GEOTECHNICAL INVESTIGATION

PROPOSED BRIDGE SITE

JUNGLE RIDGE CREEK

MILE 602.1 MACKENZIE HIGHWAY

E-2510

OCTOBER 9, 1973

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

19

R.M.HARDY & ASSOCIATES LTD.

000042

GEOTECHNICAL INVESTIGATION

PROPOSED BRIDGE SITE

JUNGLE RIDGE CREEK

MILE 602.1 MACKENZIE HIGHWAY

E-2510

OCTOBER 9, 1973

R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING ● GEOTECHNICAL DIVISION

File No. E-2510

October 9, 1973

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

Re: Geotechnical Investigation
Mackenzie Highway
Proposed Bridge Site, Jungle Ridge Creek
Mile 602.1

Dear Mr. Kimball:

We are pleased to submit a report on our geotechnical investigation at the site of the proposed bridge across Jungle Ridge 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:

G. McCormick, P.Eng.

GM/jc

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 Jungle Ridge Creek, Mile 602.1.

The location of this bridge site is shown on mosaic sheet No. 46 of a set of mosaics prepared by Department of Public Works for the Mackenzie Highway work. The site is covered by aerial photographs Nos. A22767-174 through 177 (scale 1" = 1000'). The crossing is located where the Canadian National Telecommunications right of way crosses the creek.

In addition to these mosaics and aerial photographs, R. M. Hardy & Associates was provided a sketch plan and profile showing the proposed crossing. This last drawing is entitled "Proposed Drainage Structure at Jungle Ridge Creek" dated June 15, 1973, and was used as the basis for Plate 1, Appendix A.

A report entitled "Geotechnical Investigations, Mackenzie Highway, Mile 544 to Mile 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.

DRILLING AND TESTING

Three test holes were drilled at or near the proposed crossing on March 2, 1973, using a Failing 1000 drill rig. Compressed air was used as the drilling fluid. Disturbed samples were obtained at different intervals for moisture content determinations, ice descriptions and material identification. In addition, core samples were obtained in Test Hole 885. All samples were tested in the field laboratory which formed part of the mobile camp accompanying the operation. The test hole logs are included in Appendix A.

TOPOGRAPHY

The general direction of the drainage in the area is southwesterly towards the Mackenzie River. The banks of Jungle Ridge Creek are relatively low. On the westerly (right) bank the rise from water level to the top of the bank is about 9 feet in a horizontal distance of 20 feet. On the easterly (left) bank there is a much greater increase in elevation but at a lower gradient. On this side the ground rises approximately 25 feet in a horizontal distance of 300 feet. The width of the creek at the water line is approximately 20 feet.

SOIL PROFILE

The soils in the area consist mainly of clay overlying clay till. In Test Hole 708 about three feet of silt was encountered on top of the clay till. Relatively high water contents are found in the top five feet of the soil profile but, beneath this depth, the water contents are quite low and average 10 to 15 percent. There is relatively little excess ice so that embankment subsidence due to melting of the subsurface ice will not be a serious problem. No unfrozen ground was encountered in any of these test holes. Occasional cobbles were reported within the clay till deposit.

DISCUSSION AND RECOMMENDATIONS

The effect of a stream on the 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 building purposes, presence of permafrost beneath the stream bed can be ignored. However, it should be noted that the 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. The bed of this stream consists of silt and rock (according to the surveyor's notes on the above mentioned drawing) so that some scour should be expected. The amount of scour that should be expected will depend on the flow of water during the height of the spring runoff, the constriction imposed on the stream by the bridge structure, and the width of the piers. Some erosion of the banks is probable.

While the amounts of excess ice in the clay till are extremely low, so that subsidence due to thawing will be quite small, we do not believe it would be advisable to use concrete abutments or piers. Also, because of difficulties due to logistics, it would be highly desirable that on-site work be kept to a minimum. We therefore recommend that the bridge 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 risk of damage to the timbers. Precast concrete piles should not be used due to the difficulties of transportation and also because the length of precast piles will have to be determined in advance. Steel pipe piles are an alternative possibility. However, it is possible that they would not be able to withstand the driving stresses and preboring of holes would be necessary.

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 approaches are summarized on Plate 3, Appendix A.

Driving steel H piles will require considerable energy. The weight of the pile driving hammer should be at least twice the weight of the pile being driven. If a diesel hammer is used the weight of the hammer should be at least equal to the weight of the pile. To prevent damage to the points of the piles 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 driven in the stream bed 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 foot 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, as defined above, may be designed for the full structural strength of the pile section acting as a column for the section below scour depths. However the actual design load will depend upon the allowable stresses in the pile, the column length and the arrangement of lateral bracing. Piles driven to practical refusal, as defined above will provide support equal to 2/3 of the axial load 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 increased 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 50,000 ft. lbs./blow unless calculations show that the pile can safely take higher impact stresses.

