





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



## 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

<u>Description</u>	<u>Inches Per Blow</u>
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.

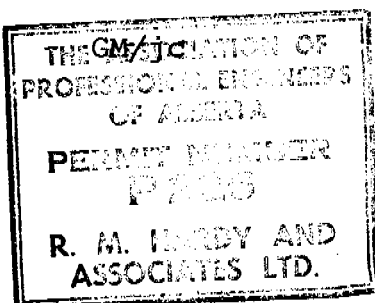
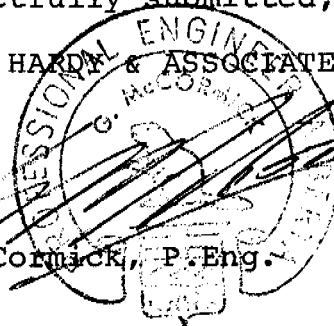
Embankments constructed below the highest expected flood level should be protected with rip-rap. As suitable rock may not be available, sandbags filled with concrete may have to be used.

Respectfully submitted,

R. M. HARDY & ASSOCIATES LTD.,

Per:

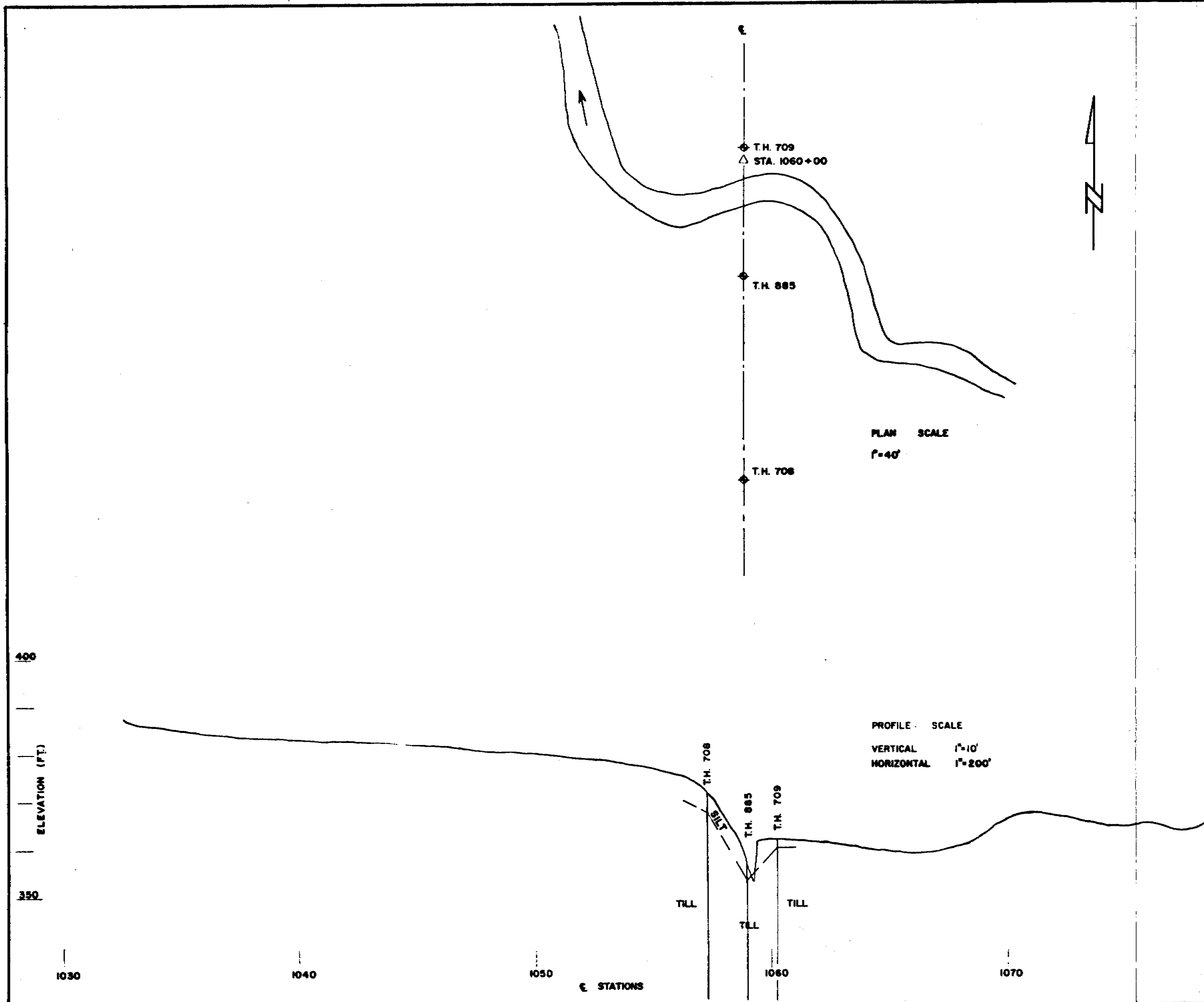
G. McCormick, P. Eng.






