Public Works
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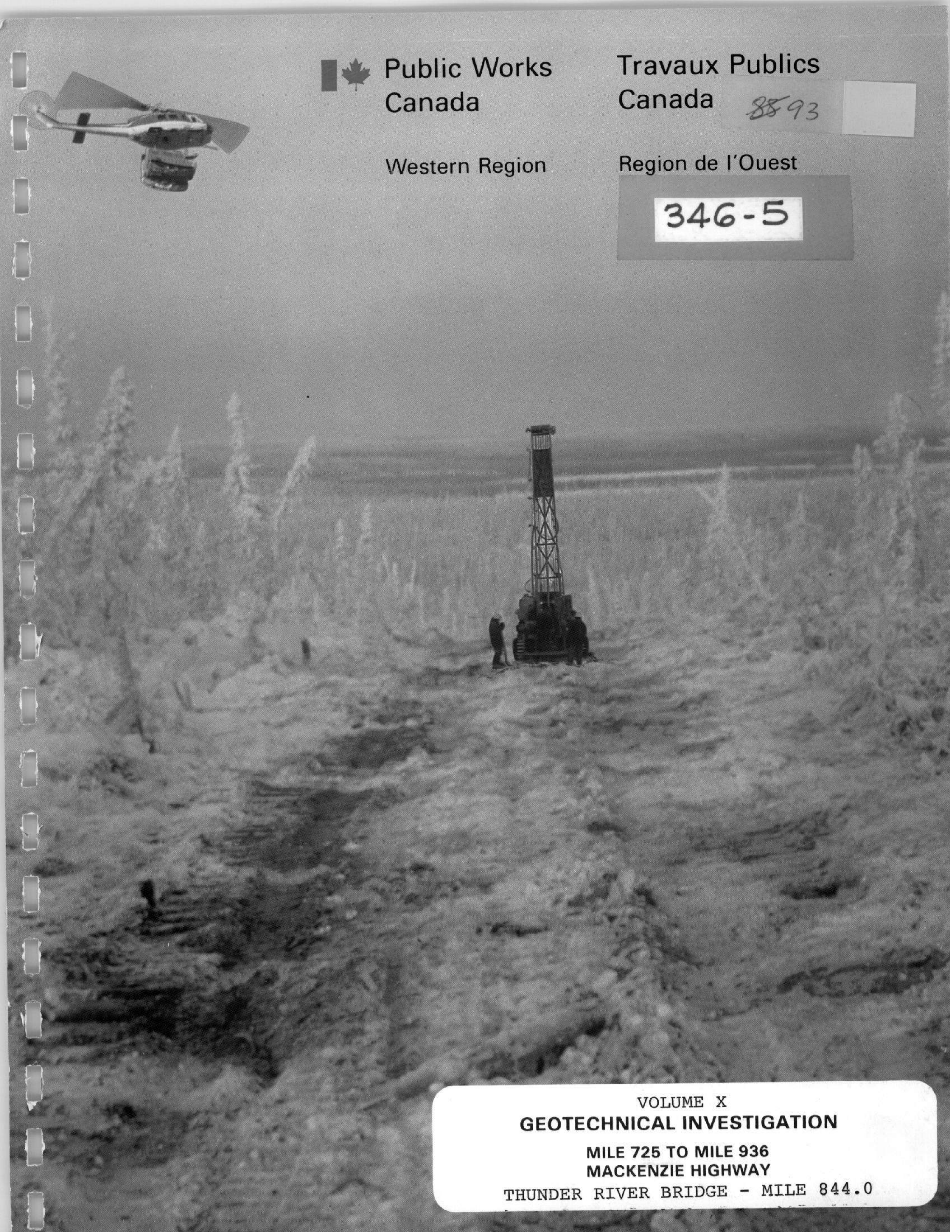
Western Region

