R.M.HARDY & ASSOCIATES LTD.

000038

GEOTECHNICAL INVESTIGATION
PROPOSED BRIDGE SITE
CANYON CREEK, MILE 620.4
MACKENZIE HIGHWAY
E-2510
OCTOBER 16, 1973

R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING ● GEOTECHNICAL DIVISION

File No. E-2510

October 16, 1973

Mr. F. E. Kimball, P.Eng.,
Manger of Northern Roads Program,
Department of Public Works of Canada,
One Thornton Court,
Edmonton, Alberta.

Re: Geotechnical Investigation
Mackenzie Highway, Proposed Bridge Site
Canyon Creek, Mile 620.4

Dear Mr. Kimball:

We are pleased to submit a report on the site of the proposed bridge across Canyon Creek.

Should you wish for any explanation or amplification of any part of this report we will be pleased to be at your service.

Respectfully submitted,

R. M. HARDY & ASSOCIATES LTD.,

Per:

GM/jc

G. McCormick, P.Eng.

10214 - 112 STREET, EDMONTON, ALBERTA T5K 1M5 PHONE (403) 426-0405
CONSOLIDATING THE SERVICES OF: R. M. HARDY & ASSOCIATES LTD., MATERIALS TESTING LABORATORIES LTD. & NON DESTRUCTIVE INSPECTION LTD.
BURNABY CALGARY DAWSON CREEK EDMONTON LETHBRIDGE PRINCE GEORGE RED DEER WINNIPEG

INTRODUCTION

At the request of Mr. F. E. Kimball, P.Eng., Manager of Northern Roads Program, Department of Public Works of Canada, Western Region, R. M. Hardy & Associates Ltd. undertook a geotechnical investigation along part of the proposed location of the Mackenzie Highway. This report deals only with that part of the investigation appertaining to the proposed bridge at Canyon Creek.

The location of this bridge site is shown on mocaic sheet No. 50 of the set of mosaics prepared by the Department of Public Works for the Mackenzie Highway work. The site is covered by aerial photographs No. A22773-159 and 160 (scale 1" = 1000'). In addition to the mosaics and aerial photographs, R. M. Hardy & Associates Ltd. was provided with a sketch plan profile showing the crossing. This drawing is entitled "Plan and Profile Showing Drainage Structure at Canyon Creek" and is not dated. It was used as the basis for Plate 1, Appendix A.

A report entitled "Geotechnical Investigations, Mackenzie Highway, Mile 544 to 635" has been previously submitted to the Department. The geotechnical conditions are discussed in Volume I while Volume II contains information on permafrost of a more general nature.

We recommend that these volumes be read in conjunction with this report.

TOPOGRAPHY

The general direction of the drainage in the area is southwesterly towards the Mackenzie River. The valley walls of Canyon Creek are very low on the southerly approach but are quite steep on the northerly side. On the southerly approach, the existing ground profile climbs 10 feet vertically in a horizontal distance of 700 feet while on the northerly approach the profile climbs 50 feet in a horizontal distance of 400 feet. The width of the creek at the water line is about 50 feet.

SOIL PROFILE

The soil profile on the southerly approach consists of glacial lake basin deposits overlying basal till. On the north approach the soils consist of basal till covered with a thin covering of slopewash. The valley walls have been classified as eroded slopes while the floor of the valley has been classified as an alluvial meander plain. Test Holes 936 and 937 were drilled on the southerly approach and Test Holes 938 and 939 were drilled on the northerly approach. The logs of the holes are in Appendix A.

The soils in Test Holes 936 and 937 consist of gravel, sand and silt overlying the basal till. The till was encountered at depths of 12 and 10 feet respectively in these test holes. Water and ice contents are high in the top four feet of the soil profile but are fairly low, below 15 percent, below that depth. In Test Hole 937, water seepage was encountered at the 11 foot depth.

The ground was frozen for the entire depth of the test hole at Test Hole 936. In Test Hole 937 the depth of frozen ground was 8 feet while the ground below this depth was unfrozen.

The soil profile in Test Hole 938 consists of gravel and silt to a depth of 4 feet overlying the basal till. The till consists of silty clay to a depth of 28 feet below which there are alternating layers or gravel, sand and silt. Water contents in the soil at this test hole were all below 30% with some samples showing water contents of less than 10%. Ice contents were also low with only small amounts of visible ice be reported.

The soil profile in Test Hole 939 consisted of silt to a depth of two feet overlying basal till which consists of a silty clay. Water contents generally ranged between 20 and 30 percent except at the four foot depth where the value is 50%. A thin unfrozen layer of soil was encountered in this test hole at the 11 foot depth.

DISCUSSION AND RECOMMENDATIONS

The effect of a stream on a permafrost profile is shown on Plate 2, Appendix A. This chart shows that the thaw bulb beneath a small creek can penetrate to considerable depths so that, for bridge purposes, the presence of permafrost beneath the stream bed can be ignored. However, it should be noted that permafrost profile beneath the sides of the stream bed plunges at an extremely steep angle.

As is well known the flow of water in northern streams varies tremendously throughout the year. Very large flows can be experienced during the spring runoff so that some scour should be expected. The amount will depend on the flow of water, the constriction imposed on the stream by the bridge, and the width of piers (if any). Some erosion of the banks is also possible.

As stated above, the existing gradient on the northerly approach is very steep. We do not recommend using a cut section on this approach to reduce the gradient. We believe the side slopes in such a cut would be unstable due to the high ice contents in the silty clay. If a cut is not used the elevation of the bridge deck will have to be raised in order to bring the gradient on the north approach within acceptable limits.

