R.M.HARDY & ASSOCIATES LTD.

000034

GEOTECHNICAL INVESTIGATION

PROPOSED BRIDGE SITE

PROHIBITION CREEK

MILE 612.4, 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.,
Manager of Northern Roads Program,
Department of Public Works of Canada,
One Thornton Court,
Edmonton, Alberta.

Re: Geotechnical Investigation Mackenzie Highway
Proposed Bridge Site, Prohibition Creek
Mile 612.4

Dear Mr. Kimball:

We are pleased to submit our report on the site of the proposed bridge across Prohibition 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 Prohibition Creek.

The location of this bridge site is shown on mosaic sheet No. 49 of a set of mosaics prepared by the Department of Public Works for the Mackenzie Highway Project. The site is covered by aerial photographs Nos. A22860-108, 109 and 110 (scale 1" = 1000'). The crossing is located approximately 80 feet upstream from the point where the creek is crossed by the Canadian National Telecommunications right-of-way.

In addition to the mosaics and aerial photographs, R. M. Hardy & Associates was provided with a sketch plan and profile showing the proposed crossing. This last drawing is entitled "Plan and Profile Showing Proposed Drainage Structure at Prohibition Creek, Revised Crossing", and is not dated. It was used as the basis for Plate 1, Appendix A.

A report entitled "Geotechnical Investigation, 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

Nine test holes were drilled at or near the proposed crossing on March 9, 10 and 11, 1973, using a Failing 1000 drill rig. Compressed air was used as the drilling fluid. Disturbed samples were obtained at frequent intervals for water content determinations, ice descriptions and material identification. In addition, core samples were obtained in Test Holes 852 and 775. All samples were tested in the field laboratory which formed part of the mobile camp accompanying the operation. Logs of these test holes are in Appendix A.

TOPOGRAPHY

The general direction of the drainage in the area is southwesterly towards the Mackenzie River. The valley of Prohibition Creek is relatively deep for such a comparatively small stream. The vertical distance from water level to the surrounding plain on the southerly side is slightly over 100 feet while the vertical distance from water level on the plain on the northerly side is 65 feet. The average gradient in the valley walls, as existing, is in excess of 12 percent for the southerly wall and 20 percent for the northerly wall. The width of the creek at the water line is approximately 100 feet.

SOIL PROFILE

The soils in the area consist of slopewash material (clay and sand) overlying basal till which overlies shale bedrock at relatively shallow depth. In the valley bottom, the terrain type has been classed as an alluvial meander plain in which the surface soils consist of sand and silt overlying gravel with shale bedrock at shallow depth. In Test Hole 852 boulders were encountered at a depth of 9 feet.

Relatively high water contents are found in the slopewash material but, beneath this depth in the till, the water contents are quite low and seldom exceed 20%. Water contents in the bedrock are generally below 10%.

In the valley bottom seasonal frost had penetrated to a depth of approximately 9 feet (due to the drilling being carried out on a winter road) but beneath this depth unfrozen material was reported everywhere beneath the floor of the valley between Test Holes 851 and 773.

The existing ground surface profile, assumed highway profile, and soil profiles are shown on Drawing E-2510-101 which is reproduced as Plate 1 in Appendix A of this report.

DISCUSSION AND RECOMMENDATIONS

Due to the steep nature of the valley sides at this site, it will be necessary either to employ cut sections on the bridge approaches at both sides or to raise the elevation of the bridge deck to such a height that cuts will not be necessary. Cuts could be avoided by employing a viaduct type of bridge. The viaduct would be approximately 2400 feet in length and would be at a height varying from 60 to 90 feet above the valley floor.

An alternative solution is to cut through the ground on both sides of the bridge and to use a bridge with a deck elevation at approximately 375.0 which is 10 feet above the banks of the stream. Such an arrangement could be used with a relatively short bridge across the stream bed and with approach embankments on either side. The embankments would constrict the flow of the stream during peak flooding periods and, for ecological reasons, might be undesirable. An alternative design might make use of trestles to support the approaches to the bridge within the confines of the valley. In this case, the total length of bridge and trestles would still be 1600 feet.

As will be seen from an examination of Drawing 101 (Plate 1) most of the cuts on the southerly side of the bridge would be in shale bedrock while on the northerly approach most of the cut would be in the sand and till.

Cuts in the shale bedrock can be designed in the same manner as for such cuts in temperate regions where permafrost is not present. However, that part of the cut which lies within the till will be less stable and slopes will have to be cut back to no steeper than 1 vertical to 3 horizontal. In addition, a horizontal berm should be left at the upper surface of the rock to allow for any movement of the till. The slopewash material which lies on the top of the till should be cut back to a slope of 1 vertical to 4 horizontal and the faces of the slope should be protected by broken rock.

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, the 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. The presence of gravel beneath the valley floor will lead to an extension of the thaw bulb due to the movement of water through the gravel. This water will degrade the permafrost.

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 rock and gravel (according to the surveyor's notes on the above mentioned drawings) so that the depth of scour should be limited. The amount of scour that should be expected will depend upon 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.

Due to the absence of permafrost beneath most of the valley floor of this stream, we believe it would be possible to use concrete spread footings for piers and abutments. However, because of difficulties due to logistics and the desire to reduce onsite work to an absolute minimum, we recommend that the piers and abutments be supported on steel H piles. We do not believe that other types of driven piles would be economical.

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 or 10 feet into the shale bedrock whichever is the lesser. Steel H piles driven into the stream bed should be driven a distance of 20 feet below the bottom of the anticipated scour or 10 feet into the bedrock whichever is the lesser.

Piles placed on the banks of the stream should be designed on the basis of an allowable skin friction of 800 psf (on the gross perimeter) with the top 10 feet assumed to carry no load. Those piles which penetrate 10 feet into bedrock may be designed for the full structural strength of the pile acting as a column.

Piles placed in the stream bed should be designed as described below.

Driving steel H piles will require considerable energy particularly if they penetrate into the shale. The weight of the pile driving hammer should be at least twice the weight of the pile being driven except that in the case of diesel hammer 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 it should be reinforced with flange plates for a distance equal to 1.5 times the size of the pile. Alternatively points 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.-lbs. 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, or 10 feet into the bedrock, may be designed for the full structural strength of the pile section acting as a column. The 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, 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 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. per blow unless calculations show that the pile can safely take higher impact stresses.

One of the problems facing 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 Prohibition 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 back-fill is not compacted.

Embankments constructed below the highest expected flood level should be protected with riprap.

