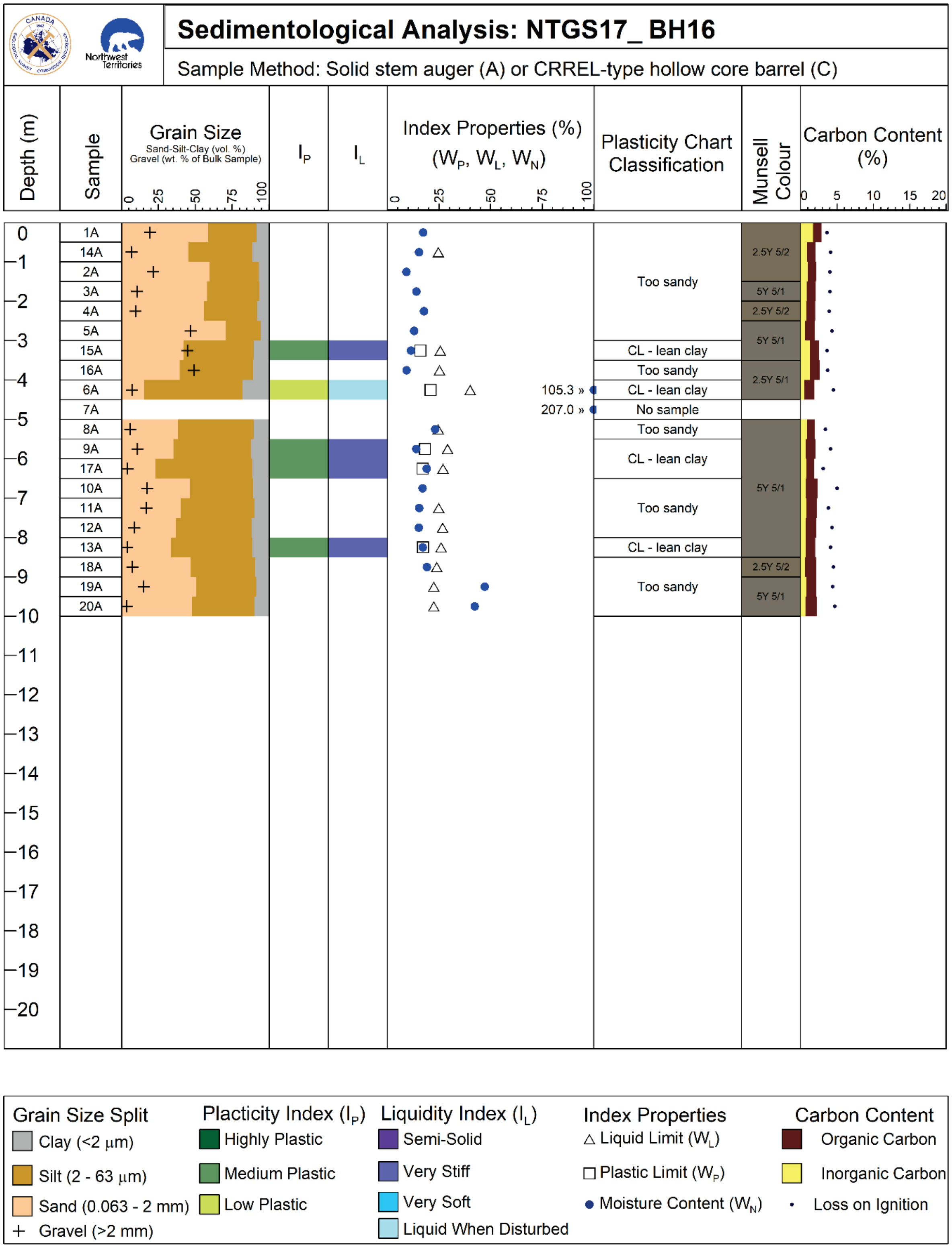


Figure 10o. Variation of sedimentological properties with depth at NTGS17-BH16 (I401A_Upper).

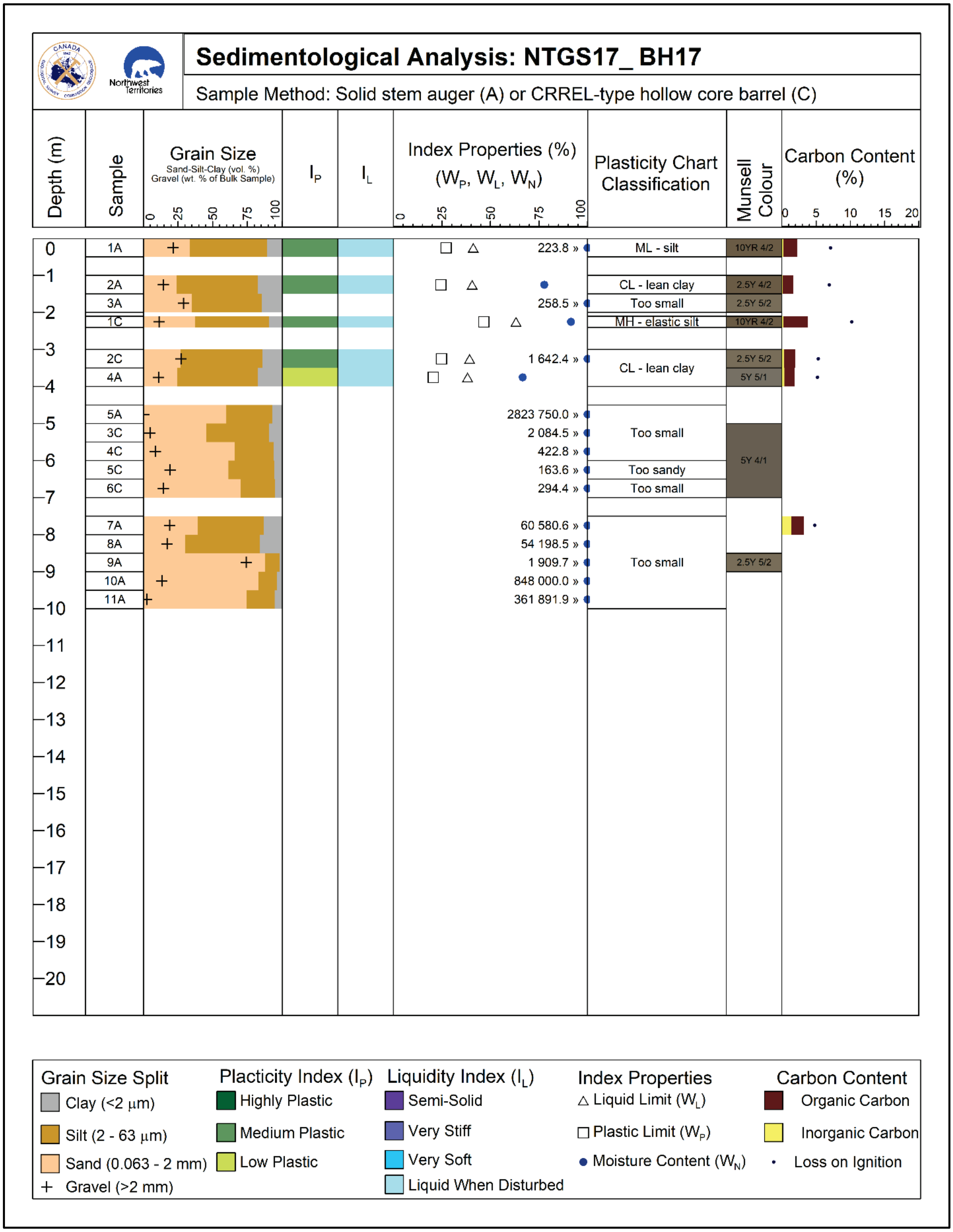


Figure 10p. Variation of sedimentological properties with depth at NTGS17-BH17 (HUS_Slump).