One of the problems facing the bridges is the possibility of log 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 the Jungle Ridge 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 a vertical face 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 lbs./cu. ft. where the backfill is not compacted.

Embankments constructed below the highest expected flood level should be protected with rip-rap. 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:

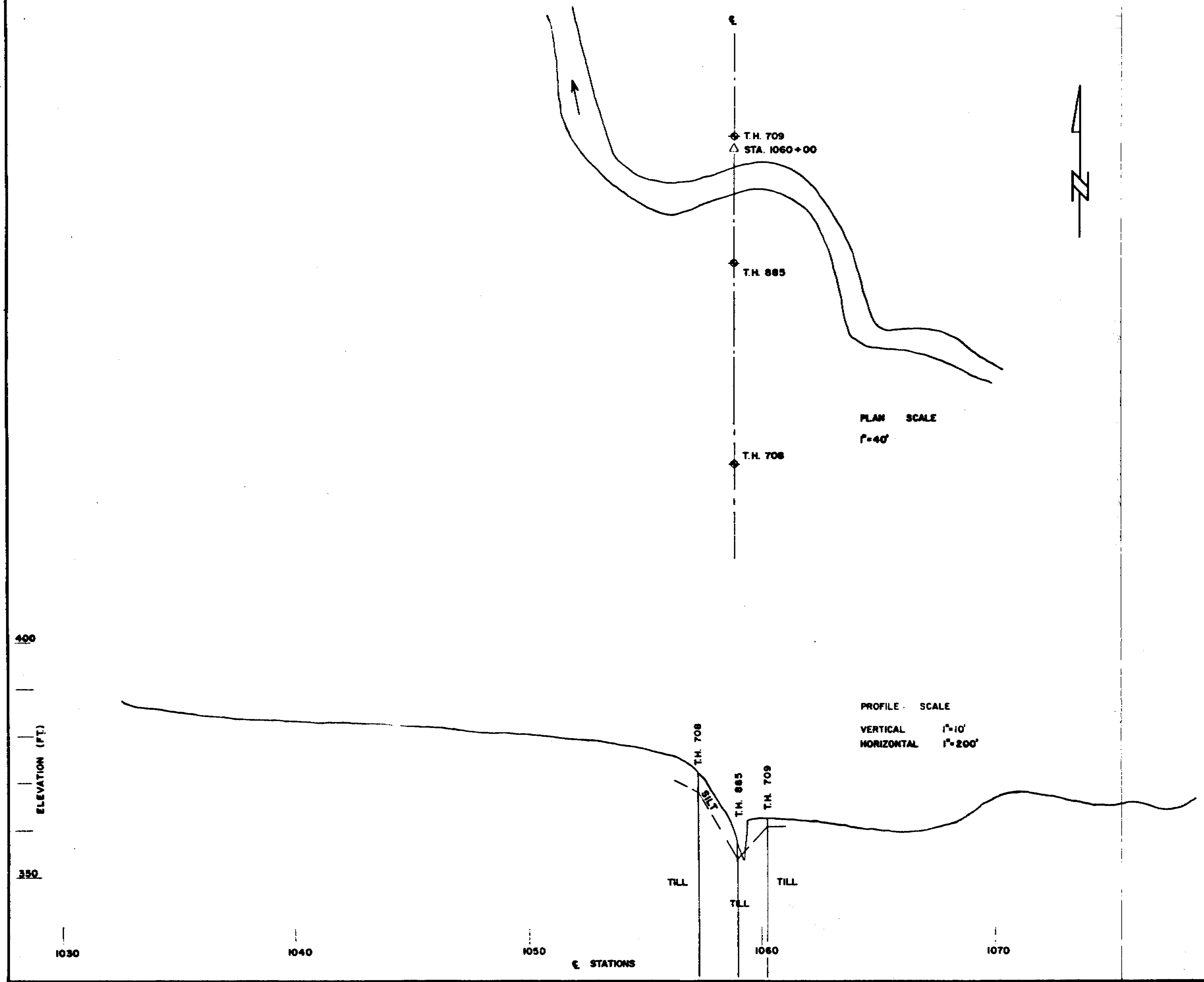
G. McCormick, P.Eng.

GM/jc

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF ALBERTA
PERMIT NUMBER
P 236
R. M. HARDY AND
ASSOCIATES LTD.