Respectfully submitted,

R. M. HARDY &ASSOCIATES LTD.,

Per:

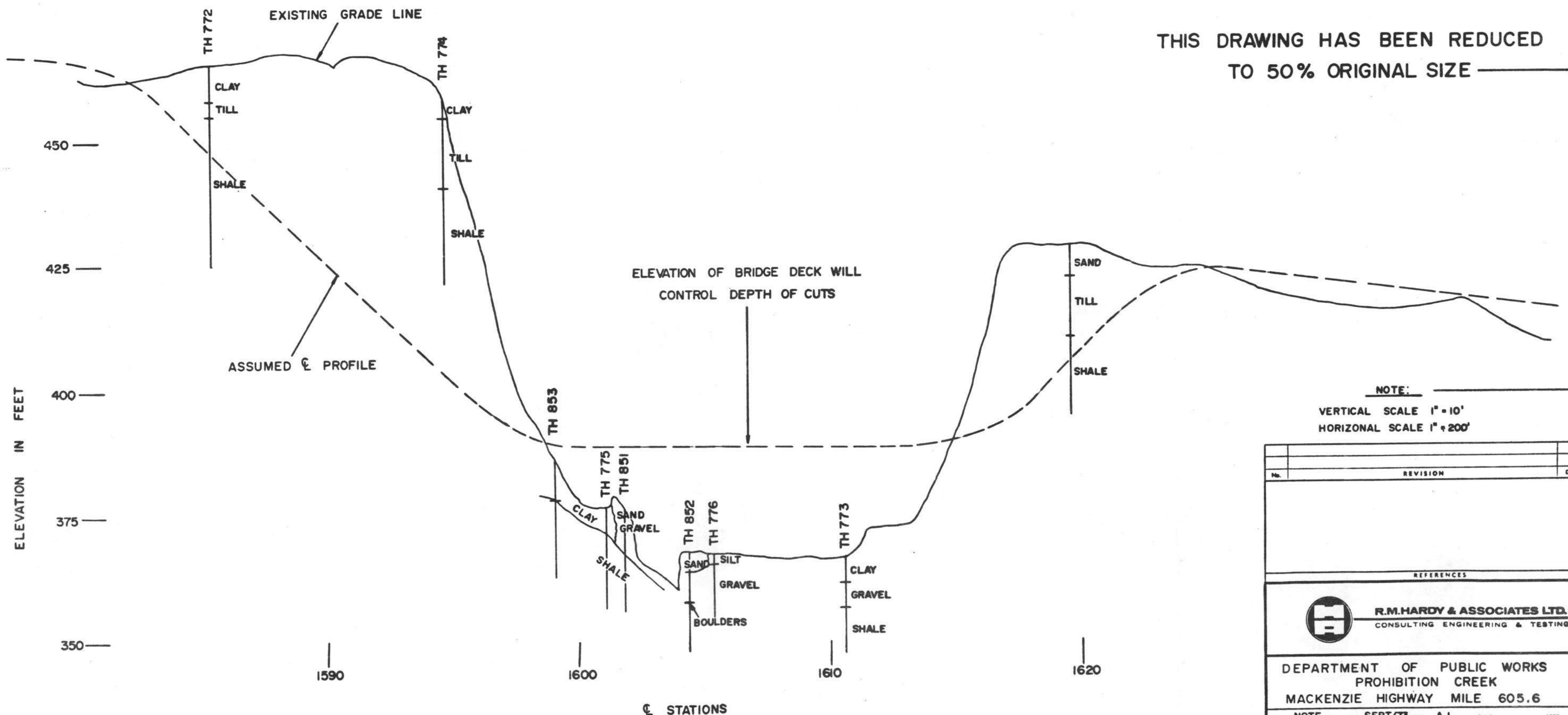
G. McCormick, P.Eng.

GM/jc

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

APPENDIX A

Chart
Section
Test Hole Logs



THIS DRAWING HAS BEEN REDUCED
TO 50% ORIGINAL SIZE

NOTE:
VERTICAL SCALE 1" = 10'
HORIZONAL SCALE 1" = 200'

No.	REVISION	DATE	BY

REFERENCES

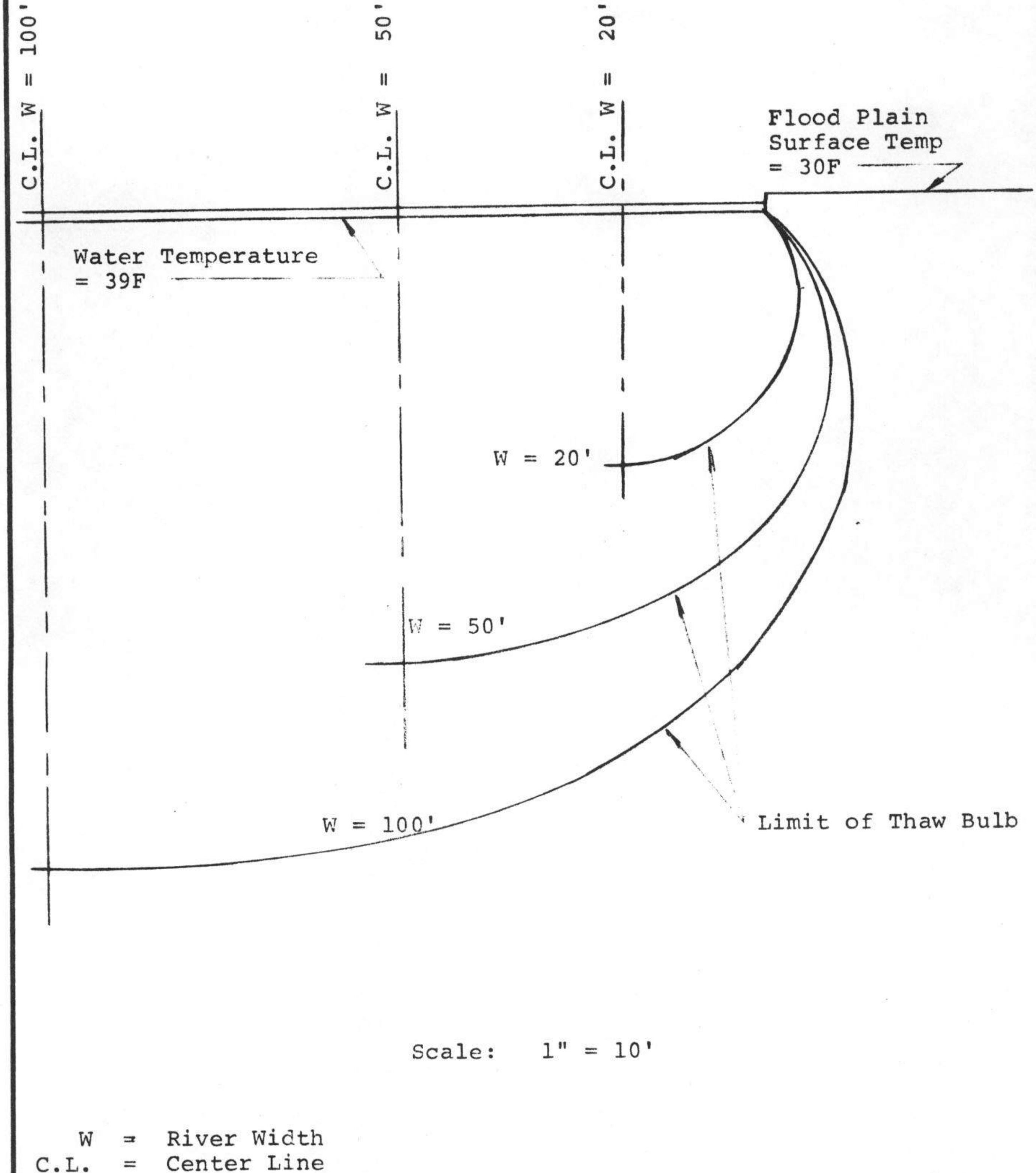
R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

DEPARTMENT OF PUBLIC WORKS
PROHIBITION CREEK
MACKENZIE HIGHWAY MILE 605.6

SCALE NOTE DATE SEPT/73 MADE A.L. CHKD APPD.