Because of the soil and permafrost conditions in the valley walls in the approach areas to this bridge site, we do not believe it would be advisable to use concrete abutments. Also, we do not recommend piers founded on concrete spread footings in the stream bed. We therefore recommend that the abutments and any piers be supported on driven steel H-piles. It is extremely unlikely that timber piles could be driven at this site without damaging them severely. Precast concrete piles should not be used due to difficulties of transportation and also because the length of the precast piles would have to be determined in advance. Steel pipe piles are not recommended because it is doubtful that they would be able to withstand the driving stresses.

Steel H piles which are to be placed on the banks where they will not be affected by scour should be driven a minimum of 30 feet below existing grade and designed on the basis of an allowable skin friction of 800 psf (on the gross perimeter) with the top 10 feet of pile being assumed to carry no load.

Steel H piles driven in the stream bed should be driven a minimum distance of 20 feet below the bottom of anticipated scour and should be designed on the basis of the "Table of Penetration Resistance" following. Design parameters are summarized on Plate 3, Appendix A. Where bedrock is encountered, the piles should be driven 10 feet into bedrock.

In driving steel H piles the weight of the pile driving hammer should be at least twice the weight of the pile being driven except where a diesel hammer is used when the weight of the hammer should be at least equal to the weight of the pile. To prevent damage to the points of the pile they should be reinforced with flange plates for a distance equal to 1.5 times the size of the pile. Alternatively, the point can be reinforced with a driving shoe. Piles should be driven to practical refusal or refusal according to the following table of penetration resistances assuming that the hammer delivers an energy of 15,000 ft. pounds per blow.

TABLE OF PENETRATION RESISTANCE

Description	Inches Per Blow
refusal	.00-.05
practical refusal	.05-.25
high resistance	.25-.50
medium resistance	.50-1.25

In order to ensure that refusal has been reached, driving should be continued for at least 100 blows after refusal is first recorded.

Piles driven to refusal in the stream bed, as defined above, may be designed for the full structural strength of the pile section acting as a column. The design load will depend upon allowable stresses in the pile, column length and the arrangement of natural bracing. Piles driven to practical refusal, as defined above, should be designed for two-thirds of the value permitted for the pile as a structural column. Consideration should be given to using battered piles on the outside of the pile bents in order to provide lateral resistance.

If a drop hammer is used in driving the piles, care should be taken that the energy delivered to the pile is not greater than 15,000 ft. pounds per blow unless calculations show that the pile can safely take higher impact stresses. As mentioned above, bedrock may be encountered before the design depth is reached. In such a case, the piles should be driven into the bedrock a distance of 10 feet.

One of the problems facing bridges in this area is the possiblity of logs jams occurring which can cause partial or complete failure of the bridge. Log jams are only likely to occur where trees travelling down the river have a greater length than the clear span of the bridge. We suggest that the height of trees growing adjacent to Canyon Creek upstream of the bridge should be checked and, should it be observed that there is a possibility of large trees being washed downstream, such facts should be borne in mind by the bridge designer. If piles are used to support vertical faces of embankment fill, the lateral force against the pile can be computed by assuming the backfill to be a fluid with a density of 60 pounds per cubic foot where the backfill is not compacted.

Embankments constructed below the highest expected flood level should be protected with riprap. As suitable rock may not be available, sandbags filled with concrete may have to be used.

Respectfully submitted,
R. M. HARDY & ASSOCIATES LTD.,

G. McCORMICK

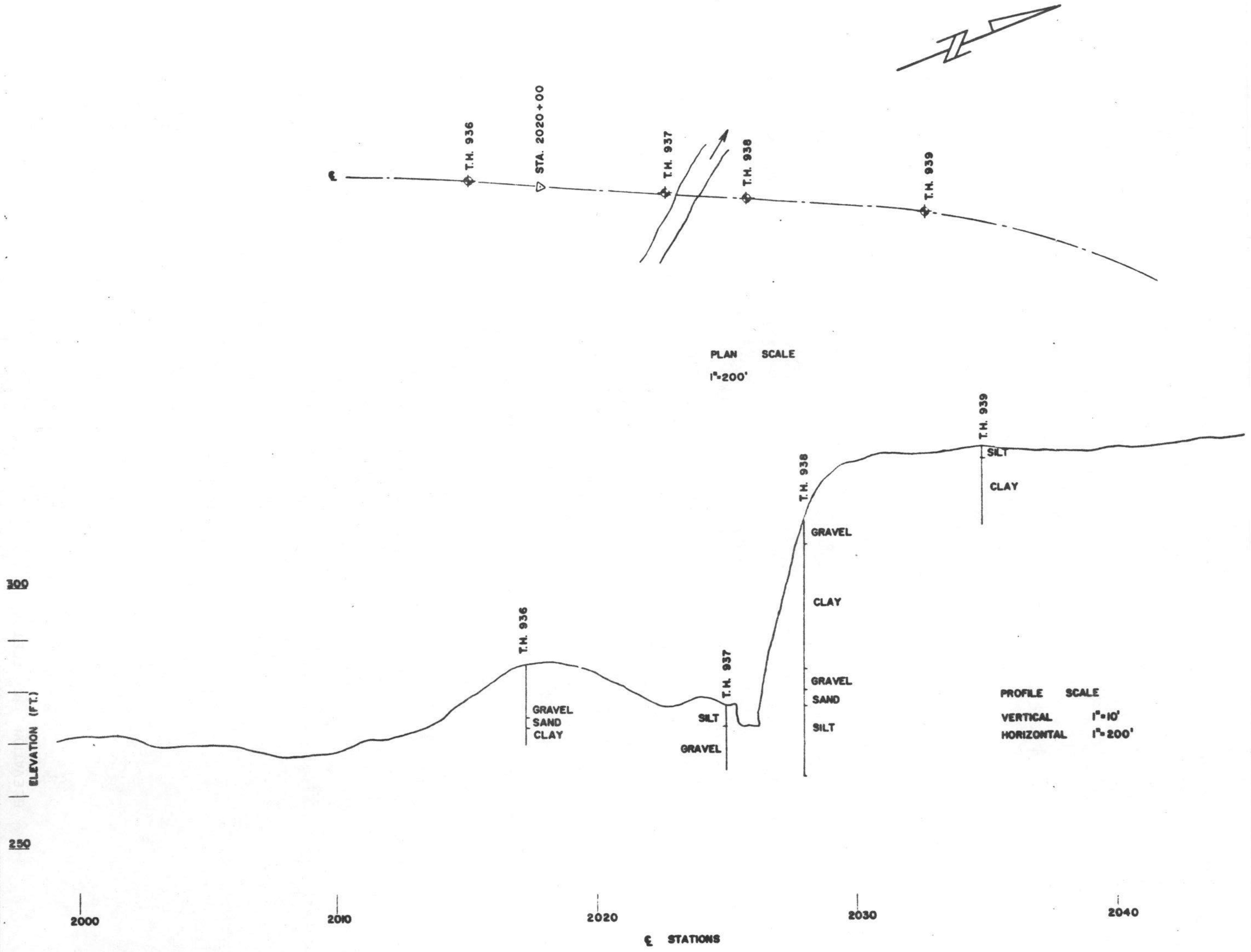
Per:
G. McCormick, P.Eng.