APPENDIX A

Sections
Charts
Test Hole Logs



NOTE

THIS DRAWING HAS BEEN REDUCED TO 50% SIZE

No	REVISION	DATE	BY

D.P.W. DWG "PROPOSED DRAINAGE STRUCTURE AT JUNGLE RIDGE CREEK"

REFERENCES

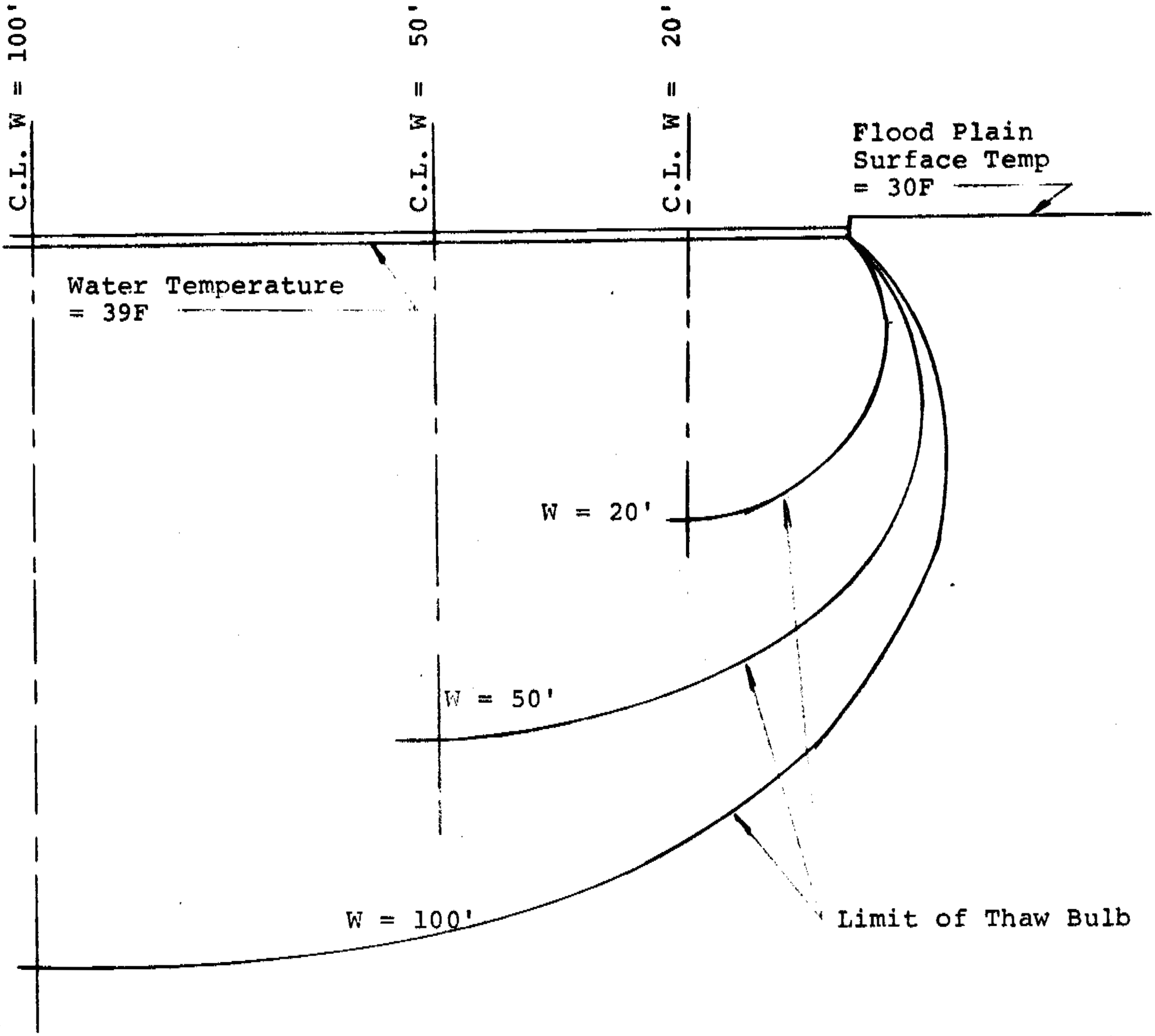
R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

DEPARTMENT OF PUBLIC WORKS
MAKENZIE HIGHWAY
JUNGLE RIDGE CREEK

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

No. E 2510-105 REV. 0

PLATE 1



Scale: 1" = 10'