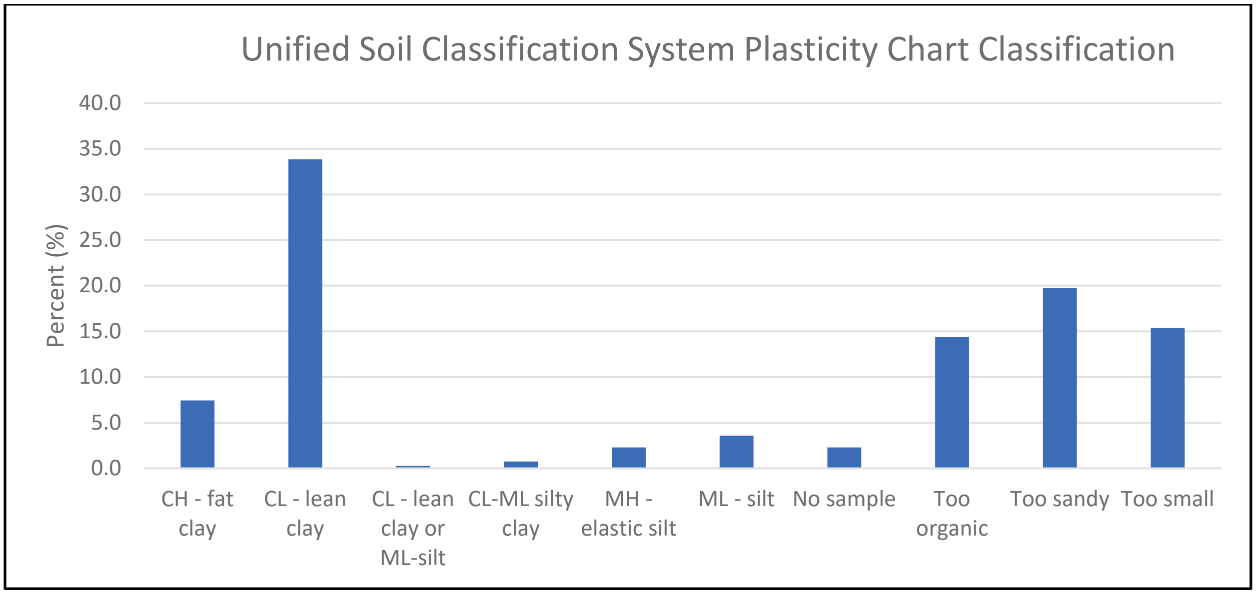


Figure 11. Distribution of Unified Soil Classification System plasticity chart classifications.

Soil geochemistry

Water chemistry

Sentinel boreholes were assessed for general water chemistry, which included conductivity, pH, DOC, and dissolved nitrogen (DN). Figures 12a through 12d present these parameters by depth, expressed using the mid-point of the sample depth interval (mid-depth). Solid points represent supernatant water (a solution that was released when permafrost samples were thawed), while hollow points represent pore water. Colours denote terrain type (hilltop, peatland, or riparian). Boreholes are grouped by latitudinal clusters (INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177)), displayed in a south to north sequence.

Conductivity values varied, ranging from 0 µS cm^{-1} to 4000 µS cm^{-1}, with higher values recorded from NTGS 8 (HUS_P) supernatant samples (Figure 12a). Conductivity appears to decline with depth, but the limited number of data points below 10 m hampers this interpretation. Sentinel borehole samples were marginally basic with most pH values around 7.5 to 8 (Figure 12b). Acidic values of 3.5 to 6 were observed in supernatant samples from NTGS 1 (INU_P) and NTGS 8 (HUS_P), and porewater samples from NTGS 5 (TVC_H). These acidic values do not appear to correspond with depth, landscape type, or latitude. Dissolved organic carbon concentrations were low to moderate and ranged from 0 mg C L^{-1} to 15 mg C L^{-1} (Figure 12c). Higher DOC concentrations were evident for peatlands between the depths of ~ 4 m and 6 m in NTGS 8 (HUS_P) and NTGS 4 (TVC_P). Dissolved organic carbon was higher in the top 3 m of NTGS 10 (Tuk_H) and NTGS 12 (177_Margin), and low for the remaining depths sampled. Dissolved nitrogen profiles are similar to DOC, with low concentrations of 0 mg N L^{-1} to 2 mg N L^{-1} for most boreholes throughout the stratigraphy (Figure 12d). The DN profile for NTGS 8 (HUS_P) had increased in concentrations at ~ 5 m in depth, corresponding to the increased DOC concentrations; this C and N alignment is muted for NTGS 1 (INU_P), and not evident for NTGS 10 (Tuk_H) and NTGS 12 (177_Margin).

Sentinel borehole samples were analysed for cation/anion concentrations, which are depicted using calcium (Ca; Figure 12e) and sulphate (SO_4; Figure 12f). Calcium values are variable and display similar profiles to conductivity (which is also a collective measure of ionic concentration). Variability in Ca is reduced at NTGS 10 (Tuk_H) and NTGS 12 (177_Margin), where Ca concentrations are low throughout the stratigraphy. While generally low in the NTGS 12 profiles, Ca concentrations are elevated in the top ~3 m consistent with conductivity, sulphate, and DOC. Overall, sulphate concentrations are less variable than Ca concentrations and conductivity values, but still have moderate concentrations of 0 mg SO_4 L^{-1} to 1000 mg SO_4 L^{-1}. Sulphate concentrations are highest for NTGS 2 (INU_H) porewater samples from ~ 15 m to 20 m in depth. This depth range may be a lacustrine deposit buried by an esker. Increased sulphate values for NTGS 4 (TVC_P) and NTGS 8 (HUS_P) align with the increased DOC concentrations, which are loosely reflected in Ca concentrations and conductivity values.

Despite slightly reduced variability for the Pit 177 cluster boreholes, most of these parameters display comparable results across site clusters (Inuvik Region, Trail Valley Creek, Husky Lakes, and Pit 177), suggesting there is little to no effect from a latitudinal gradient. The water chemistry results are also similar between the different landscape types, except for acidic peatlands that had increased ions, DOC, and DN concentrations.

Metals analysis

Sentinel borehole supernatant and porewater samples were analysed for a suite of trace metal concentrations. Arsenic concentrations were mostly low, with moderate concentrations of ~ 10 µg As L^{-1} for INU, TVC, and HUS sites between ~2 m and 5 m in depth (Figure 12g). There is a high concentration of arsenic in the porewater from NTGS 8 (HUS_P) at ~ 5 m depth. Iron concentrations are generally low but are higher in the supernatant samples from depths <5 m at NTGS 1 (INU_P), NTGS 7 (HUS_H), and NTGS 8 (HUS_P) (Figure 12h).