Region de l'Ouest



VOLUME X

GEOTECHNICAL INVESTIGATION

MILE 725 TO MILE 936
MACKENZIE HIGHWAY

THUNDER RIVER BRIDGE - MILE 844.0

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PUBLIC WORKS CANADA

WESTERN REGION

REPORT ON
GEOTECHNICAL INVESTIGATION
MILE 725 TO MILE 936
MACKENZIE HIGHWAY

VOLUME X

FOUNDATION INVESTIGATION
THUNDER RIVER CROSSING
MILE 844.0

Submitted by R. D. Cook, P. Eng.
Soils Engineer
Special Services
Western Region

JUN 75

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APPENDICES

I INTRODUCTION

The subsoil investigation at the Thunder River was undertaken as part of the overall geotechnical investigation on the Mackenzie Highway between Ft. Good Hope (Mile 725), and the junction with the Dempster Highway (Mile 936, in the winter of 1973-74. This crossing site was one of five major stream crossings which were investigated in detail during the course of the field work. General terrain analysis and borrow evaluation along the Highway has been submitted earlier in Volumes I to VIII of a report entitled Geotechnical Investigation - Mile 725 to Mile 936, Mackenzie Highway. This report on the Thunder River crossing comprises Volume X of that overall report.

All field and laboratory work associated with this investigation was carried out by the Special Services Section, Design and Construction Branch, Western Region, Public Works Canada.

II SITE CONDITIONS

The proposed bridge site is located approximately 6 miles upstream of where Thunder River empties into the Mackenzie River, and is at approximately Mile 844.0 of the proposed Mackenzie Highway. The geographic location of the crossing is shown on the 1" = 90 miles key plan, Drawing No. A-1, Appendix A. Drawing No. A-2, Appendix A, outlines the upstream drainage area of the Thunder River, and Drawing No. A-3 is a detailed 1" = 200' mosaic of the proposed crossing site.

The Thunder River Valley is a broad (1 - 1-1/2 miles), deep (300'+), depression in the central portion of the Anderson Plain. The present Thunder River is vastly undersized for the valley and the depression is thought to be a former glacial meltwater channel. Headwaters of the River, and much of the catchment area, are located in bedrock controlled uplands, however at the proposed crossing site, the valley is incised into hummocky moraine. The drainage area to the Highway is only 116 square miles (3.4)* and there are no major lakes on the main channel which effect the peak discharge. A fifty year return period design discharge of roughly 1400 c.f.s. has been recommended (3.4).

The proposed highway route descends directly downslope into the Thunder River Valley from the south at a widening in the valley, makes a sharp curve on the valley floor, then ascends the north valley wall running across the slope. Highway gradients on both sides reach a maximum of 8% for short sections. Valley slopes are glacial till at depth

* Numbers in parenthesis refer to the List of References presented at the end of this report.

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with some overlying slopwash deposits. The valley floor is wide and irregular and is marked by numerous, sharply defined, glaciofluvial features and small lakes. Highway cuts are proposed in two of the features which are primarily sand in composition. Permafrost is prevalent throughout.

The Thunder River has formed a small trough within the main valley and has developed a marked meander pattern therein. At the proposed crossing site the river is relatively straight and is only 30-35' in width. The west bank of the present channel is relatively steep, and high (15'), however the east bank is low and the 50 year design discharge would slightly inundate a small flood plain to the east. The channel annually freezes to the bottom and is subject to icing (ice build-up on the surface) from flow carried in the sub-surface gravels which frequently breaks through to the surface.

A large culvert has been tentatively considered for the Thunder River (3.4) and it is recommended that a culvert (or culverts) installation be more fully evaluated. The hydrological consultants have recommended a 220' bridge structure which would be a costly crossing for a small stream. Excerpts from the hydrological reports are included in Appendix C.

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Borehole locations and a portion of the Thunder River Valley is shown on Drawing No. A-3. The immediate area of the crossing is shown in profile on Drawing No. A-4. Photographs #1 and #2 in Appendix A provide views of the valley floor and the proposed crossing.

III EVALUATION OF SUBSOIL CONDITIONS

A. Field and Laboratory Analysis

A total of 12 test holes were drilled in the immediate vicinity of the crossing site. All holes were drilled by means of a Mayhew 1000 drill rig using compressed air as the drilling fluid. Disturbed samples were obtained at frequent intervals in all holes for water content determinations, ice descriptions and material identification. All samples were returned to Edmonton for analysis in the Departmental Laboratory. Borehole logs are included in Appendix B.