GM/jc

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF ALBERTA
PERMIT NUMBER
P[illegible]
R. M. HARDY AND
ASSOCIATES LTD.

APPENDIX A

Charts
Test Hole Logs
Sections



NOTE

THIS DRAWING HAS BEEN REDUCED TO 50% SIZE

No.	REVISION	DATE	BY

D.P.W. DWG "PROPOSED DRAINAGE STRUCTURE

AT CANYON CREEK"

REFERENCES

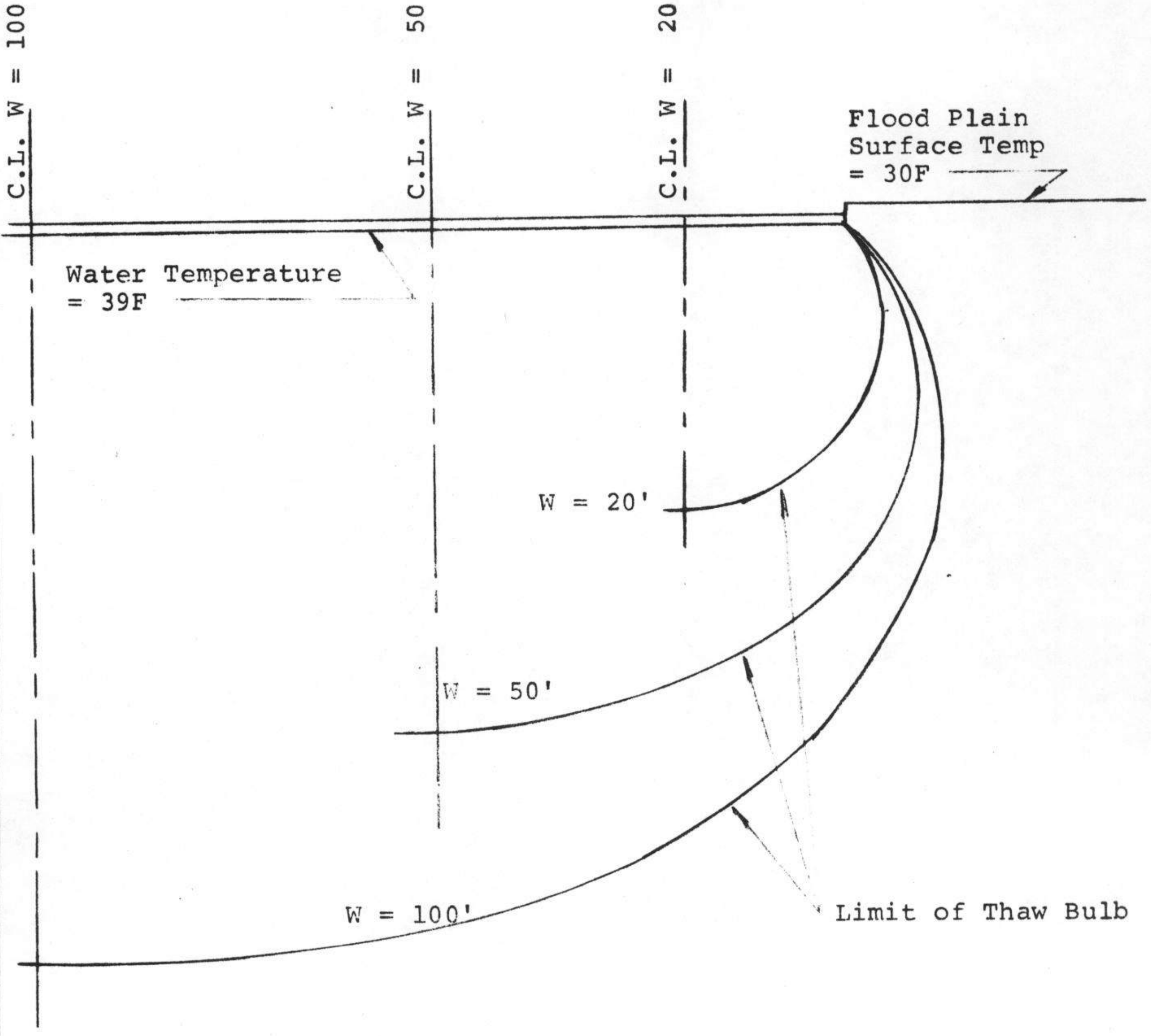
R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

DEPARTMENT OF PUBLIC WORKS
MAKENZIE HIGHWAY
CANYON CREEK

SCALE SHOWN DATE OCT. 9'73 MADE R. V. S. CHKD S. Mc. APPD.