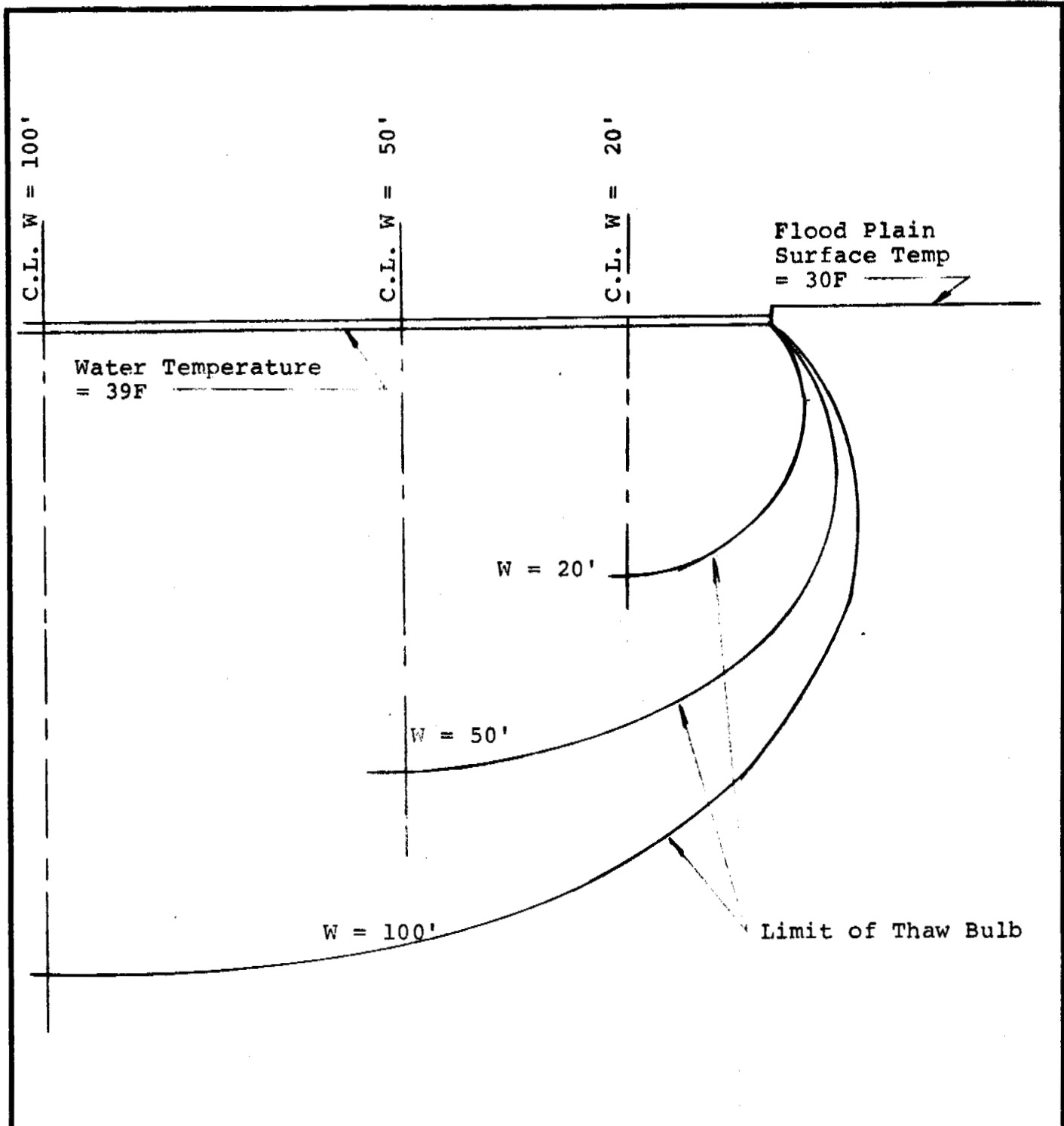
APPENDIX A

Sections  
Charts  
Test Hole Logs



**NOTE**  
 THIS DRAWING HAS BEEN  
 REDUCED TO 50% SIZE

REVISION		DATE	BY
D.P.W. DWG "PROPOSED DRAINAGE STRUCTURE AT JUNGLE RIDGE CREEK"			
REFERENCES			
 <b>R.J. HARDY &amp; ASSOCIATES LTD.</b> CONSULTING ENGINEERING & TESTING			
DEPARTMENT OF PUBLIC WORKS MAKENZIE HIGHWAY JUNGLE RIDGE CREEK			
SCALE SHOWN	DATE	MADE BY	APP'D.
No. E 2510-105	OCT. 9 '73	M.A.S.	CHD
			REV. 0



Water Temperature  
= 39F

Flood Plain  
Surface Temp  
= 30F

W = 20'

W = 50'

W = 100'

Limit of Thaw Bulb

Scale: 1" = 10'