B. Subsoil Profile

The boreholes and the inferred stratigraphic sections are shown on Drawing No. A-4 in Appendix A. The subsoil profile below the Valley floor reflects the varied and complex depositional patterns of the major stream which once occupied the Valley. The profile as shown on Drawing No. A-3 presents a very generalized pattern and individual borehole logs should be consulted for detail.

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All deposits immediately below the crossing site are sandy in nature. The upper strata to a depth of 10-15' consist of a heterogeneous mixture of silts, sands, and gravels with some very coarse granular materials (cobbles) on the stream bed. Below the 10-15' level the subsoil is more uniform and consists of sands or silty sands which extend to the maximum depth drilled - 60'. There is a very steep glacial till - sand interface with depth approximately 100' west of the present stream location, which probably defines the lateral limit of the former meltwater channel before backfilling. To the east, the sandy subsoil extends across the valley floor.

Permafrost is present throughout with the exception of a very small thaw zone below the stream in granular subsoil where subsurface flow apparently continues year round. Visual ice is categorized as 'moderate' in the sandy deposits and there is sufficient moisture on thawing to produce 'wet' or 'saturated' materials, with occasional zones which show free water. Moisture contents range from 10 to 30% but for the most part are between 15-20%. Materials are essentially non-plastic.

Approximately 5' of ice was encountered in February, 1974, much of which is attributed to overflow icing. The stream was frozen to slightly below the stream bed.

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IV FOUNDATION SUPPORT OF BRIDGE STRUCTURE

A. Abutment and Pier Foundations

If a bridge is constructed at this crossing site it is recommended the piers and abutments be founded upon steel piles frozen into the sandy subsoil at depth.

Design details for the proposed structure are not available, however an overall bridge length of 220' has been suggested by the hydrology consultants (3.4). Foundation conditions place no restrictions on the bridge design however it is assumed the design will consist of a long center span (at least 100') with shorter end-spans as required. With the exception of some warming of the permafrost soils during pile freeze-back, in the area of the piles, and possibly some surface degradation of permafrost during construction, it is not considered that any change in the permafrost conditions will occur at this site as a result of a bridge. Piles installed in pre-bored holes are recommended rather than driven piles as it is anticipated pile driving would be extremely difficult in the frozen sandy subsoil.

It is recommended the foundation elements consist of either steel H-piles (BP 12 @ 53 lbs./sq. ft.), or closed end steel pipe piles (10" diameter @ 40 lbs./ft.). The piles should

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be placed in pre-bored holes, the void space backfilled with a sand slurry and allowed to freeze into place. If H-piles are employed the piles should be driven approximately 10 feet below the depth of pre-boring to provide some immediate load-carrying capacity. Pipe piles should be driven to practical refusal or 5-6' below the pre-boring depth. Load transfer will initially be by end-bearing and friction on the lower part of the pile in the frozen sand, and, following freezeback, by tangential adfreezing along the pile surface.

Tangential adfreezing is dependent upon temperature of the permafrost soils and composition of the backfill material. There is no detailed temperature data with depth for the Thunder River area, however the National Research Council working in conjunction with D.P.W., has installed thermistors at the Eagle River in the Yukon which is at a latitude slightly south of the Thunder River. Available readings from the Eagle River are included in Appendix C and it is considered that temperature data obtained at the North abutment (cable #1) can conservatively be applied to the Thunder River (cable #2 at the South abutment is in a thaw zone of a former channel of the Eagle River). This data shows a consistent temperature near 28^{O}F with depth.

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Test data obtained by the U.S. Army Cold Regions Research and Engineering Laboratory from pile load tests in Alaska, indicate a sustained adfreeze strength for a silt-water slurry backfill and steel of more than 25 psi. at 28°F. In addition, adfreeze strengths for a saturated, well-graded sand slurry, vibrated in place, are at least 50% higher. Therefore, if a design adfreeze strength of 10 psi. is assumed, the factor of safety will be at least 3 for a sand slurry backfill. Twelve inch steel H-piles would therefore develop a load carrying capacity of 12" x 12" x 10 psi. x 4 = 5760 lbs. per lineal foot of pile, and 10" diameter pipe piles would develop π x 10" x 12" x 10 psi. = 3870 lbs. per foot.