No. E 2510-104 REV. 0

PLATE I



Scale: 1" = 10'

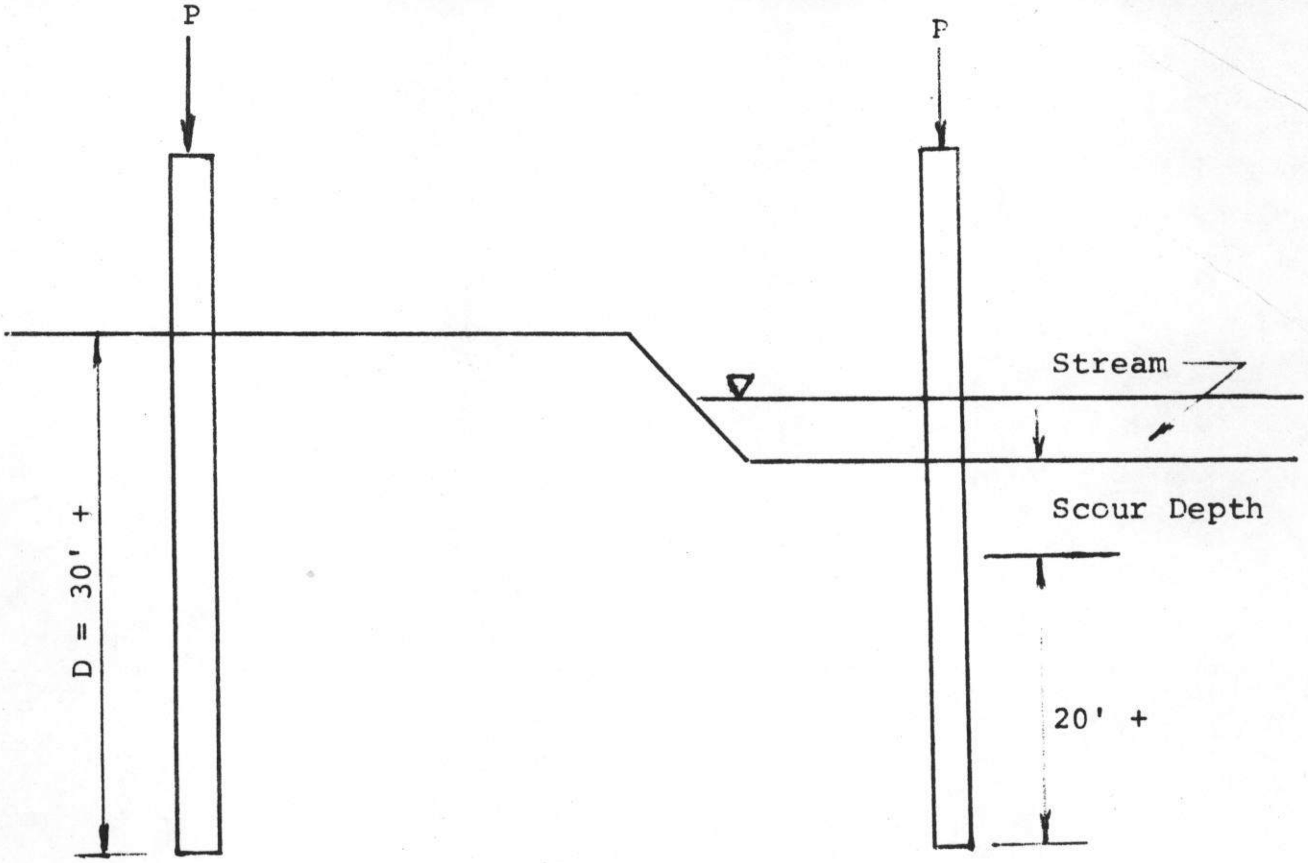
W = River Width
C.L. = Center Line

G.Mc September 14/73 E-2510

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

THAW BULBS BENEATH RIVERS
NORMAN WELLS AREA

PLATE 2



Gross Perimeter = $\frac{4H}{12} = \frac{H}{3}$ ft.

Piles on dry land to be designed on the basis of an allowable shaft friction over effective length of embedment of D-10 with D minimum = 30 ft.

Piles in stream bed to be driven to 20+ feet below scour depth and designed on the basis of penetration values (see text).