Soil carbon analysis

Soil organic carbon (SOC) is ~ 4% in the top 5 m, and ~ 1.5% for the remaining depths (Figure 12i). The highest measured SOC (~ 8%) was in the top metre of NTGS 10 (TUK_H). Soil organic carbon values are similar for all landscape types, with slightly reduced values for hilltops in most site clusters. Soil inorganic carbon (SIC) is slightly lower than SOC, with values of ~ 1% throughout the borehole stratigraphy (Figure 12j). There are increased SIC values of ~ 5% from NTGS 8 (HUS_P) in the top ~ 2 m, with concentrations declining to ~ 1% for depths below.

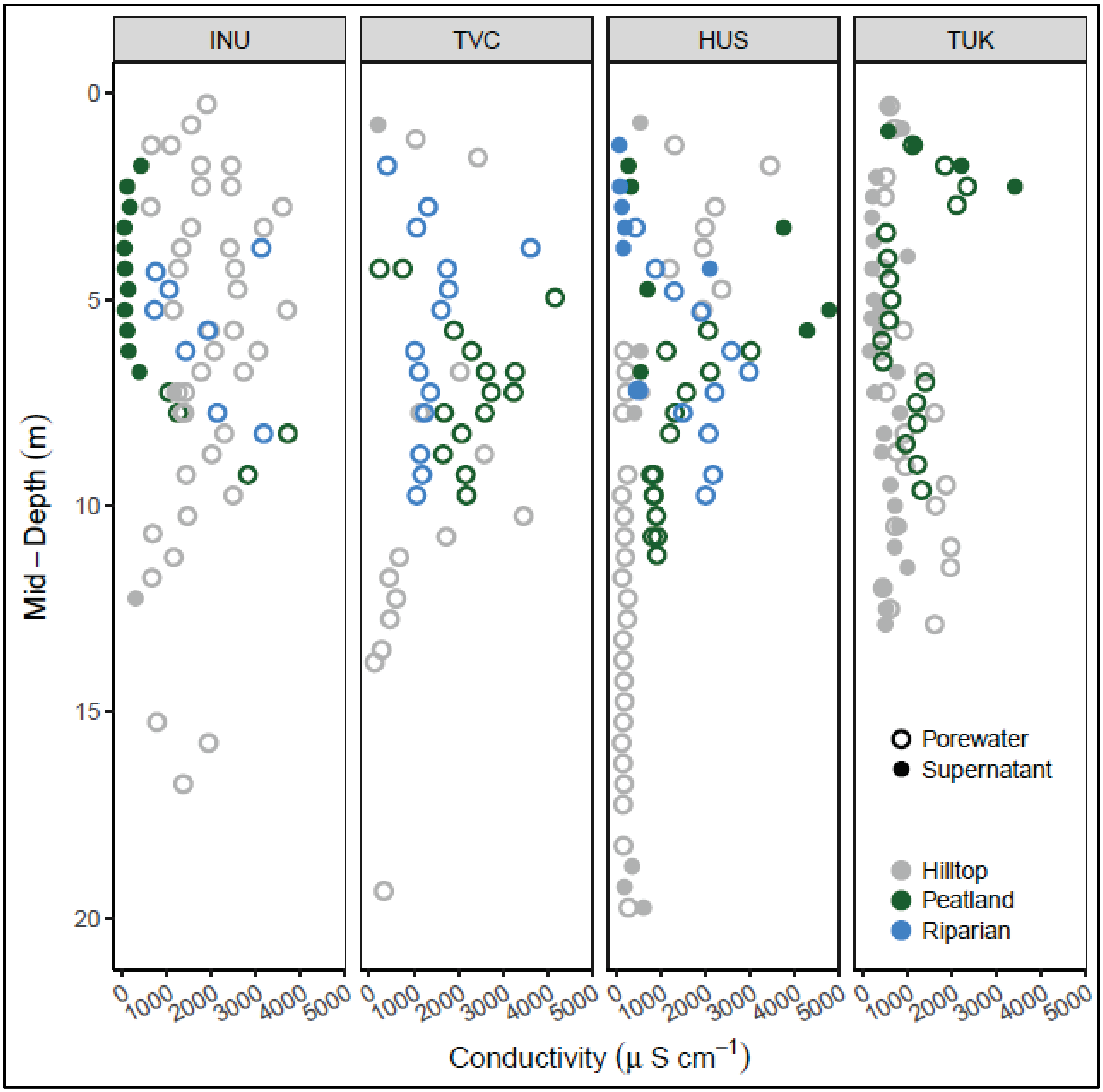


Figure 12a: Stratigraphic plots for the conductivity of Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

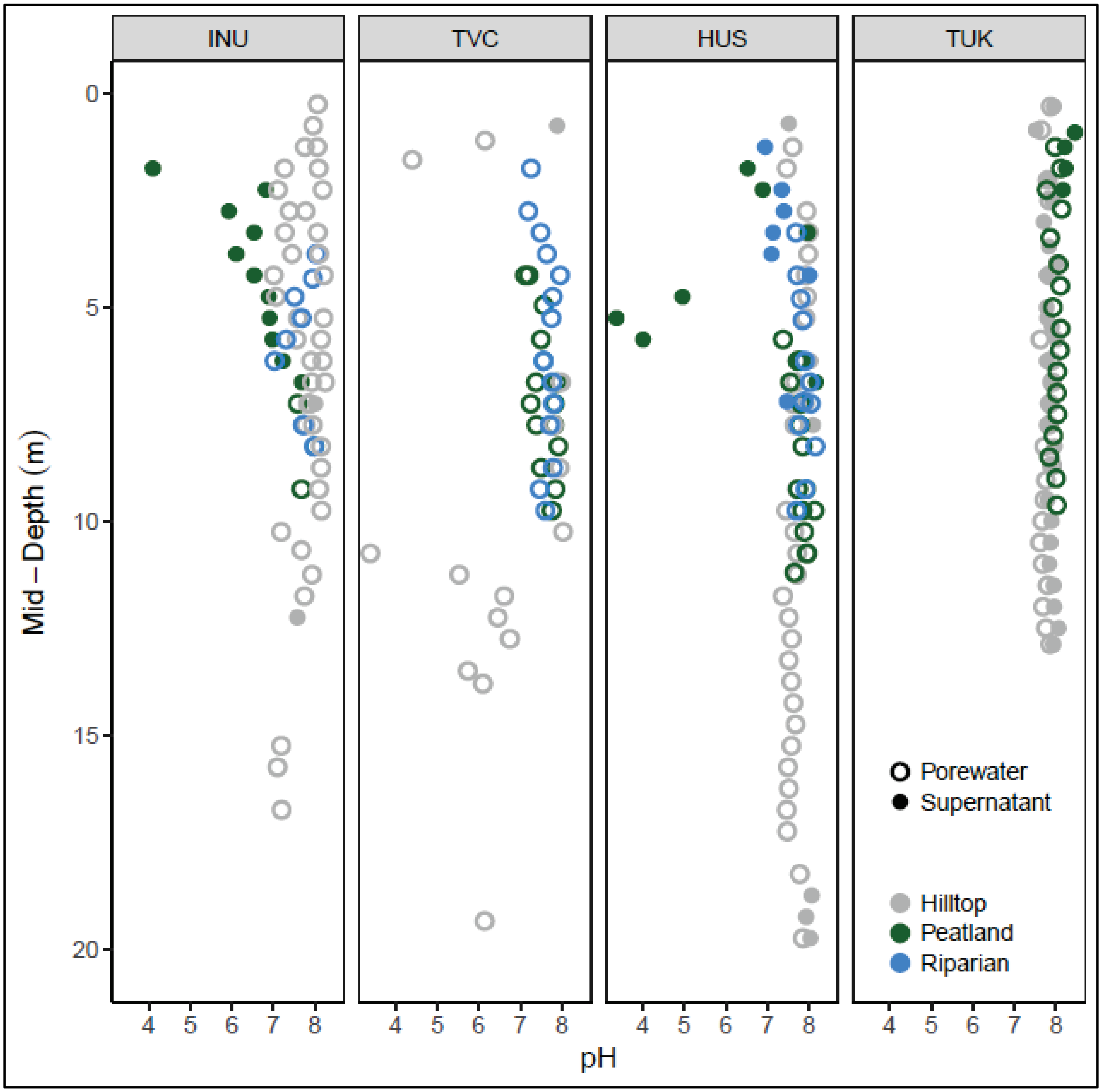


Figure 12b: Stratigraphic plots for pH at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