In order to accommodate a 12" H-pile, an 18" diameter borehole is required, and to accommodate a 10" diameter pipe pile, at least a 14" diameter hole would be required to ensure pile alignment and adequate placement of slurry backfill. Thus the void space, and the slurry requirement, for a pipe pile would be significantly less than for an H-pile. This is important as the slurry introduces heat into the ground and should be kept to a minimum.

It is recommended the backfill consist of a well-graded sand with 100% passing the #4 sieve, and less than 15% passing the #200 sieve. Sufficient water should be added to completely

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saturate the sand but excess water should be avoided. A concrete mixer will serve to mix the slurry and the temperature of the slurry should be as cold as possible to avoid introducing any unnecessary heat into the ground. It is estimated the water content of a well-saturated, well-graded sand will be in the order of 25% and the volumetric latent heat will be in the order of 3000 BTU/cu. ft. For an 18" diameter H-pile hole, the latent heat per foot of pile will be approximately 5500 BTU/foot. In comparison the volumetric latent heat for a 14" diameter pipe pile hole would be approximately 2000 BTU/foot. Based upon CRREL test data, a single H-pile installed in an 18" diameter hole with a slurry as outlined above, would require probably 9-10 days to completely freeze-back at a permafrost temperature of 28°F, whereas a 10" pipe pile in a 14" diameter hole would completely freeze-back in probably 3-4 days. Thus there are obvious advantages to using pipe piling.

Freeze-back time for a group of piles would be greater as more heat is introduced into the subsoil, and therefore the minimum number of piles possible should be used - i.e., the design should utilize heavily loaded, widely spaced piles, as opposed to closely spaced, lightly loaded members. Pile groupings increase the overall temperature of the permafrost within the area of the piles and if spacings are small, the temperature will be raised to the point that freeze-back will cease until the permafrost is made colder - i.e., until winter, if construction is in summer. For 12" H-piles in 18" diameter holes, the pile spacing should be not less than approximately 8' to obtain full freeze-back without having to wait a winter season; for 10" pipe piles in 14" diameter holes a pile spacing of not less than approximately 5 feet would be required.

Following are recommended pile lengths and depths of pre-boring for 10" pipe and 12" steel H-piles, assuming a design load in the order of 100 kips per pile. The pipe piles are preferred.

Pile	Effective length below pier or abutment	Depth of Pre-boring	Hole Size
10" pipe @40#/ft.	35'	30'	14-15"
BP12@53#/ft.	30'	20'	18"

Piles should be driven with a fairly high energy hammer below the depth of pre-boring as penetration is expected to be difficult in the dense frozen sand - an energy in the order of 20,000 ft. lbs. per blow is recommended. Detailed driving records should be maintained.

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B. Bridge Approach Fills

Fill heights immediately adjacent to the abutment on the west will be in the order of 25', and on the east roughly 40'. The permafrost table will likely rise into these embankments and stability of the approaches will not be a problem. On the west, the highway climbs out of the valley running across slope and precautions will be required to ensure surface drainage is not channeled along the upslope side of the embankment which could result in extensive erosion in the ice-rich valley walls.

There is a shortage of good backfill material in the area of Thunder River and backfill for abutments (or for culvert backfill) will have to be imported relatively long distances - see Section 18 of Volume I of Report on Geotechnical Investigation Mile 725 to 936 Mackenzie Highway. A source of granular material suitable for backfill, and with washing, suitable for concrete aggregate, is available relatively nearby at the Thunder River airstrip, however this deposit is roughly 3-1/2 miles from the highway route. Alternate sources of granular materials are at Mile 800 and Mile 896 (see Section 28 - Surfacing Materials - Volume 1 of Geotechnical Report).

R D Cook.