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

MACKENZIE HIGHWAY
BRIDGE PILES
NORMAN WELLS AREA

SCALE ______ DATE ______ MADE G.Mc CHKD. ______ JOB: E2510 PLATE ______

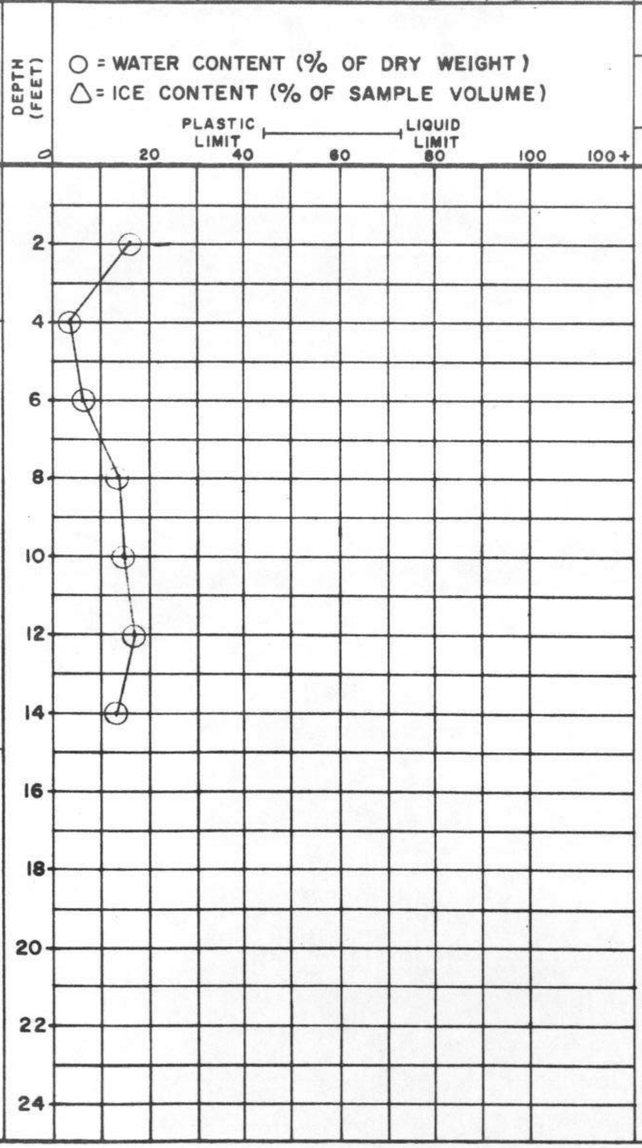
R.M. HARDY AND ASSOCIATES LTD.	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN: CRY	FIELD ENG: B.D	DATE DRILLED: 12/3/73	AIRPHOTO NO: A22934-143	CHAINAGE: 2017 + 25	OFFSET:	
CKD:	TECH: M.D	RIG: FAILING	SURFACE DRAINAGE: GOOD	VEGETATION: SEE REMARKS	ELEV:	

TEST HOLE		
MILE	B,C,S	NUMBER
620	C	936

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0					OS	(MOSS-ORGANIC SILTY CLAY COVER).									
					GM	GRAVEL; SANDY, SILTY, NON PLASTIC BROWN	F	Vx 10%							MODERATELY DENSE SPRUCE 25-50' HIGH 12"ϕ MAX OCCASIONAL BIRCH
2															
4						4' FINER		Nbn							
6						6' COARSER									
8						8' VERY SILTY, FINE SANDY									
10					SW-SM	10' SAND; COARSE, FINE GRAVELLY, VERY FINE GRAIN SAND									
12					CL	12' CLAY (TILL) SILTY, SANDY, LOW PLASTIC GREY, PEBBLES									
14															
						15' END OF HOLE									
16															
18															
20															
22															
24															

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

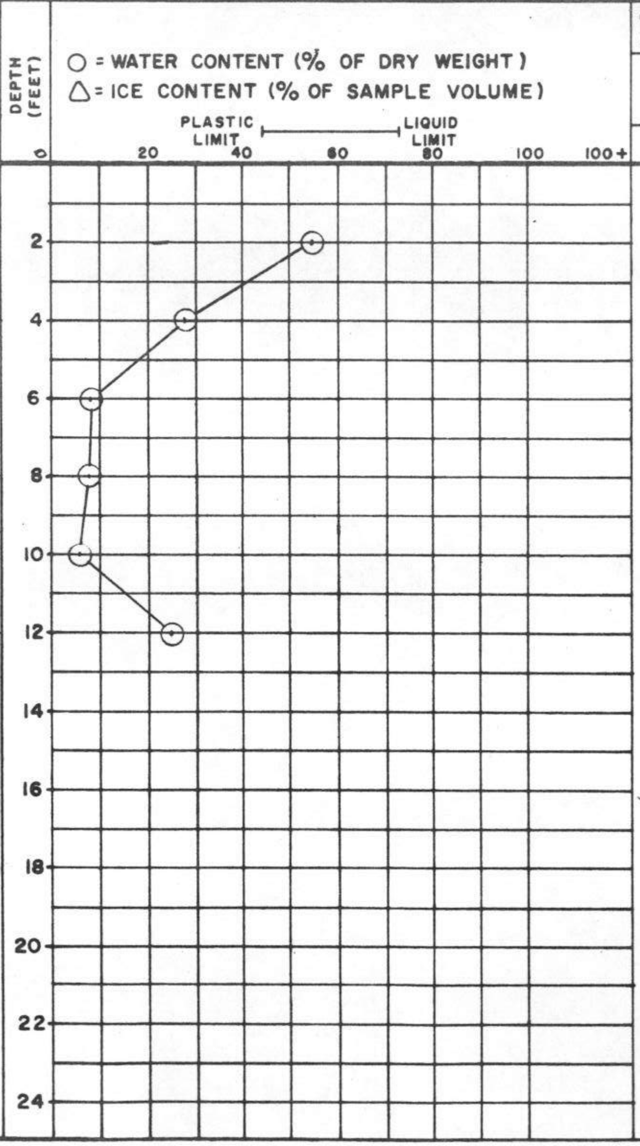
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CRA | FIELD ENG: BD | DATE DRILLED: 12/3/73 | AIRPHOTO NO: A22934-143 | CHAINAGE: 2024+80 | OFFSET:

CKD: | TECH: MD | RIG: FAILING | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
620	S	937

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST.%)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–2					ML	SILT; SANDY, CLAYEY, LOW PLASTIC ORGANICS, BROWN — 2'	F								MODERATELY DENSE SPRUCE 25-50' HIGH 12"ø MAX
2–4					ML	SILT; TRACE OF SAND, PEBBLES BROWN — 4'		Vx 10%							
4–8					GM	GRAVEL; SANDY (COARSE), SILTY BROWN — 6' LESS SILT WET-UNFROZEN — 8'		Nbn							
8–10						— 10'	UF	NO ICE							
10–12					SC	SAND (TILL); VERY SILTY, TRACE OF PLASTICITY, DK BROWN — 12'		WATER SEEPAGE →							
12						END OF HOLE									