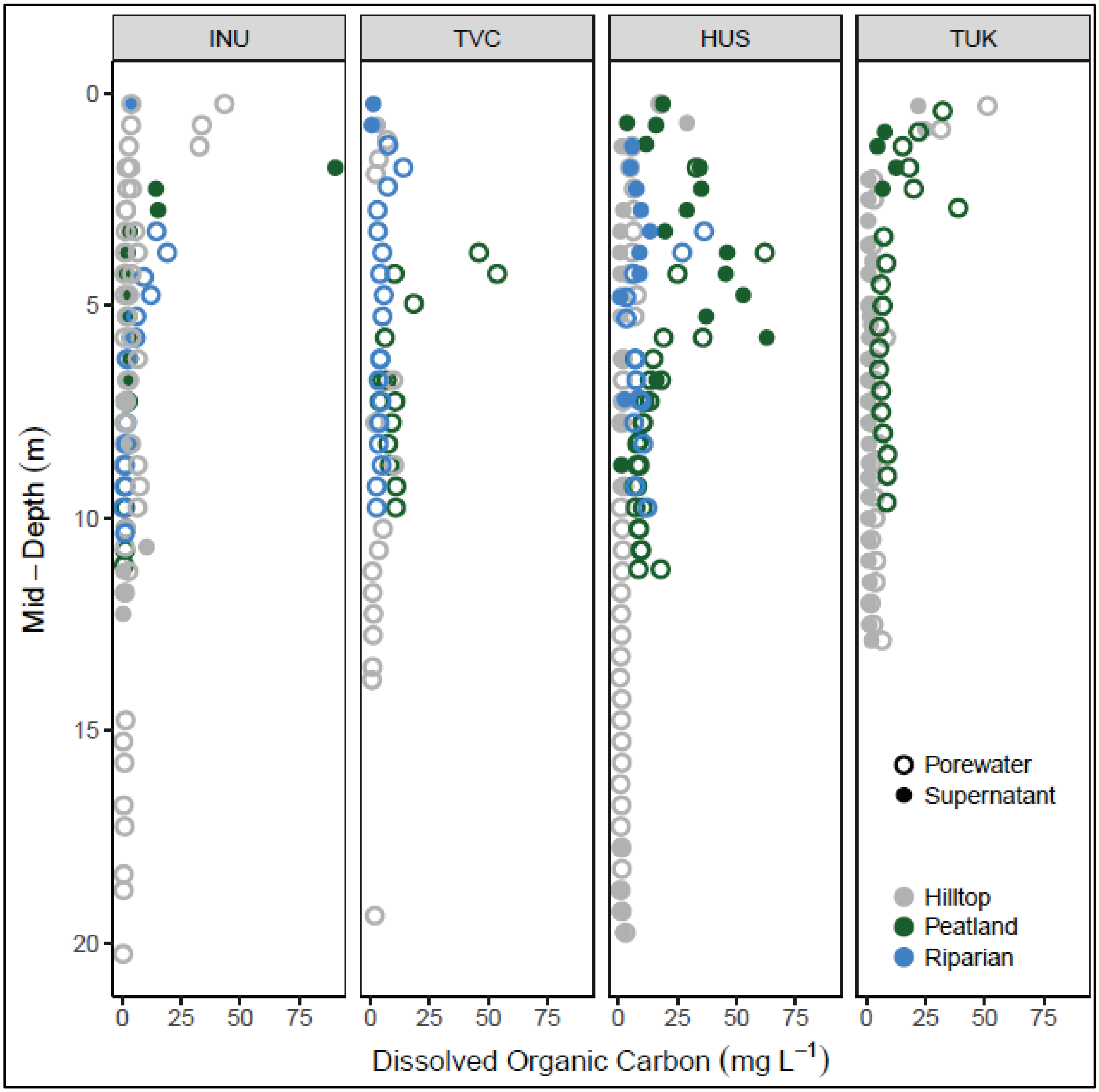


Figure 12c: Stratigraphic plots for dissolved organic carbon (DOC) at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