R. D. Cook
Soils Engineer
Special Services
Western Region

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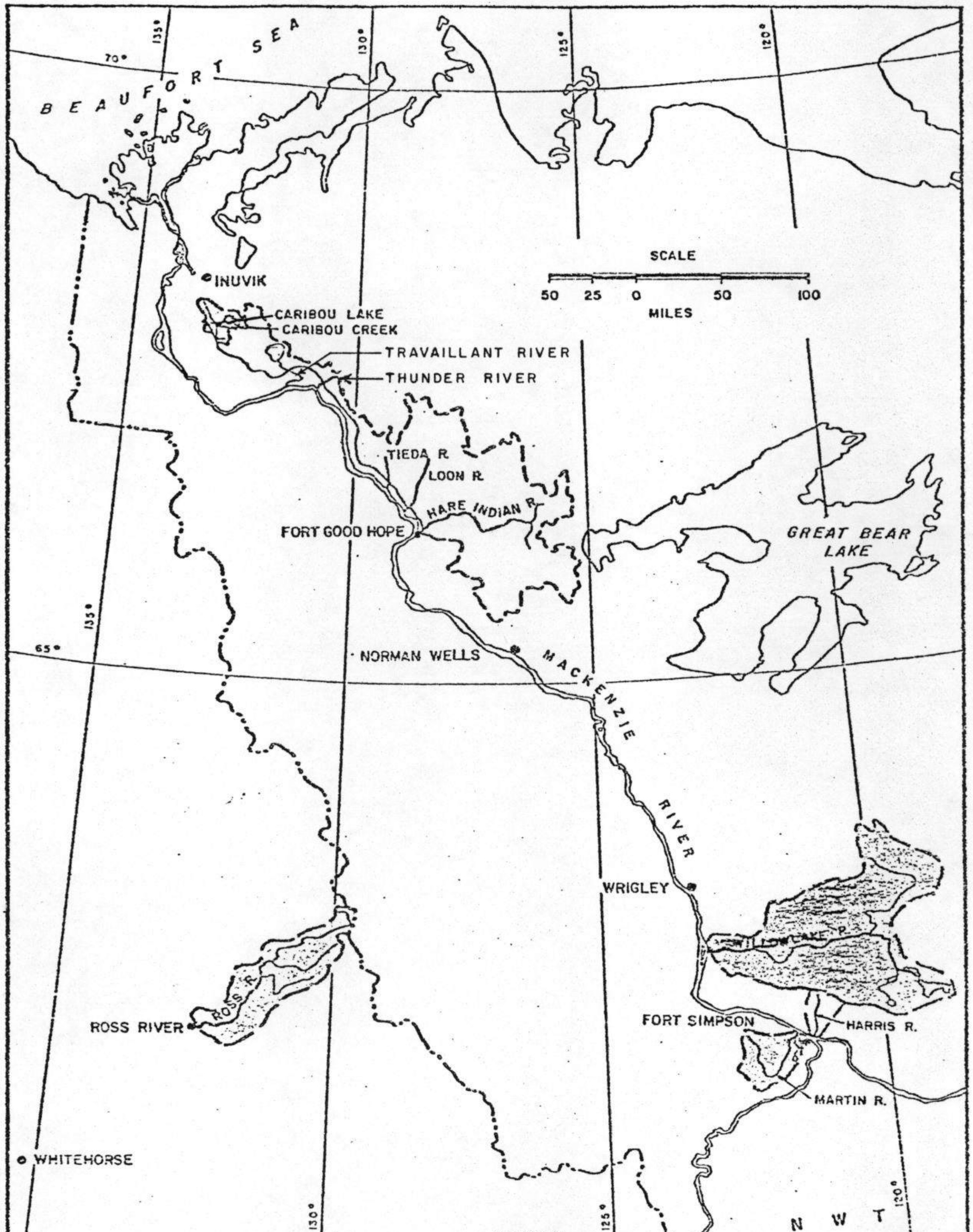
1. Brown, W. G. et al "Comparison of Observed and Calculated Ground Temperatures with Permafrost Distribution Under a Northern Lake", Canadian Geotechnical Journal, Vol. 1, No. 3, July 1964.