No. E-2510-101 REV. 0

PLATE 1

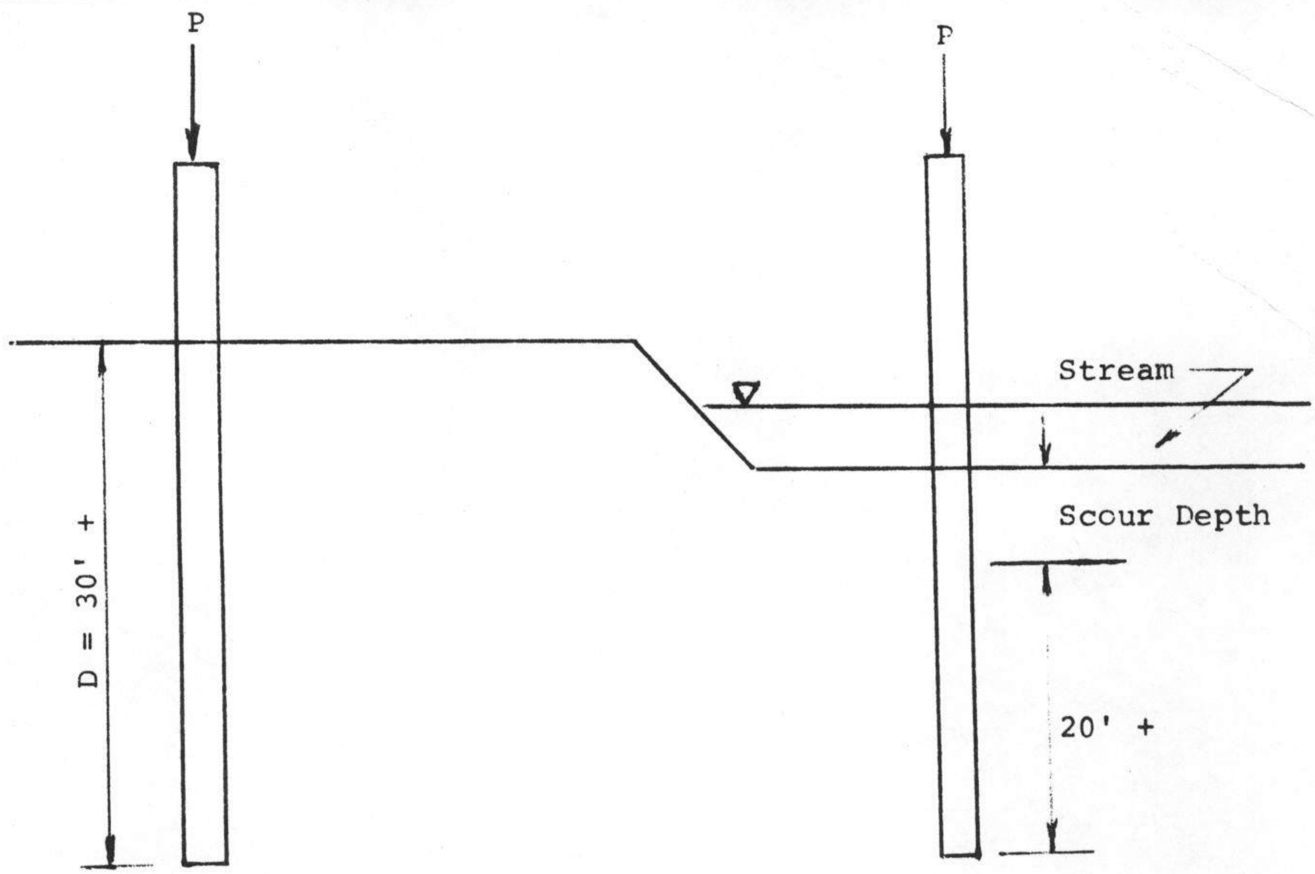


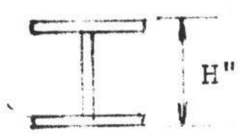
G.Mc September 14/73 E-2510

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

THAW BULBS BENEATH RIVERS
NORMAN WELLS AREA

PLATE 2





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

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

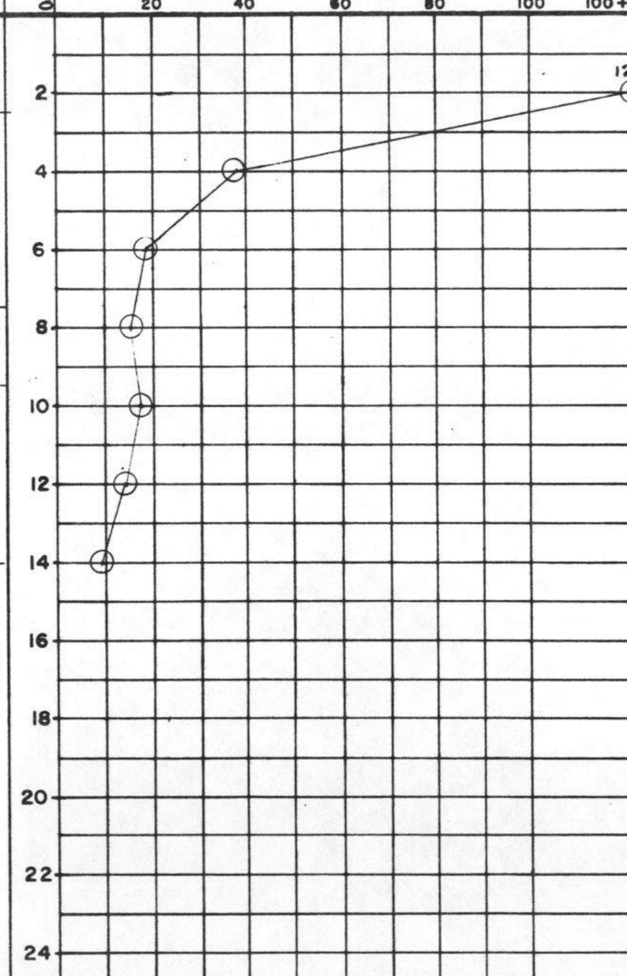
DWN: CRA	FIELD ENG: B.D	DATE DRILLED: 9/3/73	AIRPHOTO NO: A22934-147	CHAINAGE: 1586 + 00	OFFSET:
CKD:	TECH: DR & M.B	RIG: MAYHEW1000	SURFACE DRAINAGE: POOR	VEGETATION: SEE REMARKS	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
612	C	772

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST. %)
0 – 2½					OH	ORGANIC CLAY HIGH PLASTIC BLACK	F	Vx 20%
2½ – 7½					CI-CH	CLAY; SILTY, SANDY SLIGHTLY ORGANIC MED TO HIGH PLASTIC BROWN CALCAREOUS		Vx 40% Vx 10%
7½ – 9½					CI	CLAY (TILL); SILTY, SANDY MED PLASTIC, BROWN PEBBLES, CALCAREOUS BEDROCK INCLUSIONS		Nbn
9½ – 14'					CH	CLAY (SHALE); HIGH PLASTIC GREY TRACE OF CALCAREOUS		Vs 10%
14'						END OF HOLE		