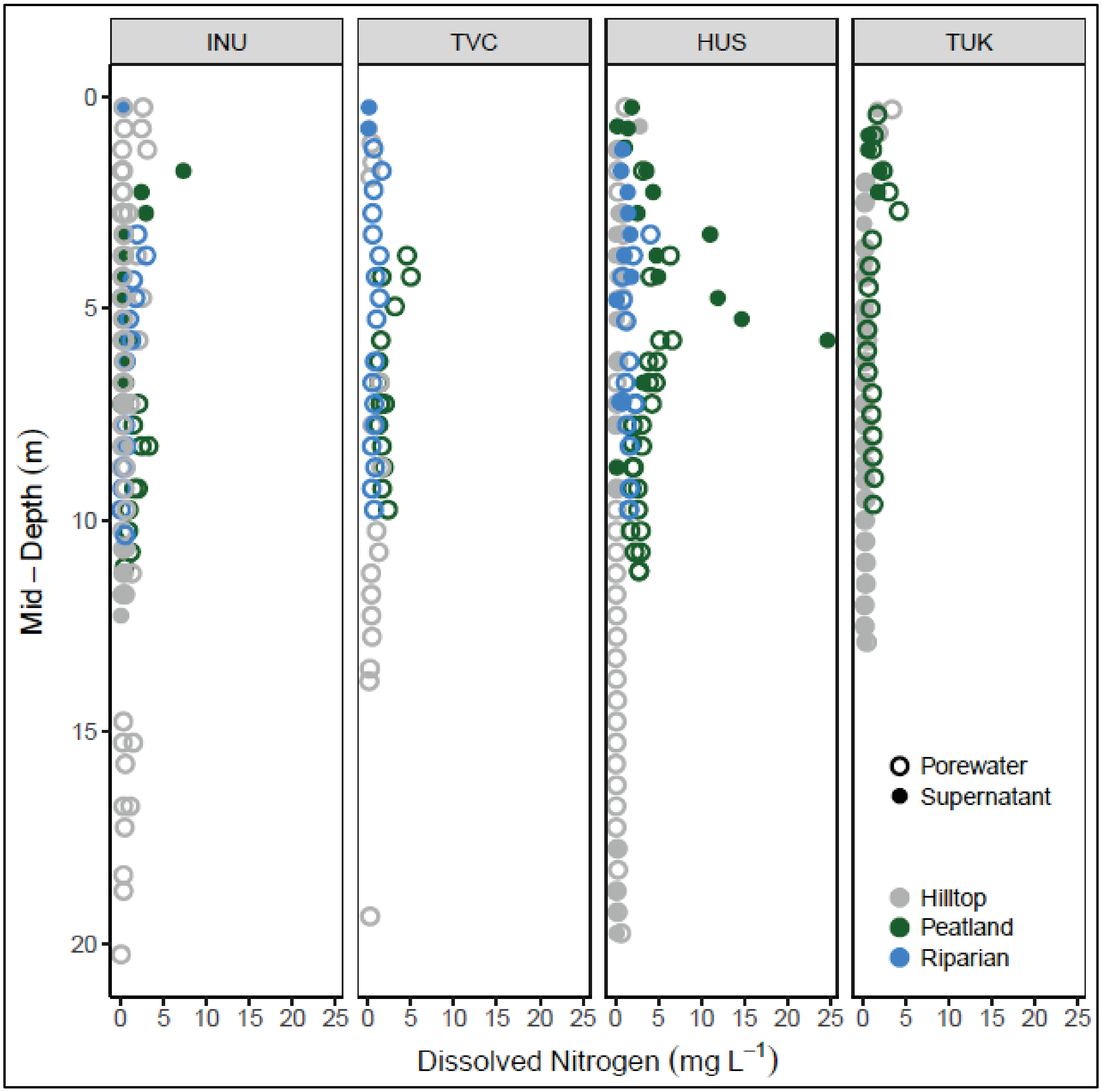


Figure 12d: Stratigraphic plots for dissolved nitrogen (DN) at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

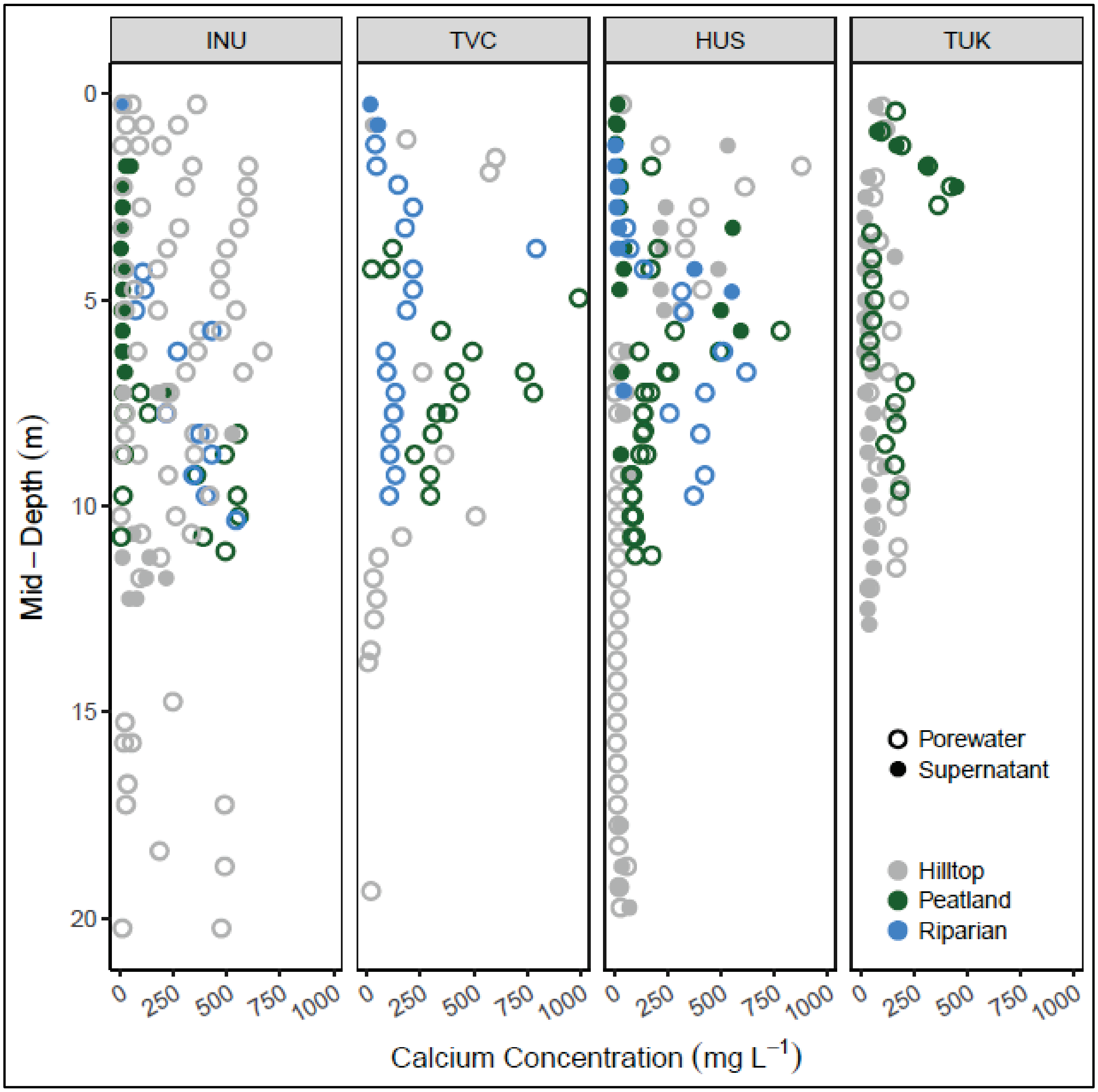


Figure 12e: Stratigraphic plots for calcium concentration (Ca) at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