2. Brown, W. G. Graphical Determination of Temperature Under Heated or Cooled Areas on the Ground Surface. Technical National Research Council, October, 1963.

3. Bridge and Culvert Hydraulics, Mackenzie Highway, Fort Good Hope to Dempster Highway, March 1974. Fenco Foundation of Canada Engineering Corporation Limited.

4. Hydrology Study, Mackenzie Highway, Fort Good Hope to Dempster Highway, March 1974. Fenco Foundation of Canada Engineering Corporation Limited.

5. Crory, Frederick E. CRREL Pile Foundations in Permafrost. International Conference on Permafrost, Purdue University, November 1963.



Dwg. No. A-1

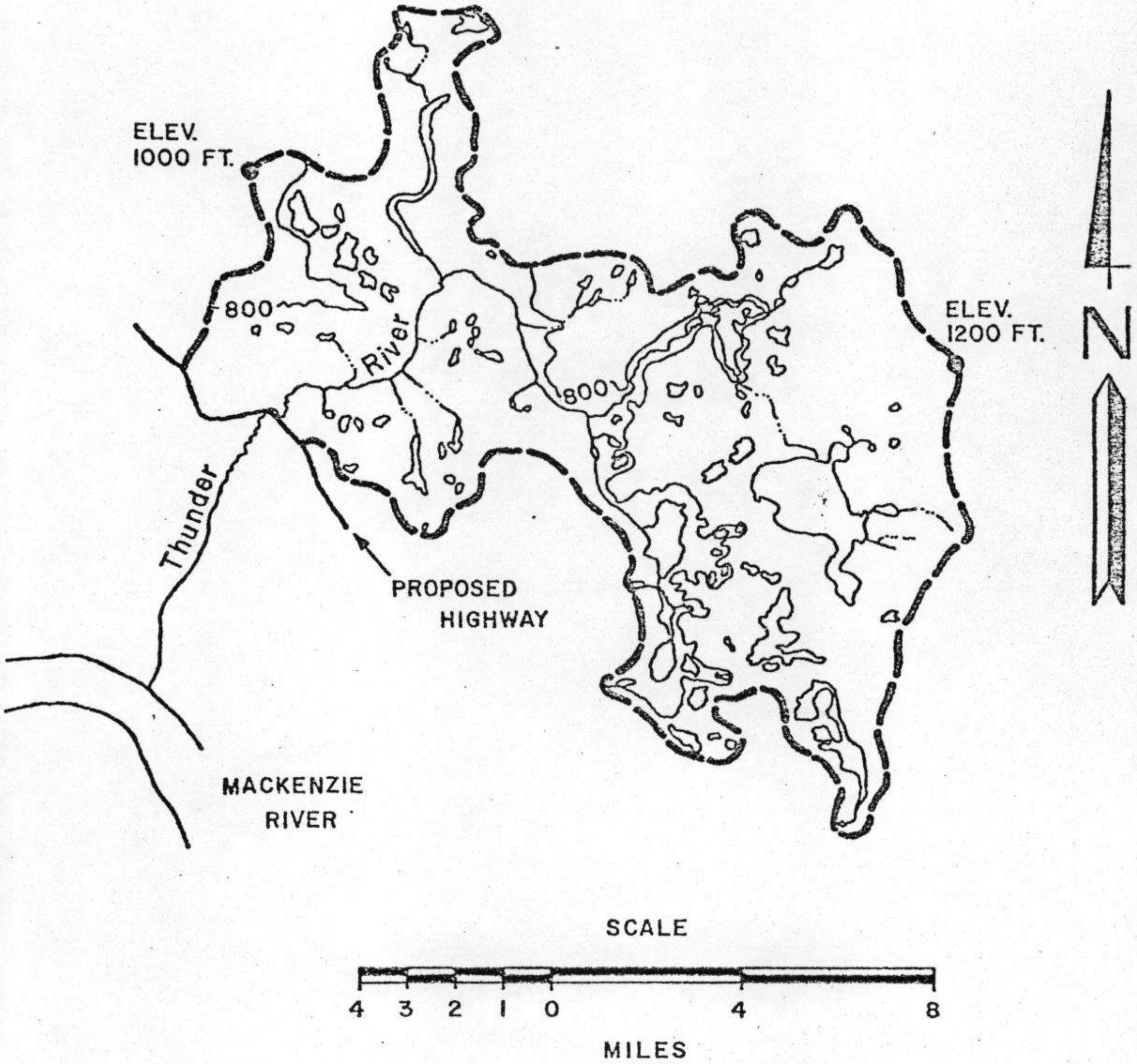
KEY PLAN

MACKENZIE RIVER, N.W.T.