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ├──┤ LIQUID LIMIT



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

REMARKS

SPARSE
SCRUB
SPRUCE
To 20' HIGH
4"ø MAX

R.M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

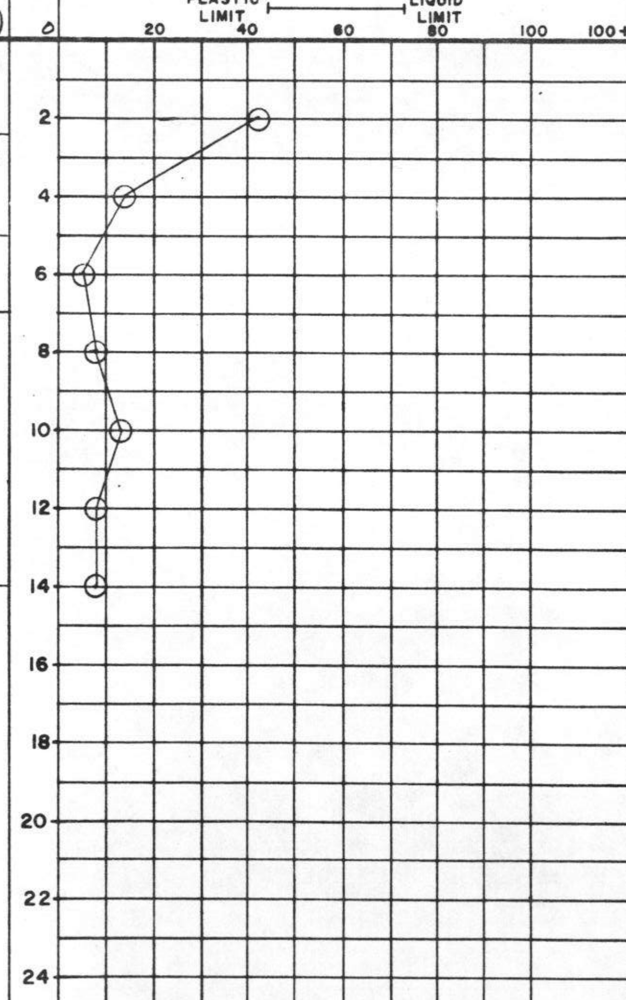
DWN: CRL | FIELD ENG: BD | DATE DRILLED: | AIRPHOTO NO: A22934-147 | CHAINAGE: 1609+60 | OFFSET:

CKD: | TECH: MB & B.F | RIG: MAYHEW 1000 | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
612	C	773

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST. %)
0–2½					OH	ORGANIC CLAY, SILTY, HIGH PLASTIC, DK BROWN — 2½'	F	Vx 30%
2½–5					CI	CLAY (TILL), GRAVELLY, SILTY, MED. PLASTIC, BROWN, CALCAREOUS — 5'		Vx < 5%
5–10					GP	GRAVEL; SANDY, BROWN, NON-PLASTIC, CALCAREOUS — 9'; SHALY WITH SILTSTONE — 10'		Nf
7–							UF	NO ICE
10–14					CH	CLAY (SHALE), SILTY, HIGH PLASTIC, GREY — 14'		
14						END OF HOLE		

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



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

REMARKS

SPARSE SCRUB SPRUCE, 5-25' HIGH, 6" ϕ MAX, OCCASIONAL POPLAR; SHRUBS

R.M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

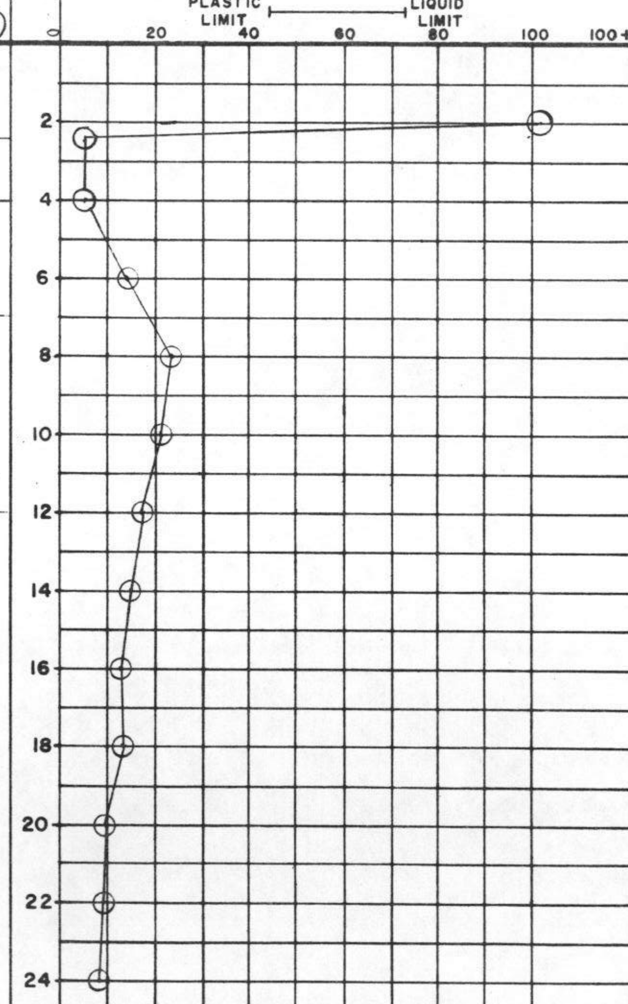
DWN: CRA	FIELD ENG: B.D	DATE DRILLED: 9/3/73	AIRPHOTO NO: A22934-147	CHAINAGE: 1592 + 27	OFFSET:
CKD:	TECH: DR & M.B	RIG: MAYHEW 1000	SURFACE DRAINAGE: POOR	VEGETATION: SEE REMARKS	ELEV:

TEST HOLE SHEET 1 OF 2

MILE	B,C,S	NUMBER
612	C	774

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST. %)
0 – 2½					OH	ORGANIC CLAY; SILTY HIGH PLASTIC DARK BROWN 2½'	F	Vx 70%
2½ – 4					SW	SAND; COARSE, SILTY 4'	UF	
4 – 9.5					CL	CLAY (TILL); SILTY, SANDY LOW PLASTIC BROWN PEBBLES COBBLES		Vx 5%
9.5 – 12					CH	HIGH PLASTIC SHALE INCLUSIONS 12'		
12 – 18					CH	CLAY (SHALE); FISSURED, RUST STAINED SILTY, BROWN LAMINATED HARD GREY & VERY HARD 18'		Nbn
18 – 24						EXTREMELY HARD SHALE FRACTURED HORIZONTALLY		

○ = 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

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DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

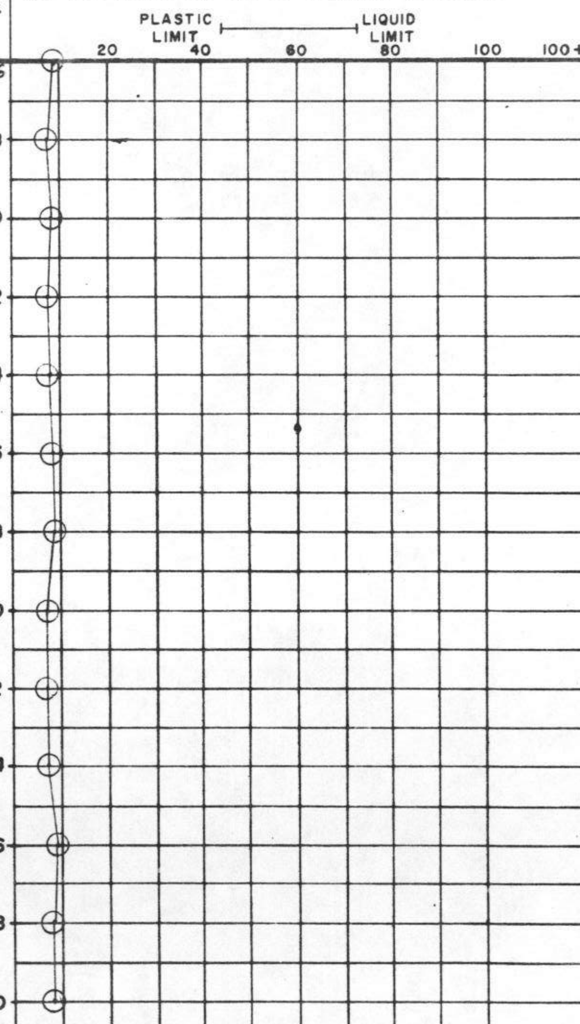
DWN: CRS	FIELD ENG: B.D	DATE DRILLED: 9/3/73	AIRPHOTO NO: A22934-147	CHAINAGE: 1592+27
CKD:	TECH: DR + W.B	RIG: MAYHEW 1000	SURFACE DRAINAGE: POOR	VEGETATION:
OFFSET:	ELEV:			