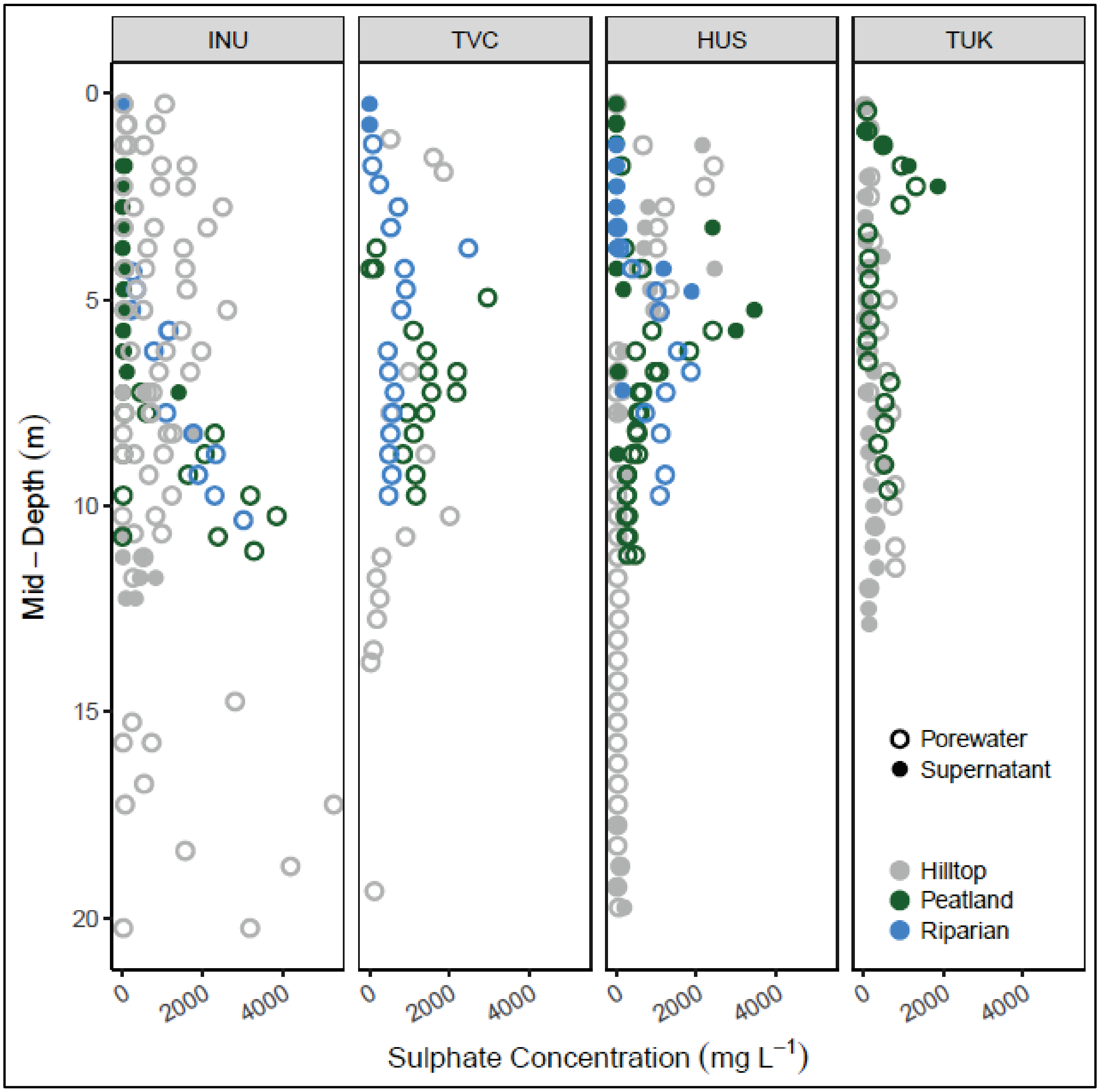


Figure 12f: Stratigraphic plots for sulphate concentration (SO_4) at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

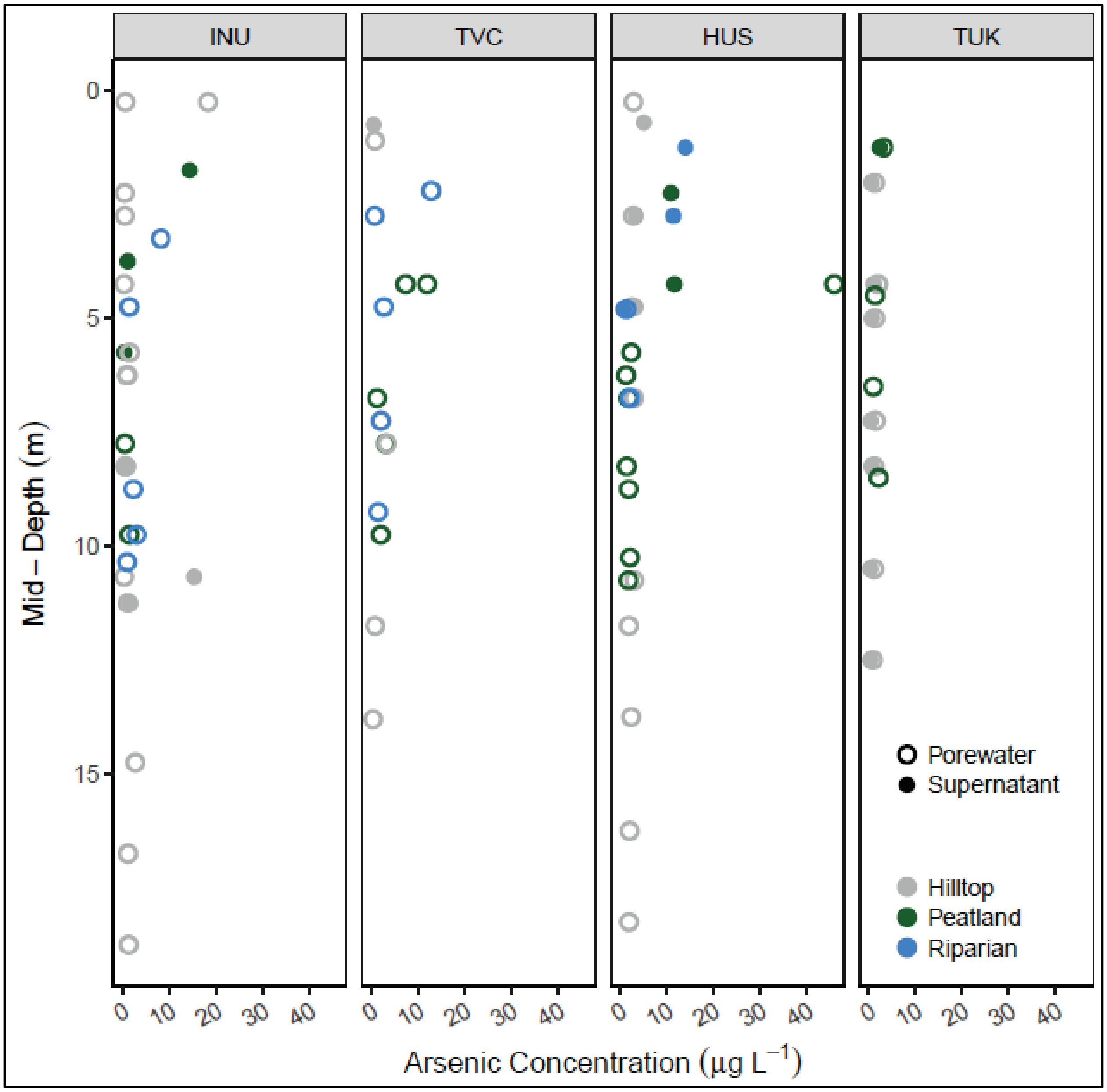


Figure 12g: Stratigraphic plots for arsenic concentration (As) at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