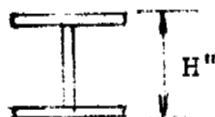
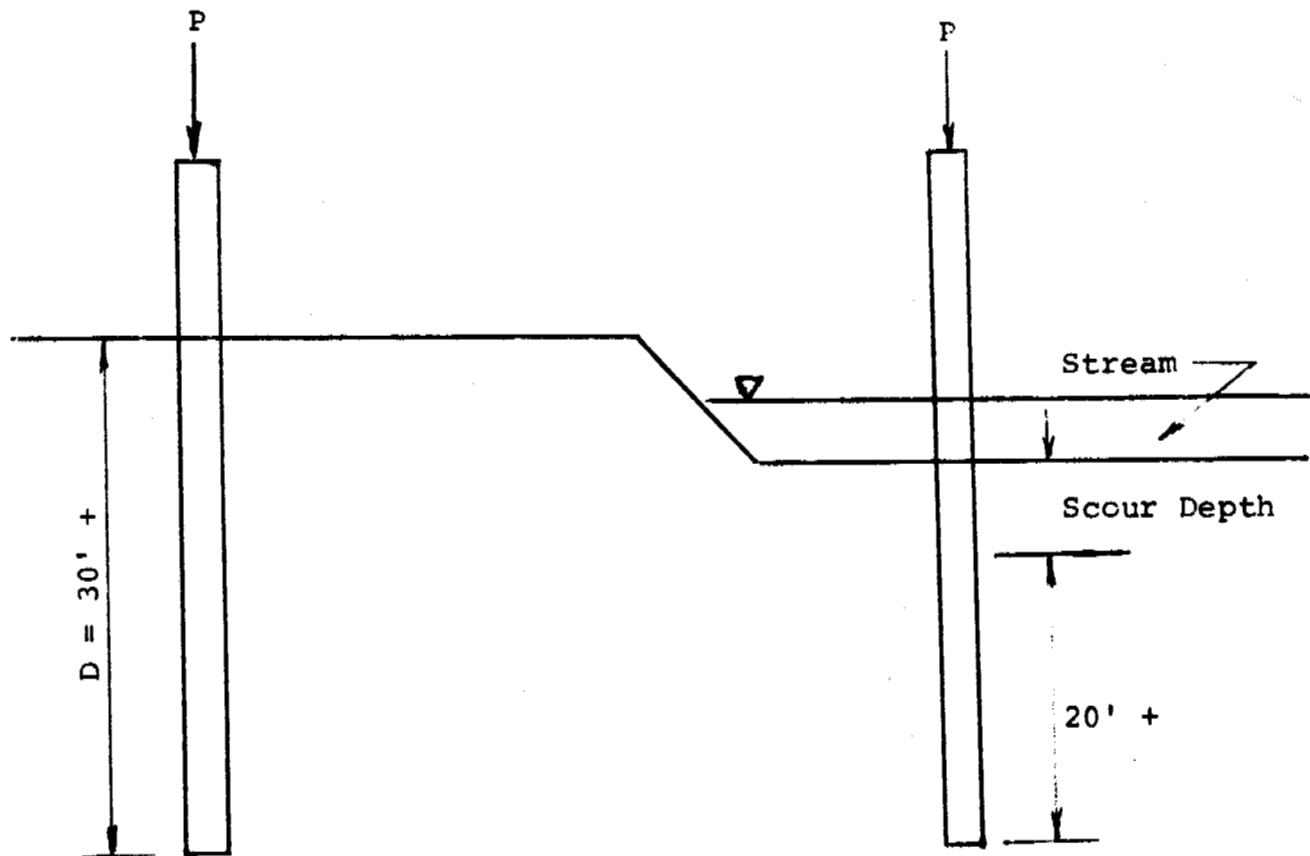
W = River Width  
C.L. = Center Line

G.Mc                      September 14/73                      E-2510



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

THAW BULBS BENEATH RIVERS  
NORMAN WELLS AREA



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

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

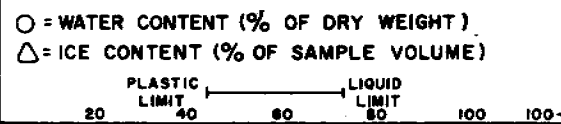
DEPARTMENT OF PUBLIC WORKS, CANADA  
MACKENZIE HIGHWAY

DWN: 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

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				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
										CLAY %	SILT %	SAND %	GRAVEL %		

MILE	B,C,S	NUMBER
602	C	708 <sup>N</sup>



2					OL	SILT organic sandy brown	FT	Nbn	2									
4					CH	CLAY (TILL) silty sandy pebbles cobbles high plastic rust specks coal specks brown		Vr 20%	4									
6								Nbn	6									
8									8									
10						more cobbles grey brown			10									
12								Vx 2%	12									
14						grey			14									
16									16									
18								Nbn	18									
20									20									
22									22									
24									24									