TEST HOLE SHEET 2 OF 2

MILE	B,C,S	NUMBER
612	C	774

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
26						EXTREMELY HARD SHALE FRACTURED	F	Nbn	26							
28									28							
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44						44' SHALESTONE		Nbn	44							
46									46							
48									48							
50						50' END OF HOLE			50							

○ = 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

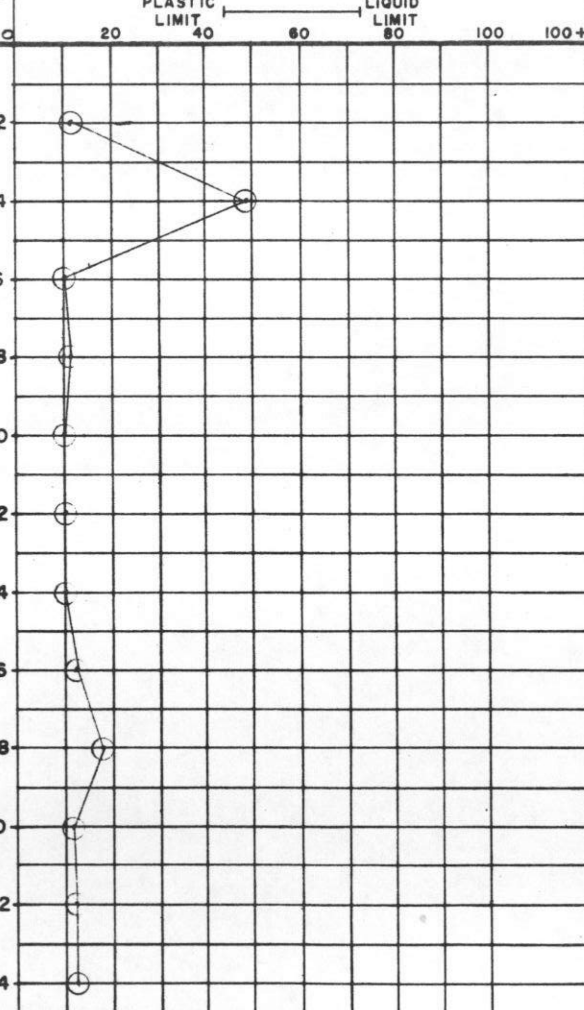
DWN: CRA	FIELD ENG: B.D.	DATE DRILLED: 11/3/73	AIRPHOTO NO: A22934-147	CHAINAGE: 160/+00	OFFSET:
CKD: [illegible]	TECH: CRA	RIG: FAILING	SURFACE DRAINAGE: GOOD	VEGETATION: SEE REMARKS	ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
612	SN	775

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
0–4					CI	CLAY (TILL); SILTY SANDY, MED PLASTIC BROWN, PEBBLES, RUSTY COAL SPECKS CALCAREOUS, SHALE INCLUSIONS BOULDERS 3 — 4	F	Vx 20%							MODERATELY DENSE SPRUCE 5-70' HIGH 10"⌀ MAX WILLOWS & OCCASIONAL BIRCH
4–14	1	C	N/R		CH	CLAY (SHALE); HIGH PLASTIC BROWN CALCAREOUS.		Vr 2%							
	2	C	N/R												
14–24	3	C	N/R			14' GREY		Nbn							

○ = 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

TEST HOLE SHEET 2		
MILE	B,C,S	NUMBER
6/3	SN	775

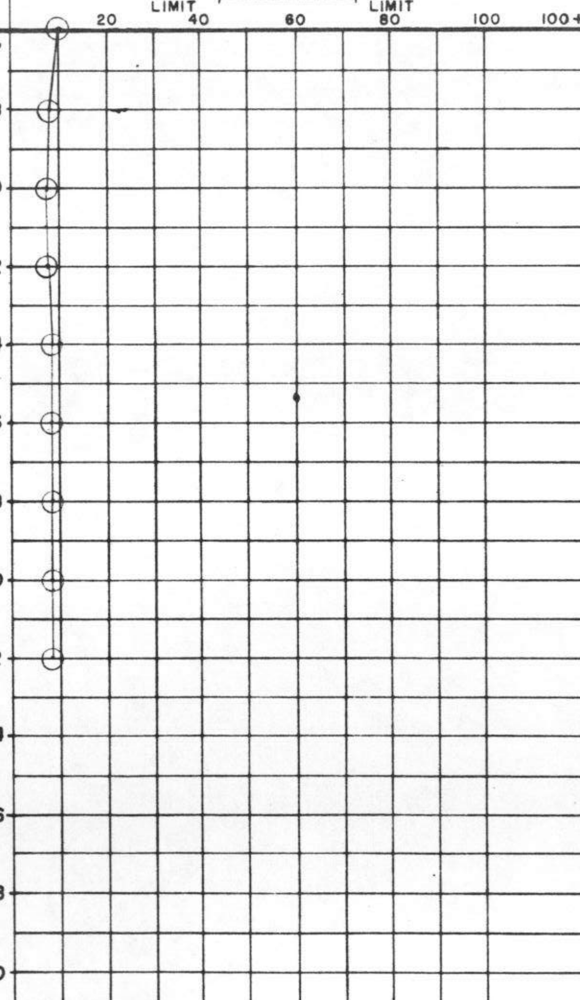
DWN: [initials] | FIELD ENG: B.D | DATE DRILLED: 11/3/73 | AIRPHOTO NO: A22934-147 | CHAINAGE: | OFFSET:

CKD: | TECH: [initials] | RIG: FAILING | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
26					CH	CLAY (SHALE)	F	Nbn	26							
						GREY										
28						HIGH PLASTIC			28							
						CALCAREOUS										
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42							42'	→	42							
						END OF HOLE		WATER								
44									44							
46									46							
48									48							
50									50							