1" = 90 MILES

Thunder River

Mile 844.0

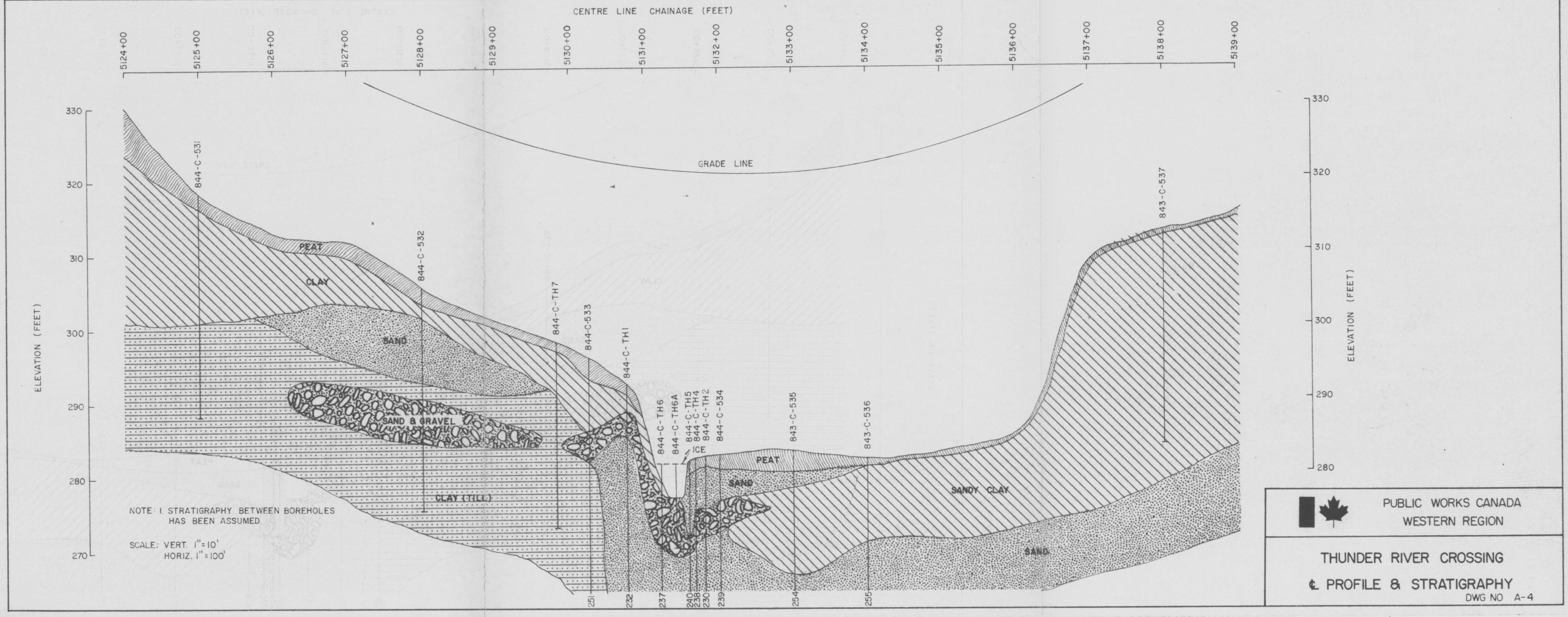


Drainage Area to Proposed Highway Crossing 116 sq. miles

Dwg. No. A-2

Thunder River Basin

THUNDER RIVER CROSSING
SITE PLAN
MACKENZIE HWY MILE 844·0
DWG NO A-3 SCALE 1"= 200'



NOTE: I. STRATIGRAPHY BETWEEN BOREHOLES HAS BEEN ASSUMED.