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DRILL HOLE REPORT

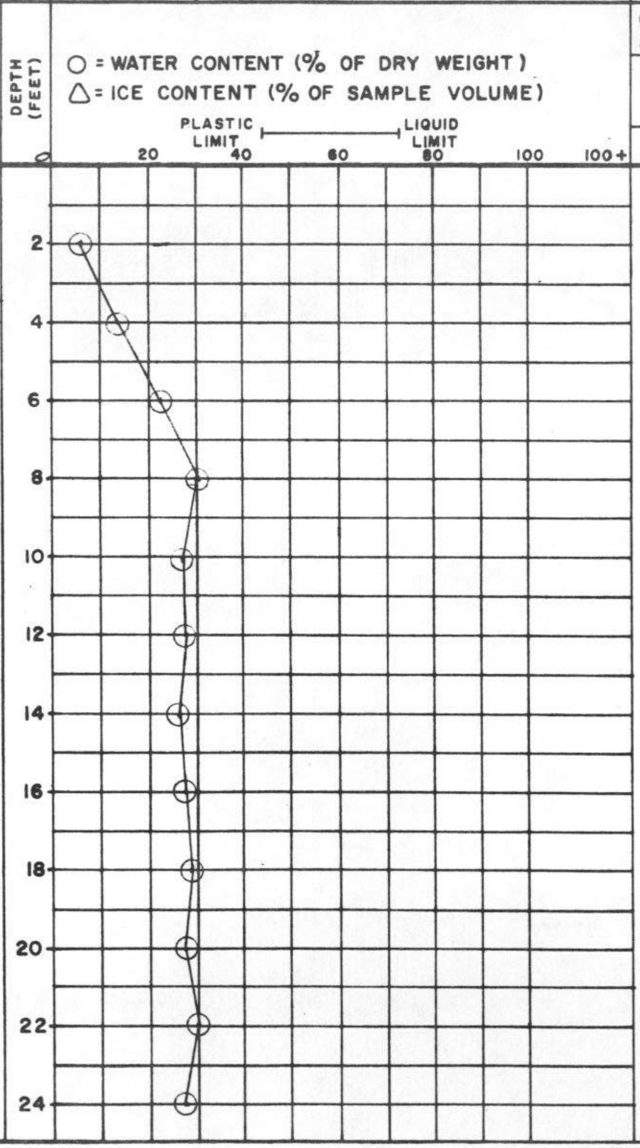
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CW
FIELD ENG: BD
DATE DRILLED: 12/3/73
AIRPHOTO NO: A22934-143
CHAINAGE: 2027 + 90
OFFSET:
CKD:
TECH: DR
RIG: MAYHEW 1000
SURFACE DRAINAGE: GOOD
VEGETATION: SEE REMARKS
ELEV:

TEST HOLE
SHEET 1 OF 2

MILE	B,C,S	NUMBER
620	S	938

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST. %)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0					GW	GRAVEL (FINE); WELL GRADED SANDY ROOTS	F	Nf							MED DENSE SPRUCE 6-25' HIGH 8" ϕ MAX
3½'					ML	SILT; SANDY LOW PLASTIC BROWN 4'		Nbn							
4'					CI	CLAY (TILL); SILTY, MED PLASTIC CALCAREOUS, PEBBLES BROWN		Vx 5%							
6'					CH	HIGH PLASTIC									
18'						DARK GREY									



R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CR | FIELD ENG: B.D | DATE DRILLED: 12/3/72 | AIRPHOTO NO: A22934-143 | CHAINAGE: | OFFSET:

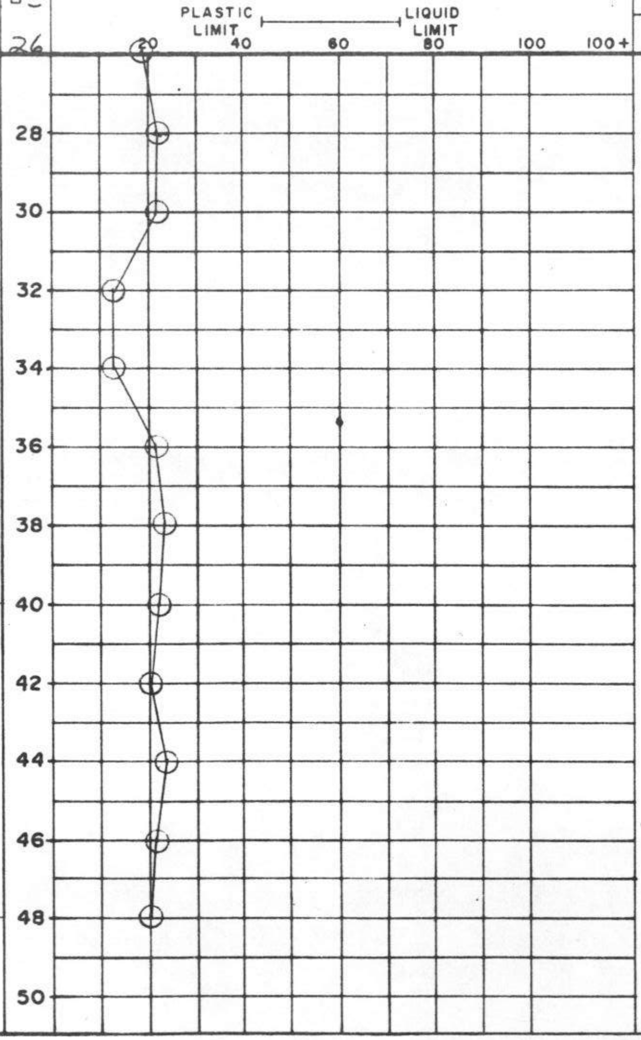
CKD: | TECH: D.R | RIG: MAYHEW 1000 | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE
SHEET 2 OF 2