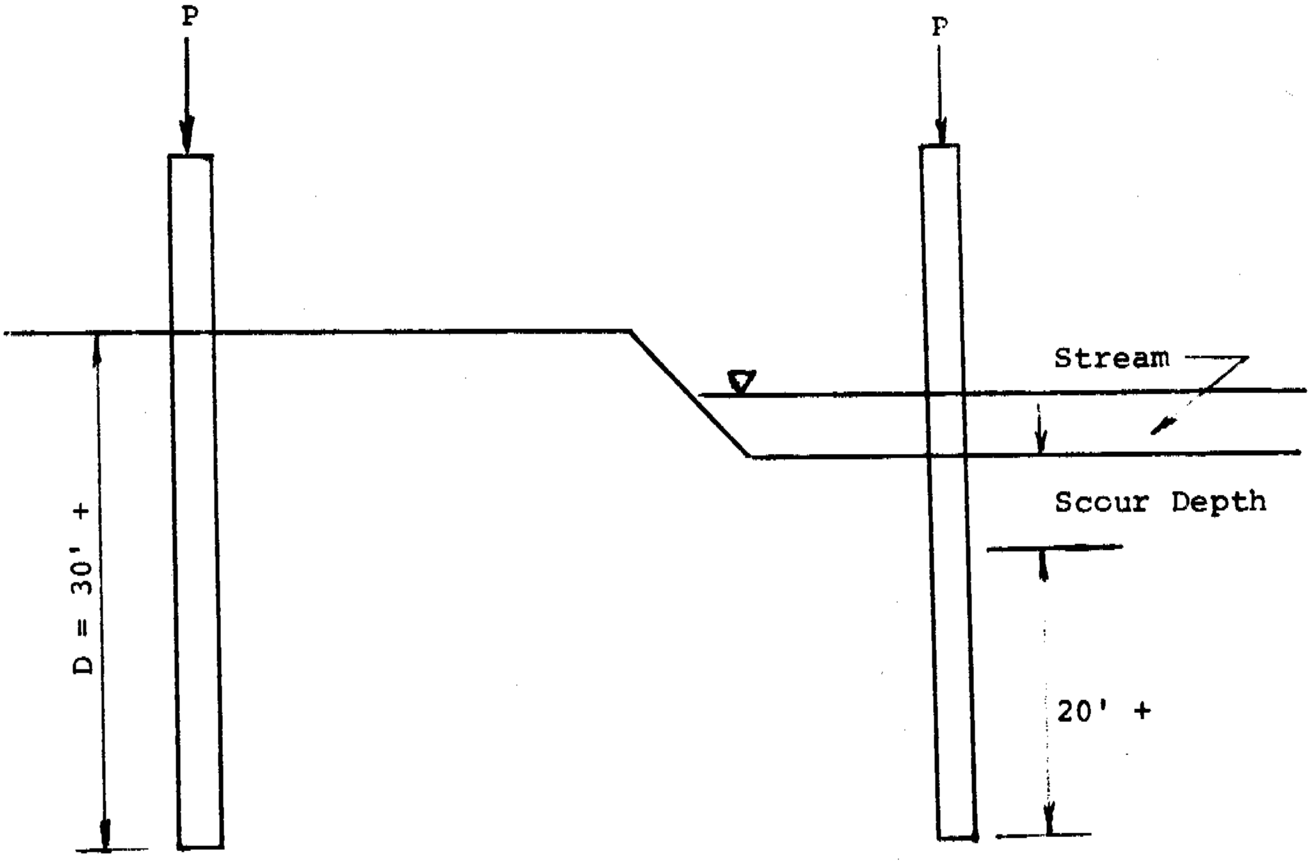
W = River Width
C.L. = Center Line

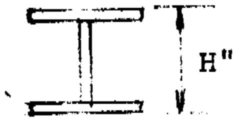
G.Mc September 14/73 E-2510

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

PLATE 3

R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: HH | FIELD ENG: BC | DATE DRILLED: 2/3/73 | AIRPHOTO NO: A 22934-151 | CHAINAGE: 1057+30 | OFFSET:

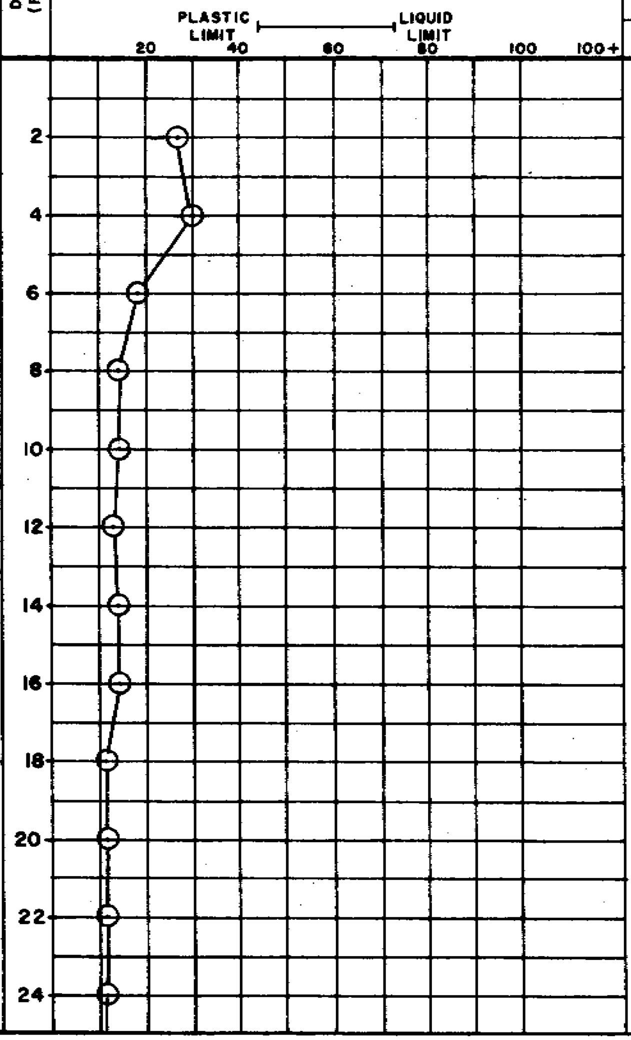
CKD: | TECH: JW | RIG: MAYHEW 1000 | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE
SHEET 1 OF 2

MILE	B,C,S	NUMBER
602	C	708*N

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

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 – 3					OL	SILT. organic sandy brown	F	Nbn							DENSE SPRUCE SPRUCE 10' TO 30' HIGH 5" MAX ϕ
3 – 10					CH	CLAY (TILL) silty sandy pebbles cobbles high plastic rust specks coal specks brown		Vr 20% (3–5) Nbn (5–11)							
10 – 14						more cobbles grey brown		Vx 2% (11–18)							
14 – 24						grey		Nbn (18–)							



R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

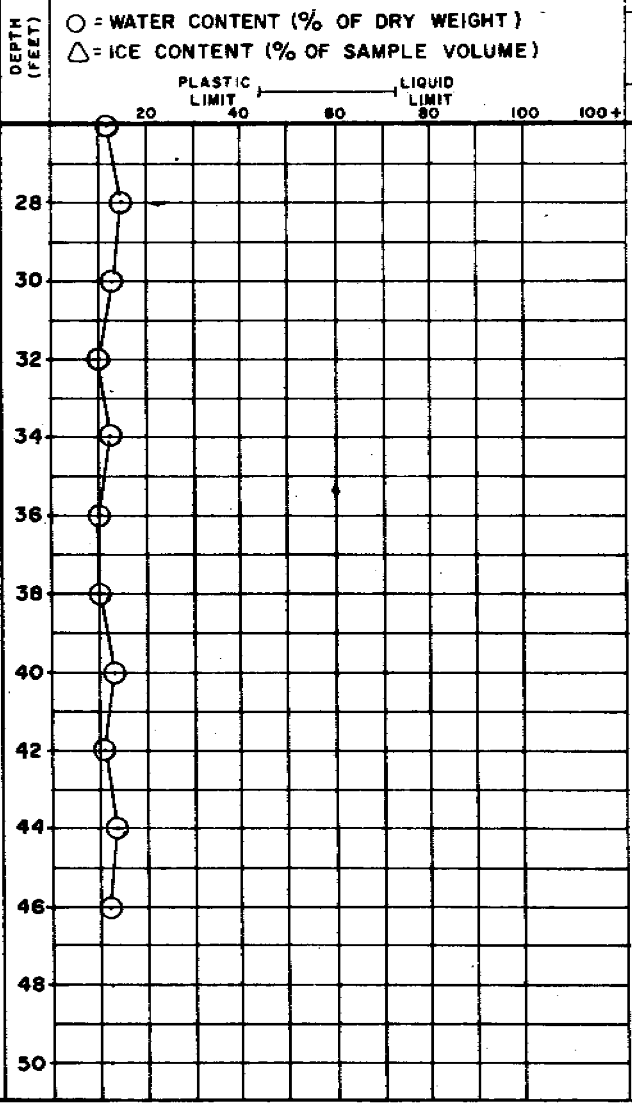
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: HH
FIELD ENG: BC
DATE DRILLED:
AIRPHOTO NO: A 22934-151
CHAINAGE:
OFFSET:
CKD:
TECH: JW
RIG: MAYHEW 1000
SURFACE DRAINAGE: GOOD
VEGETATION: SEE REMARKS
ELEV:

TEST HOLE
SHEET 2 OF 2

MILE	B,C,S	NUMBER
		708

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					CH	CLAY (TILL) silty sandy pebbles cobbles high plastic rust specks coal specks grey	F	Nbn
28								
30								
32								
34								
36								
38								
40						40 boulders		
42								
44								
46								
48								
50						50 END OF HOLE		