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT —— LIQUID LIMIT

GRAIN-SIZE ANALYSIS



R.M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

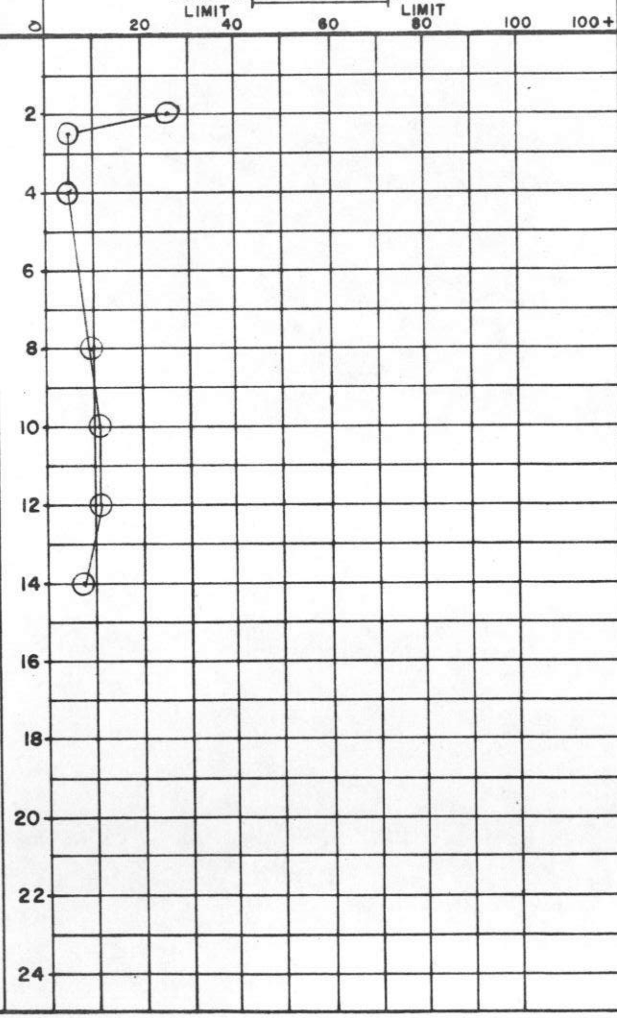
DWN: CRA	FIELD ENG: BD.	DATE DRILLED: 10/3/73	AIRPHOTO NO: A 22934-147	CHAINAGE: 1604+10
CKD: [illegible]	TECH: MB & B.F	RIG: MAYHEW 1000	SURFACE DRAINAGE: GOOD	VEGETATION: SEE REMARKS
OFFSET:	ELEV:			

TEST HOLE

MILE	B,C,S	NUMBER
612	S	776

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST. %)
0 – 2½					OL	ORGANIC SILT; CLAYEY, TRACE OF SAND; LOW PLASTIC; DK BROWN	F	Vx 10%
2½ – 4						SHALE STONE; HARD; GRAVEL INCLUSIONS; CLEAN		Nf
4 – 6					G.P.	SHALY GRAVEL; SILTY		
6 – 10						SILTIER, TRACE OF CLAY		
8							UF	NO ICE. →
10 – 14						WATER; SILTY CLAYEY		
14						LESS GRAVELLY; END OF HOLE		

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ——— LIQUID LIMIT



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

REMARKS

MODERATELY DENSE
SPRUCE 20-50' HIGH 6" ϕ MAX
WILLOWS
OCCASIONAL POPLAR

R. M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CKA | FIELD ENG: B.D. | DATE DRILLED: 10/3/73 | AIRPHOTO NO: A22934-147 | CHAINAGE: 1617+50 | OFFSET:

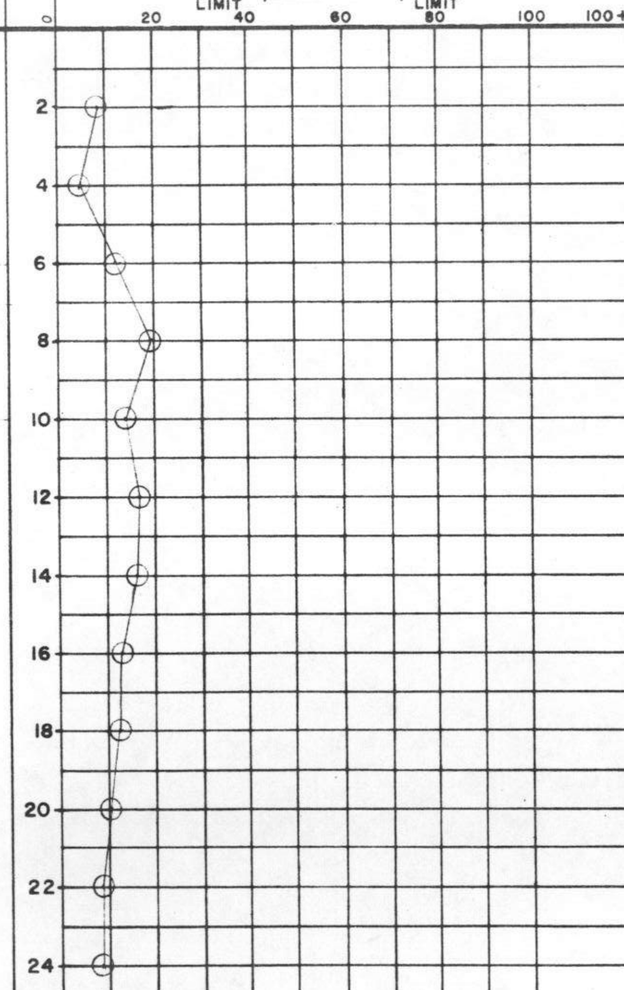
CKD: [illegible] | TECH: MB & B.F. | RIG: MAYHEW 1000 | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE SHEET 1 OF 2

MILE	B,C,S	NUMBER
612	C	777

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					SP	SAND; COARSE GRAVELLY	F	Nf							SPARSE SCRUB SPRUCE 5'-20' HIGH 6" ϕ MAX; SHRUBS WILLOWS
4'					SW	FINE GRAVELLY									
6'					CI	CLAY (TILL) SILTY, SANDY. GRAVELLY MED PLASTIC BROWN CALCAREOUS		Vx 15%; Vs 20%							
10							UF	No ICE							
14'						GREY									
18'					CH	CLAY (SHALE) HIGH PLASTIC GREY									

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT



R. M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

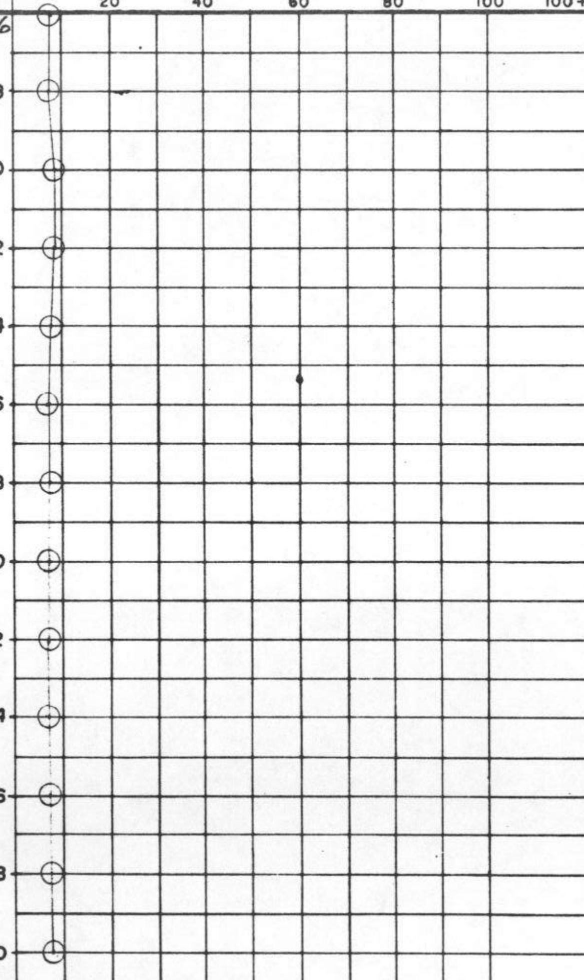
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: CLA	FIELD ENG: B.D.	DATE DRILLED: 10/3/73	AIRPHOTO NO: A22934-147	CHAINAGE:
CKD:	TECH: WB & B.F	RIG: MAYHEW 1000	SURFACE DRAINAGE: GOOD	VEGETATION: SEE REMARKS
OFFSET:	ELEV:			