MILE	B,C,S	NUMBER
	S	938

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P C F)	DRY DENSITY (P C F)	REMARKS
26					CH	CLAY (TILL) SILTY, HIGH PLASTIC PEBBLES GREY CALCAREOUS, STRATIFIED 28'		Vx 5%							MODERATELY DENSE SPRUCE 6-25' HIGH 8"φ MAX
28					GM	GRAVEL (TILL); SANDY, FINE, SILTY, GREY STRATIFIED, CLAYEY									
30															
32					SM	SAND; SILTY, ANGULAR AND SUBROUNDED									
34															
36					ML-SM	SILT; SANDY, NON PLASTIC, GREY 38									
38					ML	SILT (TILL); SANDY, CLAY (TILL) INCLUSIONS GREY 40'									
40					ML	SILT; FINE SAND, CLAYEY, LOW PLASTIC GREY.		Nbn							
42															
44															
46															
48						48' END OF HOLE									
50															

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)



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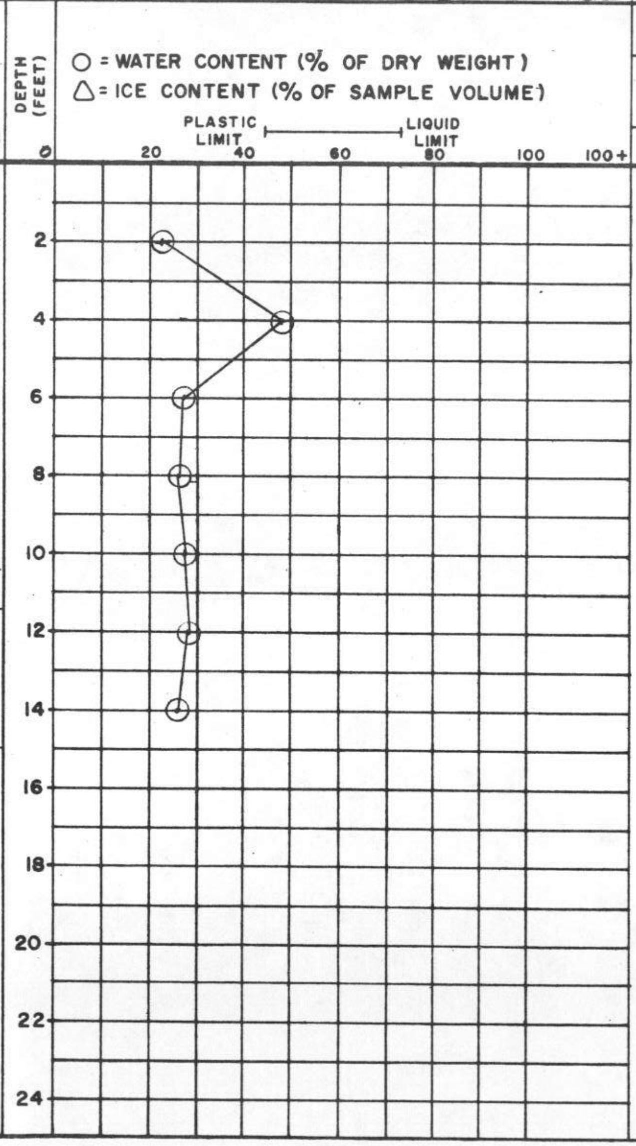
DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CRA
CKD: [illegible]
FIELD ENG: B.D.
TECH: D.R
DATE DRILLED: 12/3/73
RIG: MAYHEW 1000
AIRPHOTO NO: A 22934-143
SURFACE DRAINAGE: POOR
CHAINAGE: 2034+75
VEGETATION: SEE REMARKS
OFFSET:
ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
620	C	939

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST.%)
0						✓ MOSS COVER		
					ML	SILT; CLAYEY SANDY, LOW PLASTIC ORGANIC INCLUSIONS, BROWN — 2'	F	Nbn
2					CL	CLAY; SILTY, LOW PLASTIC BROWN		Vx 50%
4								
6						— 6' TILL INCLUSIONS — 7'		
					CH	HIGH PLASTIC		
8						— 9½'		
					CI	LOW TO MED PLASTIC VERY SILTY		
10							UF	
							F	Vs 5%
12								
14						— 15'		
						END OF HOLE		
16								
18								
20								
22								
24								



GRAIN-SIZE ANALYSIS				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
CLAY	SILT	SAND	GRAVEL		
%	%	%	%		

REMARKS

MODERATELY DENSE
SPRUCE
20' HIGH
6"⌀ MAX
'OCCASIONAL
BIRCH

APPENDIX B

Explanation Sheets

EXPLANATION OF TERMS AND SYMBOLS USED ON TEST HOLE LOG SHEETS

Depth

This column refers to the depth below the ground surface in feet.

Sample Number

Tube and core samples were numbered consecutively from the surface. Grab samples were not numbered.

Sample Type

This column indicates the depth interval and condition of each sample attempted. Undisturbed samples in this program were obtained with Shelby tubes of 18 inches length and 3 inches diameter, manufactured from 11 gauge steel, or by core drilling. Cores were of 2.85 inch diameter and up to 36 inches long.

Disturbed samples were obtained from the returned cuttings.

T indicates tube sample

C indicates core sample

⧄ indicates large grab sample

Note: Grab samples taken for water content and visual examination are not indicated in this column.

Percent Recovery

This column shows the length of sample recovered as a percentage of the length attempted. 100% recovery is not indicated and may be assumed where no value is shown.

Penetration Resistance

No standard penetration tests were performed during this program.

Soil Symbol

The soil symbols used are explained in full on page 5 of this appendix.

Soil Description

Soils of different engineering classification are grouped generically for ease of reference. The system used is the Modified Unified Classification System for Soils.

Frozen Ground

The depth intervals over which frozen and unfrozen ground were encountered are indicated by F and UF respectively. No attempt was made to differentiate between seasonal frost and permafrost.