REMARKS

DENSE SPRUCE  
 SPRUCE  
 10' TO 30' HIGH  
 5" MAX Ø

R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

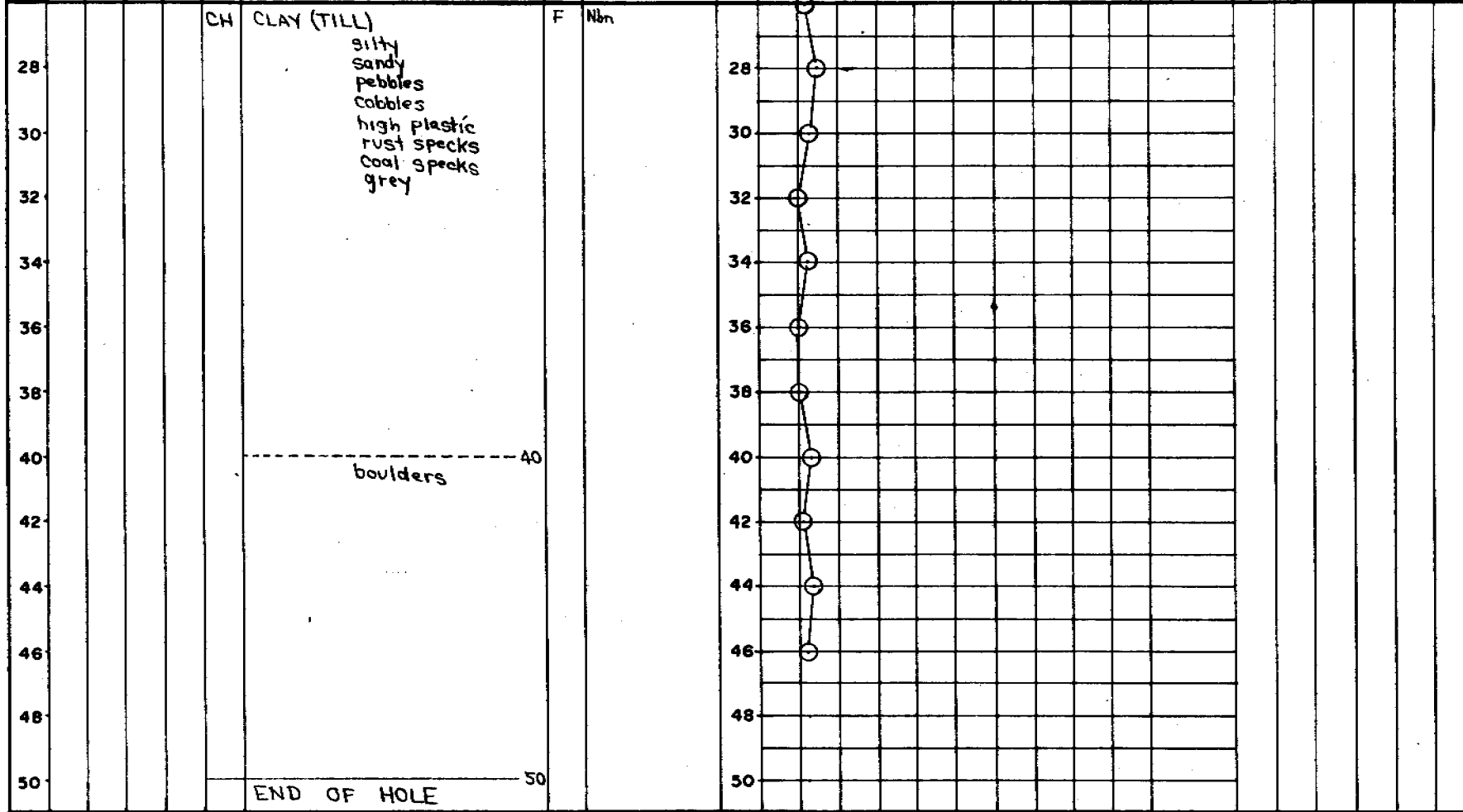
DEPARTMENT OF PUBLIC WORKS, CANADA  
MACKENZIE HIGHWAY

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

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				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
										CLAY %	SILT %	SAND %	GRAVEL %		

MILE	B,C,S	NUMBER
		708



REMARKS



R.M. HARDY AND ASSOCIATES LTD.