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

R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

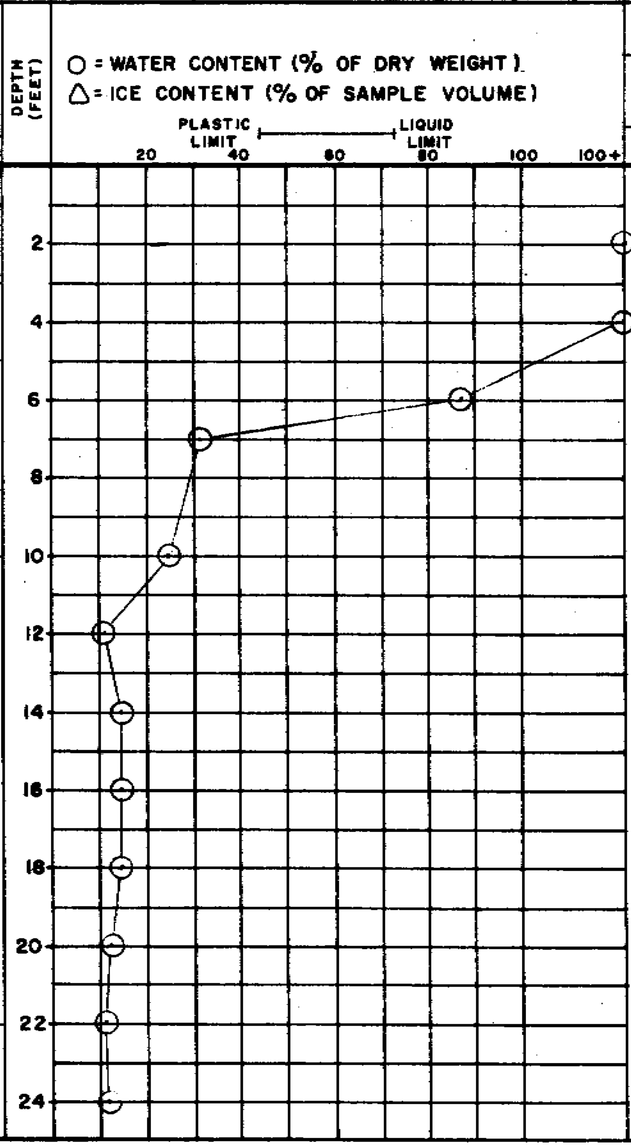
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CBY	FIELD ENG: BC	DATE DRILLED: 2/3/73	AIRPHOTO NO: A 22934-151	CHAINAGE: 1060+05	OFFSET:
CHK:	TECH: J.W	RIG: MAYHEW 1000	SURFACE DRAINAGE: POOR	VEGETATION: SEE REMARKS	ELEV:

TEST HOLE
SHEET 1 OF 2

MILE	B,C,S	NUMBER
602	C	709

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
					OH	CLAY - ORGANIC BLACK 1'	F	Vr 40%							LOW DENSITY
					CI	CLAY (TILL) SILTY, SANDY MEDIUM PLASTIC RUST, COAL STONES COBBLES GREY		Vx 10%							SPRUCE 20-45' HIGH 6" ϕ MAX
2															
4															
6															
8															
10								Vx <5%							
12															
14															
16															
18															
20															
22								Nbn							
24															



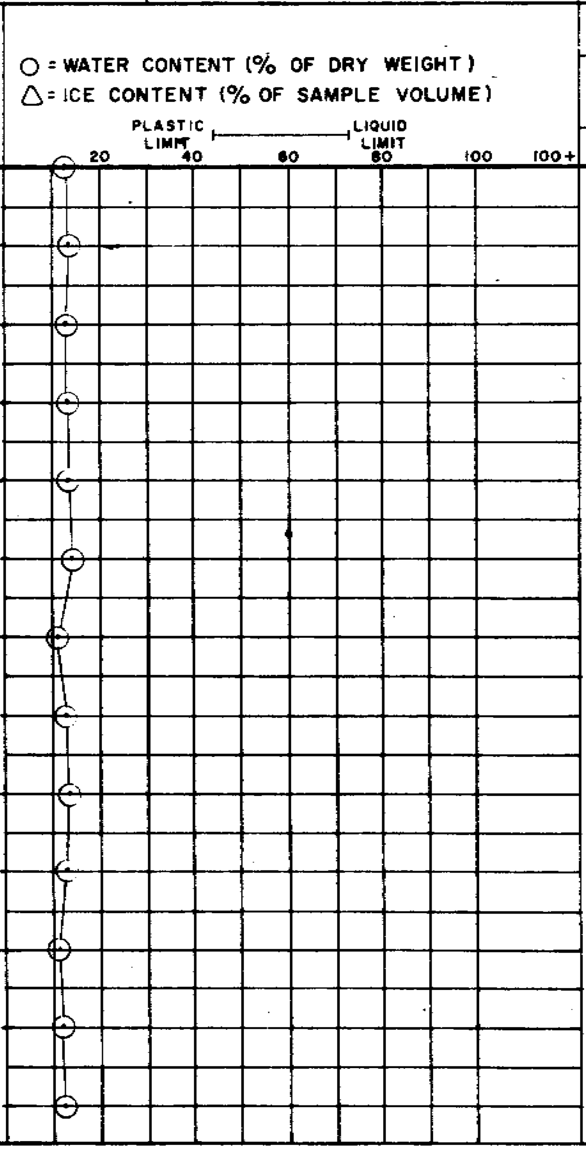
R.M. HARDY AND ASSOCIATES LTD. | **DRILL HOLE REPORT** | **DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY**