Ice Description

The ice content of permafrost soils has been classified according to the National Research Council System for describing permafrost. A brief review of the NRC System is contained on page 9 of this appendix. Where no entry is made, the type was not recorded in the field.

The amount of ice contained in a soil sample was estimated in the field laboratory by inspection. The value arrived at by the laboratory technician has been left unchanged.

Water Content

The natural water content of the soil at the time of drilling is plotted against depth on the chart at the right hand side of the log. The water content, which is indicated by a circle, is expressed as a percentage of the dry weight of the soil. It will be observed that water contents in excess of 100% are indicated in the column at the right of the chart by figures.

Volume of Ice

The total volume of ice in undisturbed samples is indicated on the same chart as water contents. The value is indicated by a triangle. This volume is the total volume of ice in an undisturbed sample and includes intersticial ice, as well as excess ice, and is expressed as a percentage of the total volume of the sample.

Grain Size Analysis

The proportions of clay, silt, sand and gravel in a sample are summarized. Grain size curves for each sample so analyzed are on separate sheets.

Wet Density

The wet in situ density of undisturbed samples is the total weight of the sample in pounds (including ice and water) divided by the volume of the sample in cubic feet.

Dry Density

The dry in situ density of undisturbed samples is the weight of dry soil divided by the volume of the sample in cubic feet.

Atterberg Limits

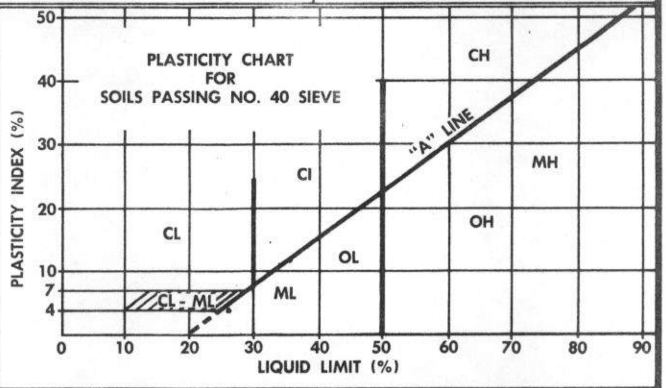
The plastic and liquid limits are shown on the water content chart by a horizontal bar. The Atterberg system is discussed in the following section.

NOTES ON ATTERBERG LIMITS

Soils which possess a significant fraction of clay can exist in liquid, plastic or solid states according to the water content. Where the water content is very high, so that the soil is in the form of a slurry, the soil behaves as a liquid. If the water content is reduced, for example through evaporation, the clay will enter into a plastic state. If the water content is reduced yet further, the clay will become a solid. The transition from one state to another occurs gradually over a range of water content. Atterberg, a Swedish agronomist, developed a method for delineating the boundaries between the three states. If his method is used, the water content which marks the dividing line between the plastic and liquid state is known as the Liquid Limit. These water contents are all expressed as percentages of the dry weight of soil. The range of water content between the plastic

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW	⁂	RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP	⁂	RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM	▥	YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			GC	▨	YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW	∴	RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP	∴	RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM	▥	YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			SC	▨	YELLOW	CLAYEY SANDS, SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	▥	GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH	▥	BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL	▨	GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI	▨	GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH	▨	BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL	▥	GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH	▨	BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt	≈	ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	



1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11.
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%.

and liquid limit is known as the plastic range and the numerical difference between the liquid and plastic limits is called the Plasticity Index.

It will be appreciated that where the natural water content is in excess of the liquid limit, the soil mass will be most unstable and will readily flow into excavations or trenches. Such considerations will not apply where the soil mass is kept frozen. However, in cases where the frozen soil is allowed to thaw, the relationship between the natural water content and liquid limit becomes critical.

On page 5 there is a chart showing the relationship between the Plasticity Index, the Liquid Limit and the group symbols of the Unified Classification System. The Atterberg Limit system is extremely useful for identifying and classifying soils.

NOTES ON THE RADFORTH SYSTEM FOR CLASSIFYING PEAT

The Radforth classification system for describing muskeg (organic terrain) is a method for classifying the three elements of vegetation, topography and organic surface cover using letter and figure symbols. Height and type of vegetation is described by using capital letters (A through I). Topography is described by using lower case letters (a through p) Organic cover type if described by using figures (1 through 16).

Table I outlines these figure symbols and the peat structure and type represented by them. A complete description of the Radforth system is contained in "Guide to a Field Description of Muskeg" published by National Research Council, Ottawa, from which has been copied Table I.

TABLE I

SUBSURFACE CONSTITUTION

Predominant Characteristic	Category	Name
	1.	Amorphous-granular peat
	2.	Non-woody, fine-fibrous peat
	3.	Amorphous-granular peat containing woody fine fibres
	4.	Amorphous-granular peat containing woody fine fibres
	5.	Peat, predominantly amorphous-granular, containing non-woody fine fibres, held in a woody, fine fibrous framework.
	6.	Peat, predominantly amorphous-granular containing woody fine fibres, held in a woody, coarse-fibrous framework.
	7.	Alternate layering of non-woody, fine fibrous peat and amorphous-granular peat containing non-woody fine fibres.
	8.	Non-woody, fine-fibrous peat containing a mound of coarse fibres.
	9.	Wood, fine fibrous peat held in a woody, coarse-fibrous framework.
	10.	Woody particles held in a non-woody, fine-fibrous peat.
	11.	Woody and non-woody particles held in fine-fibrous peat.
	12.	Woody, coarse-fibrous peat.
	13.	Coarse fibres criss-crossing fine-fibrous peat.
	14.	Non-woody and woody fine-fibrous peat held in a coarse-fibrous framework.
	15.	Woody mesh of fibres and particles enclosing amorphous-granular peat containing fine fibres.
	16.	Woody, coarse-fibrous peat containing scattered woody chunks.