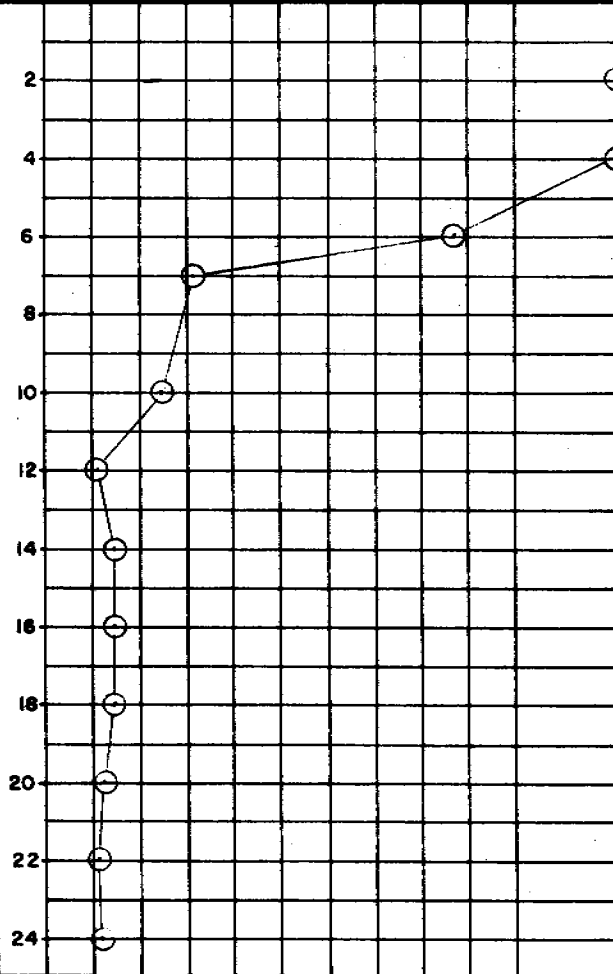
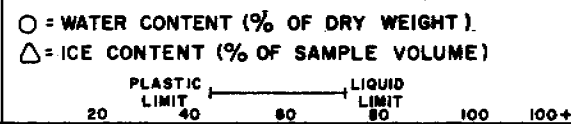
DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA  
MACKENZIE HIGHWAY

DWN: ~~084~~ FIELD ENG: 30 DATE DRILLED: 3/3/73 AIRPHOTO NO: A 22934-151 CHAINAGE: 1060+05 OFFSET:  
~~085~~ TECH: J.W. RIG: HA/HW 1000 SURFACE DRAINAGE: POOR VEGETATION: SEE REMARKS ELEV:

TEST HOLE SHEET 1 OF 2  
 MILE 602 B,C,S C NUMBER 709  
 REMARKS

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				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
										CLAY %	SILT %	SAND %	GRAVEL %		
						OH CLAY - ORGANIC BLACK 1'	F	Vr 40%							
						CI CLAY (TILL) SILTY, SANDY MED. PLASTIC RUST, COAL STONES COBOLES GREY		Vx 10%							
								Vx < 5%							
								Nbn							



Low Density  
 Spruce  
 20-45' HIGH  
 6" φ MAX

R.M. HARDY AND ASSOCIATES LTD.

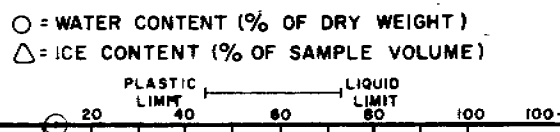
DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA  
MACKENZIE HIGHWAY

DWN: *CEI* FIELD ENG: *BC* DATE DRILLED: AIRPHOTO NO: *A 22934-151* CHAINAGE: OFFSET: TEST HOLE SHEET 2 OF 2

CKD: ~~CEI~~ TECH: *J.W* RIG: *MAYHEW 1000* SURFACE DRAINAGE: *POOR* VEGETATION: *SEE SHEET #1* ELEV: MILE B,C,S NUMBER

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				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
										CLAY %	SILT %	SAND %	GRAVEL %			
					<i>CI</i>	<i>CLAY (TILL)</i>		<i>Nbn</i>								
<i>28</i>						<i>LESS COBBLES</i>		<i>Vx &lt; 5%</i>	<i>28</i>							
<i>30</i>									<i>30</i>							
<i>32</i>									<i>32</i>							
<i>34</i>									<i>34</i>							
<i>36</i>									<i>36</i>							
<i>38</i>									<i>38</i>							
<i>40</i>									<i>40</i>							
<i>42</i>									<i>42</i>							
<i>44</i>									<i>44</i>							
<i>46</i>									<i>46</i>							
<i>48</i>									<i>48</i>							
<i>50</i>						<i>END OF HOLE</i>			<i>50</i>							