DWN: CPH
CKD:
FIELD ENG: B.C.
TECH: J.W
DATE DRILLED:
RIG: MAYHEW 1000
AIRPHOTO NO: A 22934-151
SURFACE DRAINAGE: POOR
CHAINAGE:
VEGETATION: SEE SHEET #1
OFFSET:
ELEV:

TEST HOLE
SHEET 2 OF 2

MILE	B,C,S	NUMBER
		709

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
					CI	CLAY (TILL)	F	Nbn								
28						28'			28							
						LESS COBBLES		Vx < 5%								
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							
50						50' END OF HOLE			50							



R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

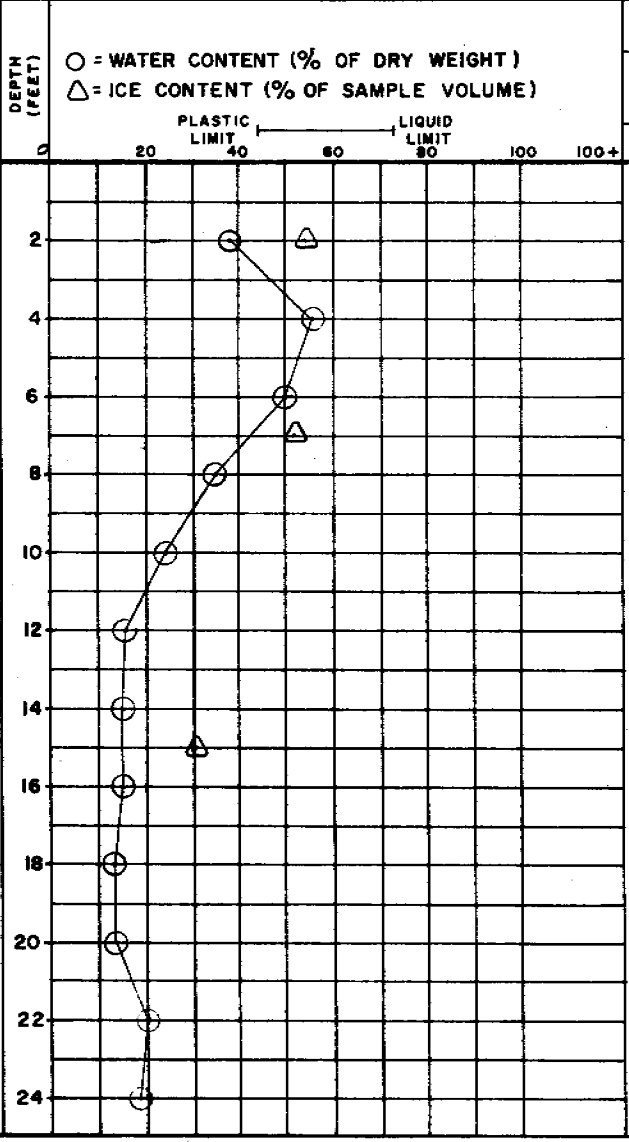
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CRA
CKD: [illegible]
FIELD ENG: BD
TECH: GKA & MR
DATE DRILLED: 8/3/73
RIG: TAILING
AIRPHOTO NO: A22934-151
SURFACE DRAINAGE: FAIR
CHAINAGE: 1059+00
VEGETATION: SEE REMARKS
OFFSET: 80' LT
ELEV:

TEST HOLE
SHEET 1 OF 2

MILE	B,C,S	NUMBER
602	SN	885

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						MOSS COVER									
0–2½	(1)	T	33		OL	ORGANIC SILT; FINE SANDY, CLAYEY, LOW TO NON PLASTIC ROOTLETS, LIGHT BROWN	F	Vs - 40%					112.8	83.0	MED DENSE SPRUCE 5'—50' HIGH 12"ϕ MAX
2½–8	(2)	T	100		CI-CL	CLAY (TILL-LIKE) ORGANIC SILTY. VERY SANDY MED. TO LOW PLASTIC GREY, ROOTLETS, PEBBLES SAND LENSES, SILTSTONE INCLUSIONS		Vs - 30%					95.0	66.6	
8–	(1)	C	N/R		CI	CLAY (TILL) SILTY, SANDY MED PLASTIC GREY PEBBLES		Vx - 10%							
–16'	(2)	C	81			COBBLES							132.7	116.2	
18'						DARK GREY		Vr 10%							



R. M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CBA. | FIELD ENG: B.D. | DATE DRILLED: 8/3/73 | AIRPHOTO NO: A22984-151 | CHAINAGE: | OFFSET:

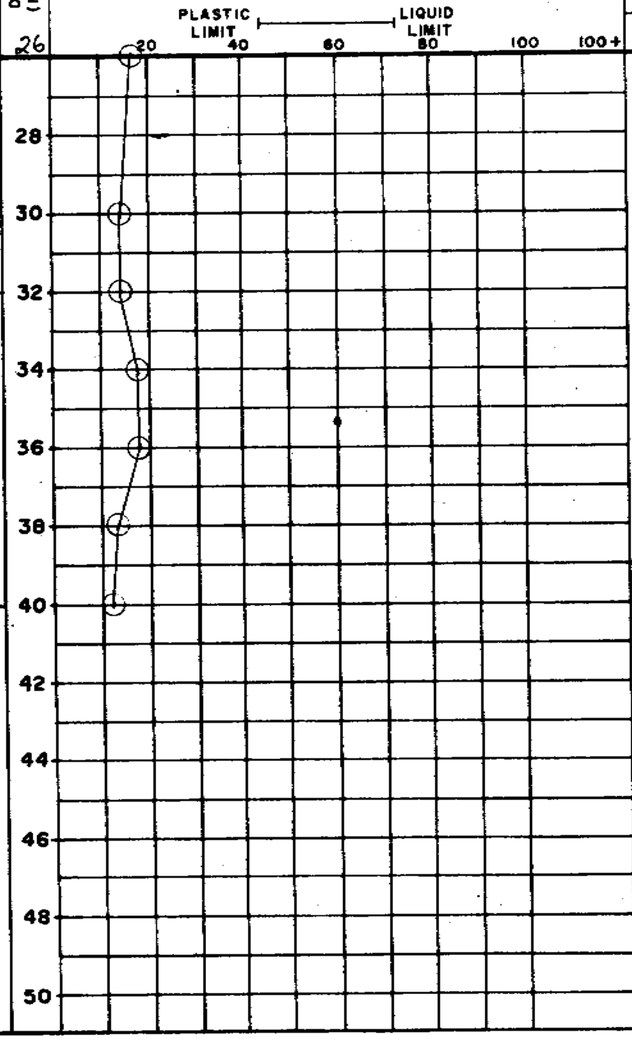
CKD: | TECH: CBA & MD | RIG: FAILING | SURFACE DRAINAGE: FAIR | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE
SHEET 2 OF 2

MILE	B,C,S	NUMBER
603	SN	885

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST.%)
26					CI	CLAY' (TILL), SILTY - SANDY MED PLASTIC GRAY PEBBLES	F	Vr 10%
28								Nbn
30								
32								Vx - 10%
34								
36								
38								
40						40'		
						END OF HOLE		
42								
44								
46								
48								
50								

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



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

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.

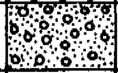
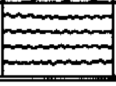
Atterberg Limits

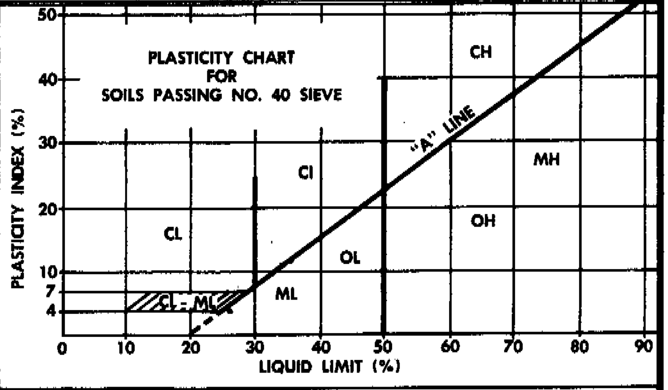
The plastic and liquid limits are shown on the water content chart by a horizontal bar. The Atterberg system is discussed in the following section.

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.