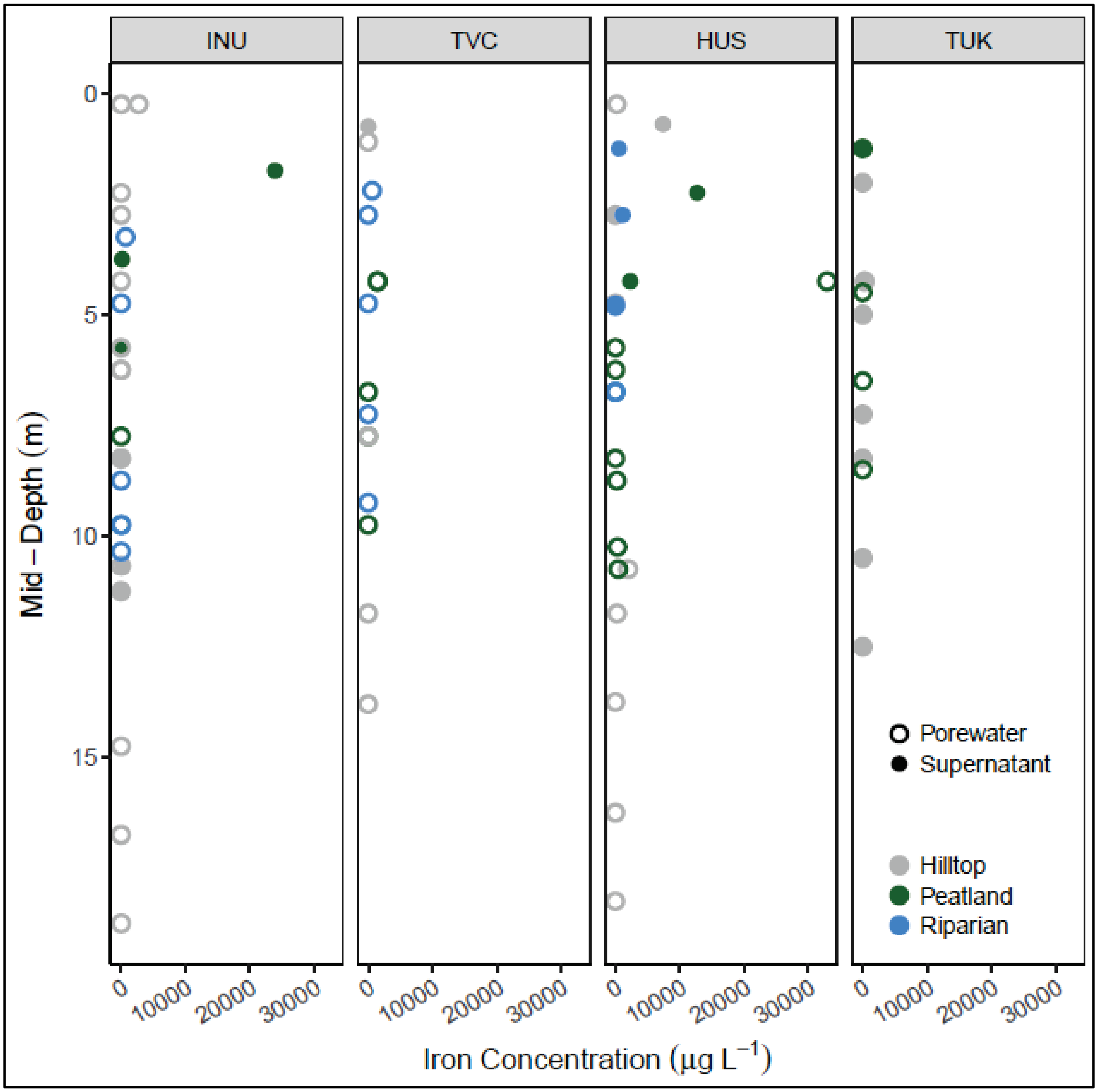


Figure 12h: Stratigraphic plots for iron concentration (Fe) at mid-depth for the Sentinel boreholes. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

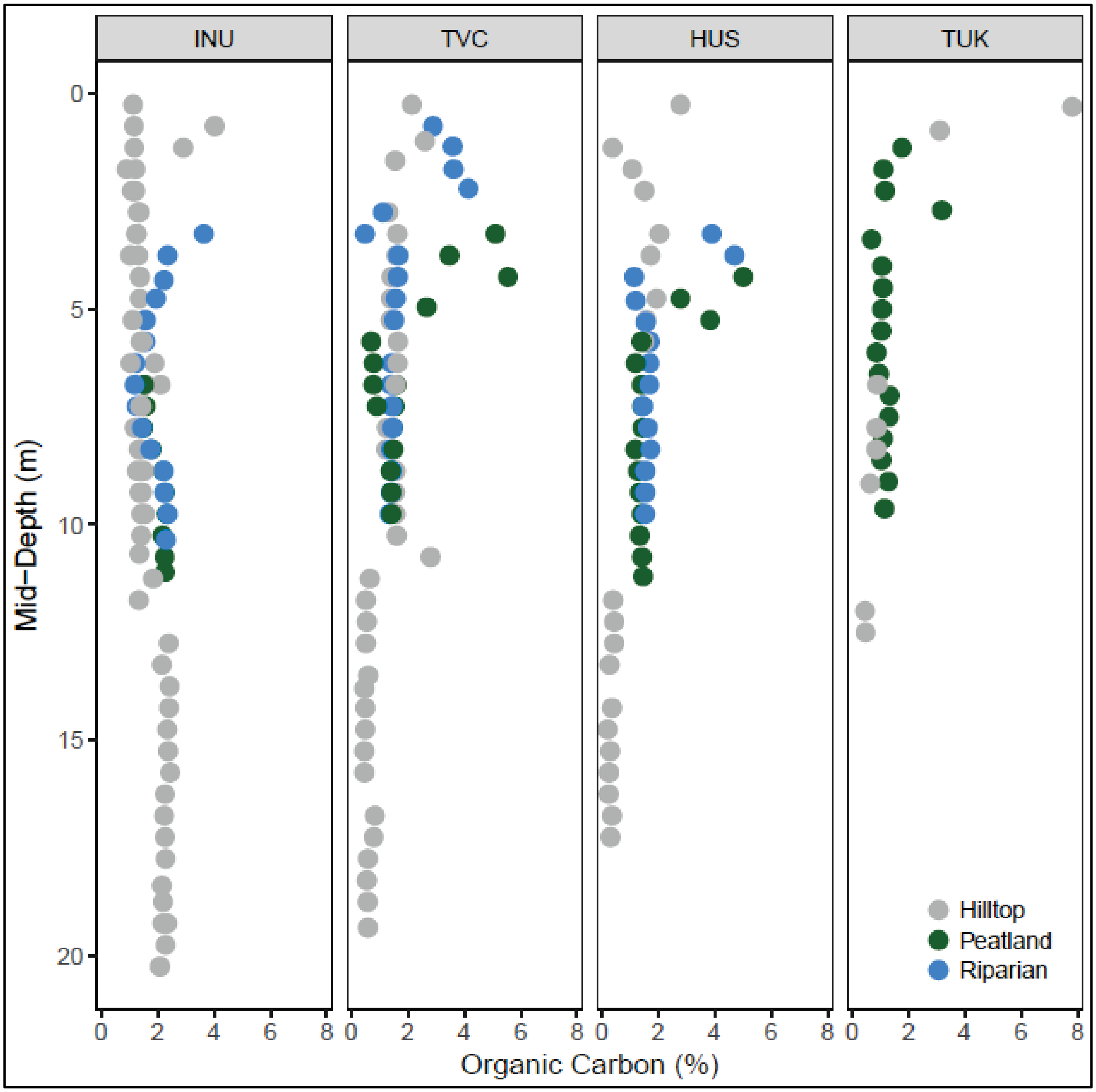


Figure 12i: Stratigraphic plots for organic carbon at mid-depth for the Sentinel boreholes. Points represent the concentration of organic carbon in soil samples. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