TEST HOLE SHEET 2		
MILE	B,C,S	NUMBER
614	C	777

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
26					CH	CLAY (SHALE); HIGH PLASTIC GREY	UF	NO ICE	26							SPARSE SPRUCE 5-20' HIGH 6"ϕ MAX SHRUBS & WILLOWS
28									28							
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							
50						END OF HOLE 50'			50							

○ = 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

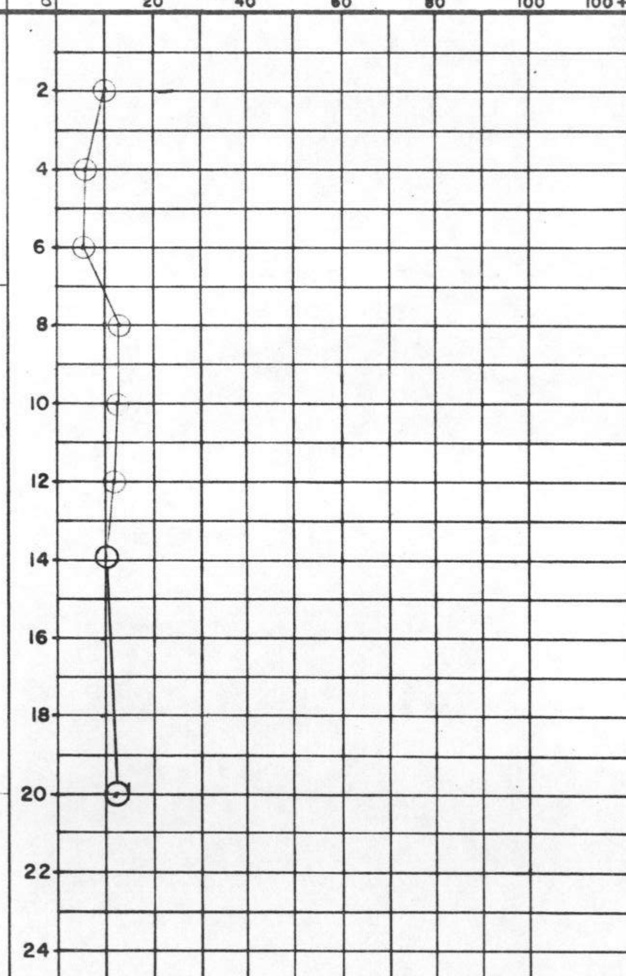
DWN: GA | FIELD ENG: B.D | DATE DRILLED: 9/3/73 | AIRPHOTO NO: A22934-147 | CHAINAGE: 1601+70 | OFFSET:

CKD: AB | TECH: Dram B. | RIG: MAYHEW 1000 | SURFACE DRAINAGE: POOR | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
612	S	851

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0					OH	ORGANIC CLAY, SILTY LOW MED PL — 1/4'	F	Nf
2					SM	SAND; SILTY, PIECES OF SANDSTONE & SILTSTONE, ROOTLETS — 3'		
4					GS	GRAVEL; SANDY, WELL-GRADED, CLEAN — 7'		
8					CI	CLAY (TILL), SANDY, SILTY, MED PLASTIC, BROWN, SHALE INCLUSIONS, CALCAREOUS — 10'	UF	
10					CH	CLAY (SHALE), HIGH PLASTIC, LAMINATED, GREY, FISSURED — 20'		WATER BEARING.
20						END OF HOLE		

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT



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

REMARKS:

SPARSE SPRUCE
50' HIGH
8' ϕ MAX

WILLOWS & POPLAR

R.M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY

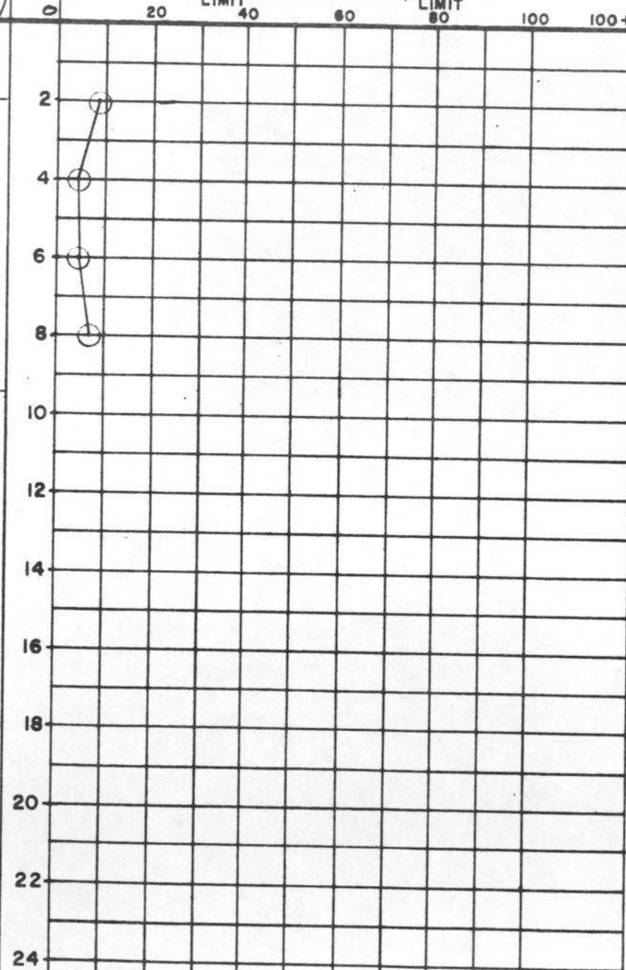
DWN: [illegible] | FIELD ENG: BD | DATE DRILLED: 9/3/73 | AIRPHOTO NO: A 22934-147 | CHAINAGE: 1603+25 | OFFSET:

CKD: [illegible] | TECH: DR + W.B. | RIG: MAYHEW 1000 | SURFACE DRAINAGE: POOR | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE		
MILE	B,C,S	NUMBER
612	C,S	852

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (EST. %)
0					OH	ORGANIC CLAY; SILTY — 1/4'		
					GC	HARD SHALE & PEA GRAVEL SILTY, SANDY, CLAYEY, BROWN — 2'	F	Vx > 5%
2					SW	SAND - SILTY. CLEAN BROWN — 4'		Nbn
4	(1)				GP	HARD SHALE & GRAVEL SLIGHTLY SILTY NON-PLASTIC CALCAREOUS — 8'		
8						SANDIER — 9 1/2'		
10						END OF HOLE (REFUSAL BY BOULDERS)		

O = WATER CONTENT (% OF DRY WEIGHT)
Δ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT — LIQUID LIMIT



DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)
4	← 8 →		62	30		

REMARKS

MODERATELY DENSE

SPRUCE 30' - HIGH 8" ϕ MAX

WILLOWS & POPULAR

R.M. HARDY AND ASSOCIATES LTD. — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA — MACKENZIE HIGHWAY

DWN: CRA | FIELD ENG: B.D | DATE DRILLED: 10/3/73 | AIRPHOTO NO: A22934-147 | CHAINAGE: 1598 + 90 | OFFSET:

CKD: [illegible] | TECH: M'B & B.F | RIG: WAYNE 1000 | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

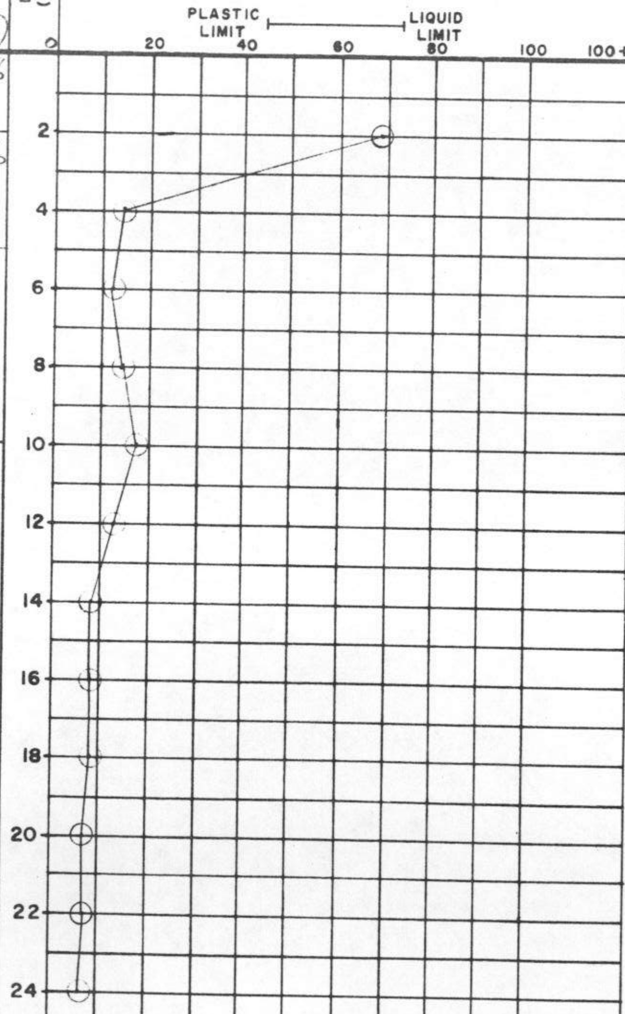
TEST HOLE — SHEET 1 OF 2

MILE	B,C,S	NUMBER
612	C	853

DEPTH (FEET)	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION (Est. %)	REMARKS
0–2'	OL/OH	ORGANIC CLAY; SILT, MED PLASTIC, DK BROWN	F	Vx 25%	SCRUB SPRUCE 5-30' HIGH 6"ϕ MAX & OCCASIONAL BIRCH
2'–8'	CI	CLAY (TILL) SILTY, SANDY, MED PLASTIC, BROWN, PEBBLES, CALCAREOUS SHALE INCLUSIONS GRAVEL & ROCK FRAGMENTS		Vs 30% (2'–5'); Nf	
8'–	CH	CLAY (SHALE) HIGH PLASTIC, GREY, CALCAREOUS, PROGRESSIVELY HARDER	UF (from 10')	Nbn	

SAMPLE NUMBER, SAMPLE TYPE, % RECOVERY, PENETRATION RESISTANCE, GRAIN-SIZE ANALYSIS (CLAY %, SILT %, SAND %, GRAVEL %), WET DENSITY (P.C.F.), DRY DENSITY (P.C.F.): no entries.

○ = 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: CPA | FIELD ENG: B.D | DATE DRILLED: 10/3/73 | AIRPHOTO NO: A 22934-147 | CHAINAGE: | OFFSET:

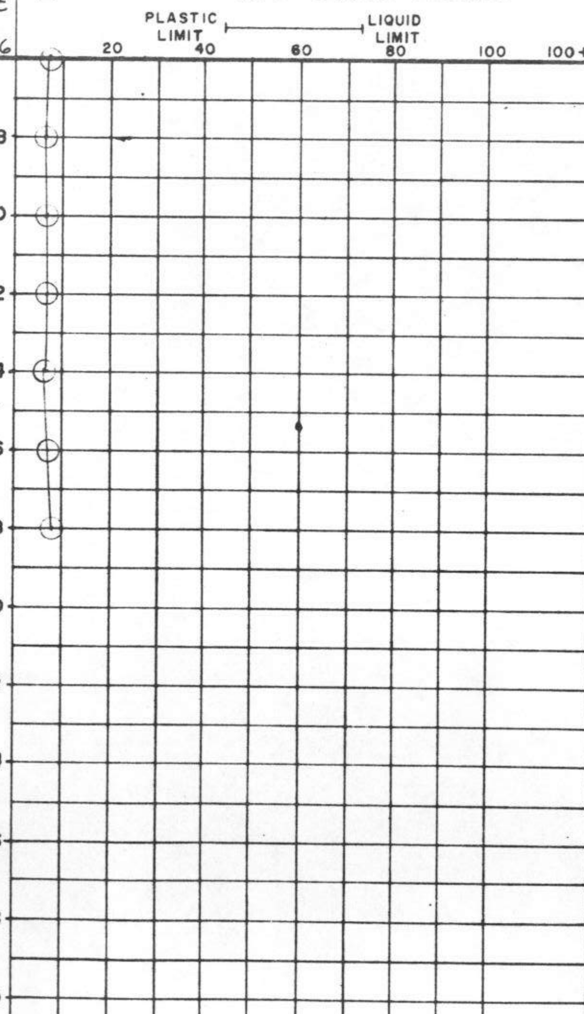
CKD: [signature] | TECH: MB & B.F | RIG: MAYHEW 1000 | SURFACE DRAINAGE: GOOD | VEGETATION: SEE REMARKS | ELEV:

TEST HOLE SHEET 2 OF 2		
MILE	B,C,S	NUMBER
612	C	853

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
26					CH	CLAY (SHALE) GREY HIGH PLASTIC CALCAREOUS, PROGRESSIVELY HARDER.	UF		26							SPRUCE 5-30' HIGH 6"ϕ MAX SHRUBS & OCCASIONAL BIRCH
28									28							
30									30							
32									32							
34									34							
36									36							
38									38							
40									40							
42									42							
44									44							
46									46							
48									48							
50						END OF HOLE 50'			50							

○ = WATER CONTENT (% OF DRY WEIGHT)

△ = ICE CONTENT (% OF SAMPLE VOLUME)



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

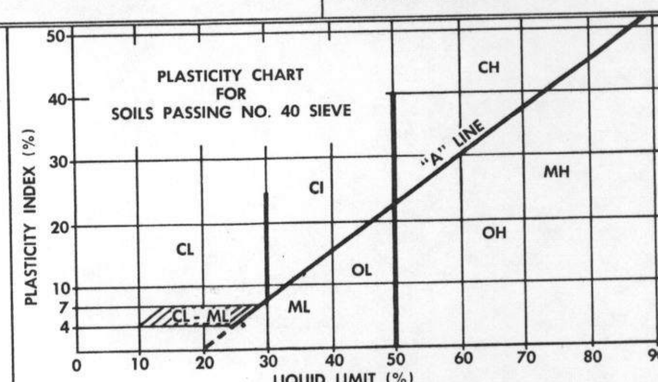
The plastic and liquid limits are shown on the water content chart by a horizontal bar. The Atterberg system is discussed in the following section.

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.