R. M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

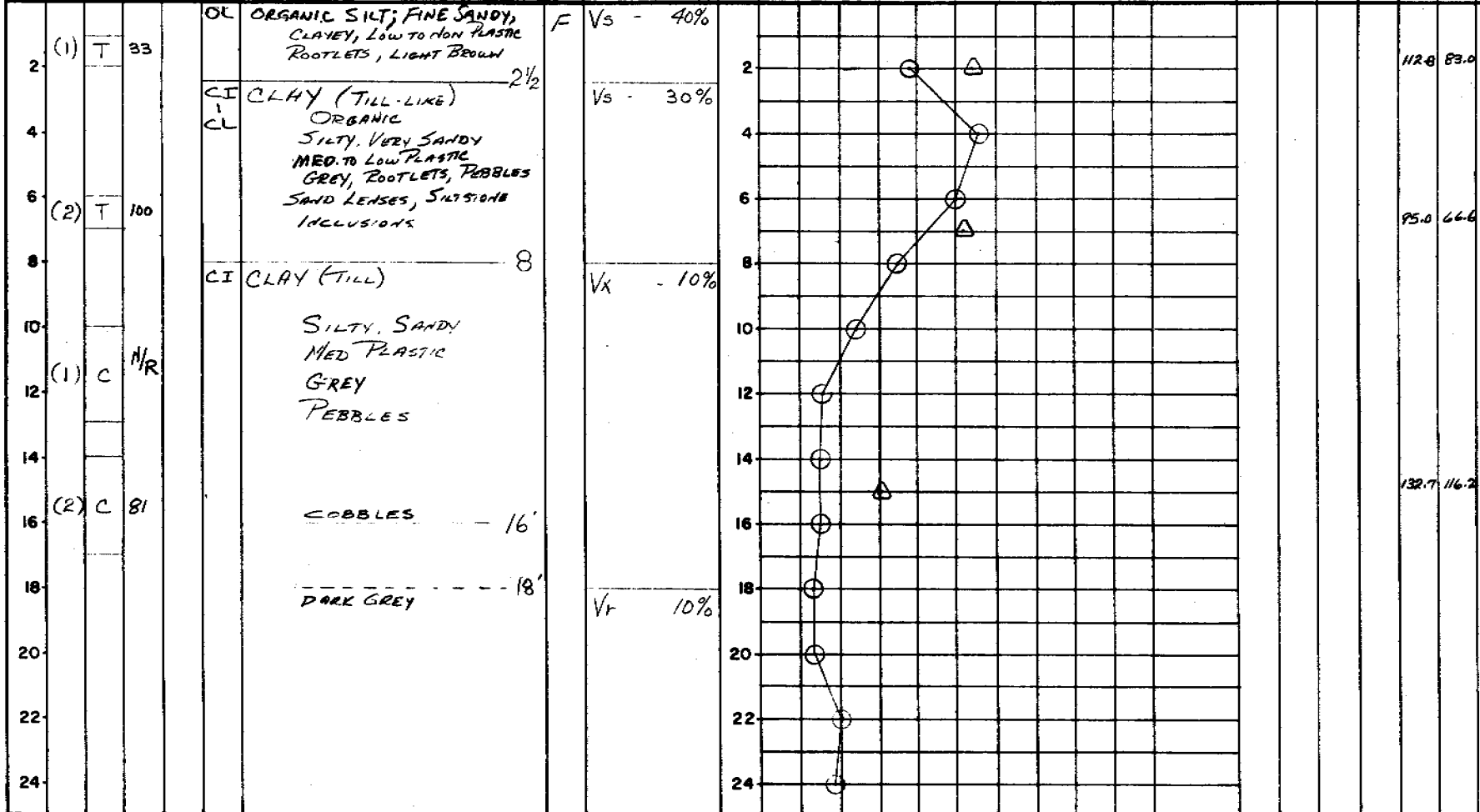
DEPARTMENT OF PUBLIC WORKS, CANADA  
MACKENZIE HIGHWAY