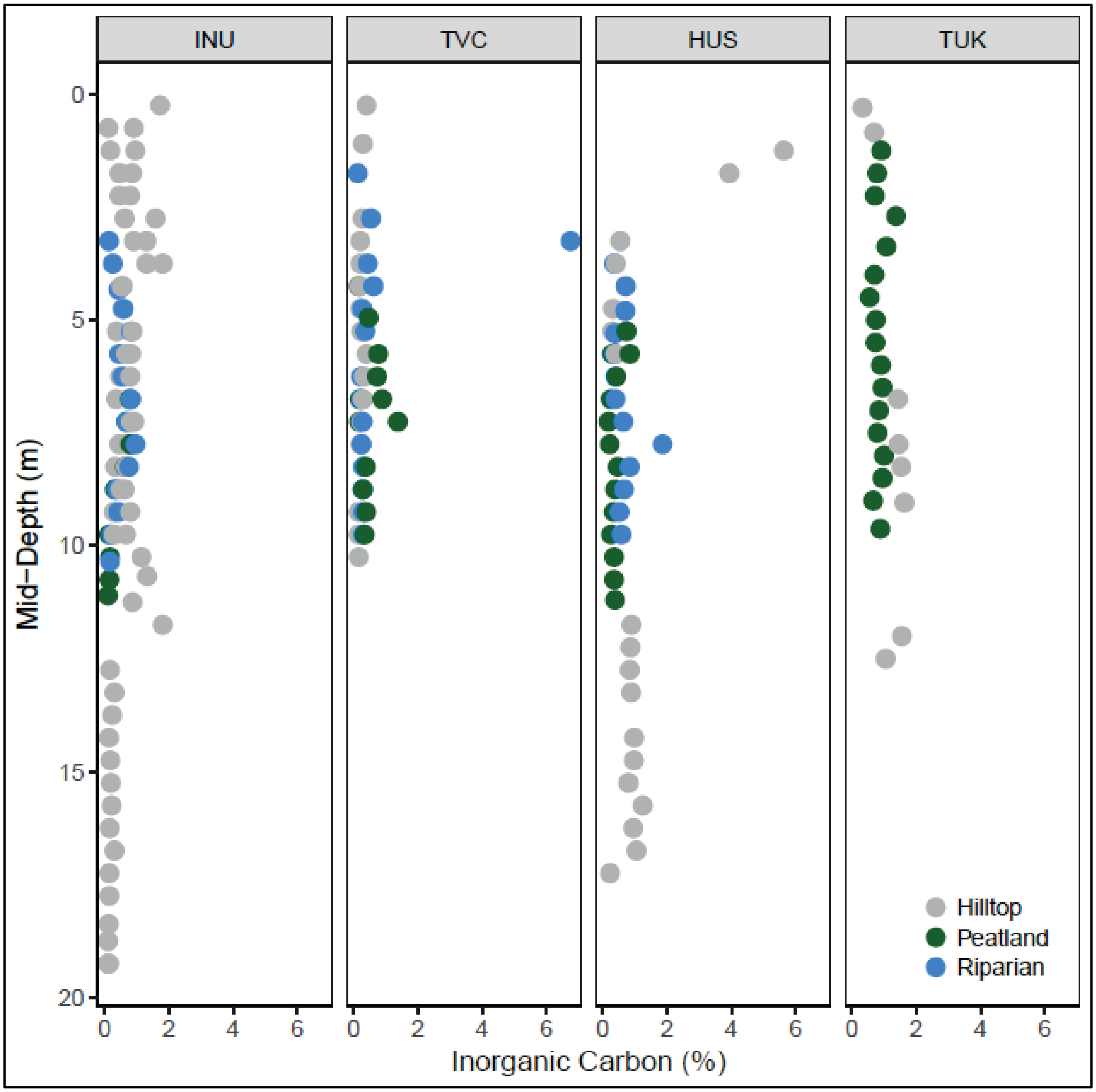


Figure 12j: Stratigraphic plots for inorganic carbon at mid-depth for the Sentinel boreholes. Points represent the concentration of inorganic carbon in soil samples. INU=Inuvik, TVC=Trail Valley Creek, HUS=Husky Lake, and TUK=Tuktoyaktuk (same cluster as Pit 177).

Stratigraphic plots for the water quality parameters, metals, and soil carbon parameters shown in the Figure 12 series are presented in Appendix F separately for each Sentinel borehole, including the Pit I401A, 312, and 177 sites. Additional metals and ionic concentrations are also presented.

Additional data analysis

Further analyses of the data presented in this Open Report by existing and new collaborators and stakeholders are likely to provide additional interpretations of data and to contextualise results within the existing literature on regional Quaternary sedimentology, geochemistry, and permafrost distribution. Two current activities are outlined here.

Extraction of stratigraphic ground ice data

The raw geotechnical borehole data collected between 2012 and 2017 along the Inuvik-Tuktoyaktuk Highway, in addition to boreholes used to assess granular resources (Kavik-Stantec 2012b-f, 2013a-q, 2014a-d) are being processed to extract information relevant to ground ice content and characteristics. This cryostratigraphic data set will include data on the stratigraphy of materials using ASTM-D2488 (Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)), whether the materials were frozen, and the reported visible ice content and information on cryostructures extracted from each borehole log using ASTM-D4083 (Standard Practice for Description of Frozen Soils (Visual-Manual Procedure)). Additionally, an estimate of gravimetric ice and excess ice content for each visible ice class will be derived using material samples collected from these geotechnical boreholes (2012-2017) and which were processed for water content using ASTM-D2216 (Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass).

Variables derived from this cryostratigraphic data set will be processed and plotted using a set of functions written in R. These variables will include the materials found above and below layers of massive ice as this stratigraphic context can be used to interpret origins. Massive ice occurring at lithostratigraphic boundaries suggests a segregated and intrasedimental origin (Mackay 1971; Mackay and Dallimore 1992) whereas buried ice is more closely associated with melt-out tills and morainic deposits (Mackay 1973).

The derived variables will also summarise stratigraphic data for each borehole and include information on surficial geology, depth to massive ice and excess ground ice content within defined depth intervals. These variables will be used to explore relationships between ground ice characteristics and latitudinal gradients as the alignment of the ITH is parallel to a regional climatic gradient controlled by latitude and proximity to the Beaufort Sea (Burn 1997) which results in the spatial variability of soils, vegetation, topography, and snow cover (Kokelj *et al.* 2017). Exploring these links will help us gain further insight on the distribution, characteristics and origins of ground ice and excess ground ice along the ITH.

The datasets, methods, and R package will be made available and described in length in a future manuscript as part of a Ph.D. project with Carleton University for reproducibility and so that additional geotechnical borehole data may be used to add to the dataset.

Stable isotope composition

Analyses of the deuterium (^2H) and oxygen-18 (^{18}O) composition of supernatant and pore water from sediment samples are ongoing. This work has the potential to inform investigations of palaeoclimatology, Quaternary sedimentology, and watershed geochemistry.

Geotechnical data compilation

Geotechnical metadata and data for the boreholes summarised in this report were compiled using the format for the Northwest Territories Geotechnical Database and are provided by Ensom and Kokelj (2020) and Rudy *et al.* (2020a; b). The format and fields for the metadata compilation were based in part on recommendations by Tetra Tech Ltd. (2017). Appendix G provides Sentinel site data obtained through aggregate and core processing activities ARI in Inuvik by the Sentinel research team in February and March of 2017.

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Appendices

Appendix A: Geotechnical Borehole Summary

Appendix B: Sentinel Data

Appendix C: Detailed Sentinel Laboratory Procedure

Appendix D: Detailed Sentinel Sedimentological Results

Appendix E: Detailed Quantitative X-Ray Diffraction Analyses – Sentinel Program

Appendix F: Ion, Metal, and Water Chemistry Stratigraphic Plots – Sentinel Program

Appendix G: Geotechnical Data Compilation

Appendix H: Bridge Piling Hole Logs

Appendix I: Figure I1

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