DWN: *CPA* FIELD ENG: *BD* DATE DRILLED: *8/3/75* AIRPHOTO NO: *A22934-151* CHAINAGE: *1059+00* OFFSET: *80' LT*  
 CKD: *MB* TECH: *GRAND M* RIG: *TAILING* SURFACE DRAINAGE: *FAIR* VEGETATION: *SEE REMARKS* ELEV:

TEST HOLE SHEET 1 OF 2

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				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
										CLAY %	SILT %	SAND %	GRAVEL %		

MILE	B,C,S	NUMBER
602	SN	885



REMARKS

MED DENSE SPRUCE  
5'-50' HIGH  
12" φ MAX

R.M. HARDY AND ASSOCIATES LTD.

DRILL HOLE REPORT

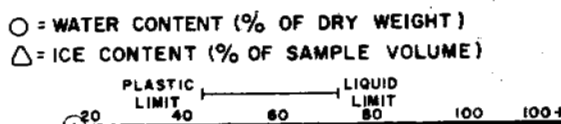
DEPARTMENT OF PUBLIC WORKS, CANADA  
MACKENZIE HIGHWAY

DWN: *CB1* FIELD ENG: *BD* DATE DRILLED: *8/3/73* AIRPHOTO NO: *A22934-151* CHAINAGE: OFFSET: ELEV:

CKD: *CB1* TECH: *CB1 & MD* RIG: *FALLING* SURFACE DRAINAGE: *FAIR* VEGETATION: *SEE REMARKS*

TEST HOLE SHEET 2 OF 2  
MILE *603* B,C,S *SN* NUMBER *885*  
REMARKS

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				WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
										CLAY %	SILT %	SAND %	GRAVEL %		
26					CI	CLAY (TILLY) SILTY-SANDY MED PLASTIC GRAY PEBBLES	F	Vr (EST) 10%	26	○ 20					
28								Nbn	28						
30									30	○					
32								Vx - 10%	32	○					
34									34	○					
36									36	○					
38									38	○					
40						END OF HOLE	40'		40	○					
42									42						
44									44						
46									46						
48									48						
50									50						





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 interstitial 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

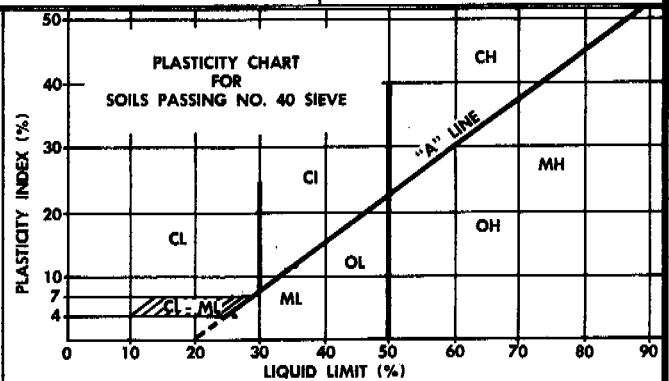
The plastic and liquid limits are shown on the water content chart by a horizontal bar. The Atterberg system is discussed in the following section.

#### 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	$C_u = \frac{D_{60}}{D_{10}} > 6$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
		DIRTY GRAVELS (WITH SOME FINES)	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	$C_u = \frac{D_{60}}{D_{10}} > 4$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
		DIRTY SANDS (WITH SOME FINES)	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 NEGLECTIBLE 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 NEGLECTIBLE 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	
$W_L > 50\%$			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.