SCALE: VERT. 1" = 10'
HORIZ. 1" = 100'

PUBLIC WORKS CANADA
WESTERN REGION

THUNDER RIVER CROSSING
℄ PROFILE & STRATIGRAPHY

DWG NO A-4

PHOTO No. 1

Thunder River Valley looking upstream. Cutline is proposed route location. Note depositional features on valley floor.

PHOTO No. 2

Thunder River looking North on proposed centerline.

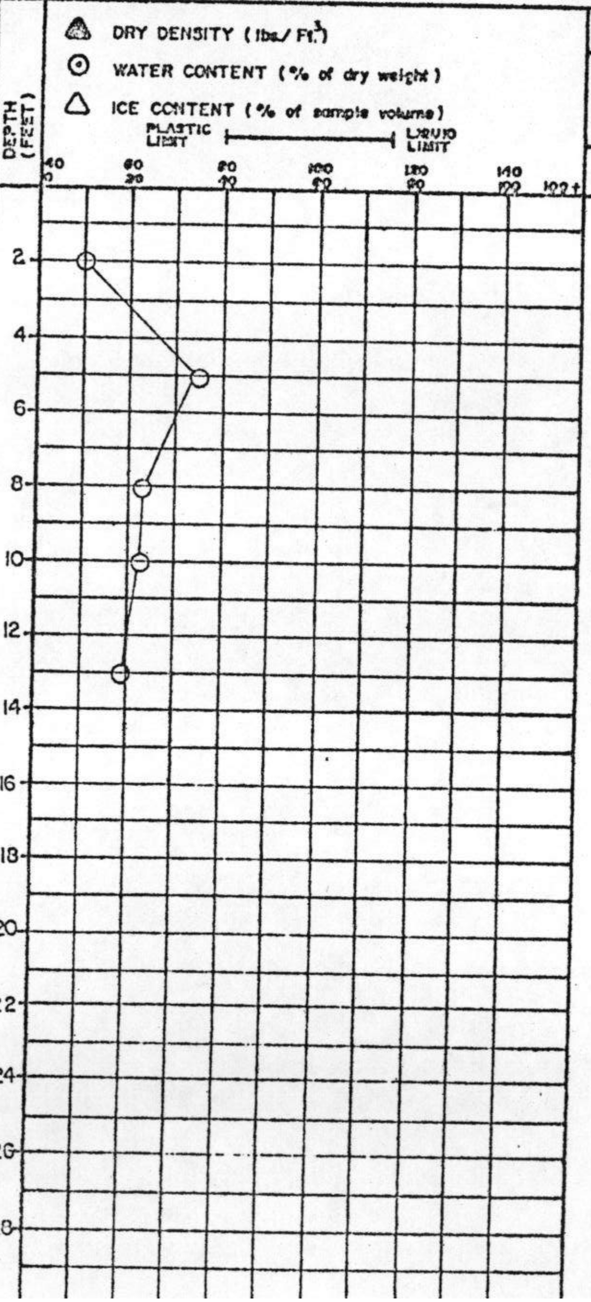
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA	DATE DRILLED. 29/1/74	AIRPHOTO NO. A 23329-168	CHAINAGE. 5121+00		OFFSET. ȼ		
TECH. JOHNSON	RIG. MAYHEW - #2	SURFACE DRAINAGE.	VEGETATION.		ELEV.	TEST HOLE	530
						MILE	844

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT		Low							
2						2' CLAY -Sandy Silty Low plastic		Ice Vx	2	-64-		35	1	Moist	
4									4	-61-		37	2	Free Water	
6								High Ice	6						
8					CL	Pebbles		Vs	8	-52-		38	10	Sat.	
10							F	Moderate	10	-56-		39	5	Wet	
12								Ice	12						
14									14	-54-		38	8	Moist	
16						15' CLAY -Sandy Silty Pebbles		Vc - Vr	16						
18									18						
20									20						
22						?			22						
24						Rocks			24						
26									26						
28						30'			28						

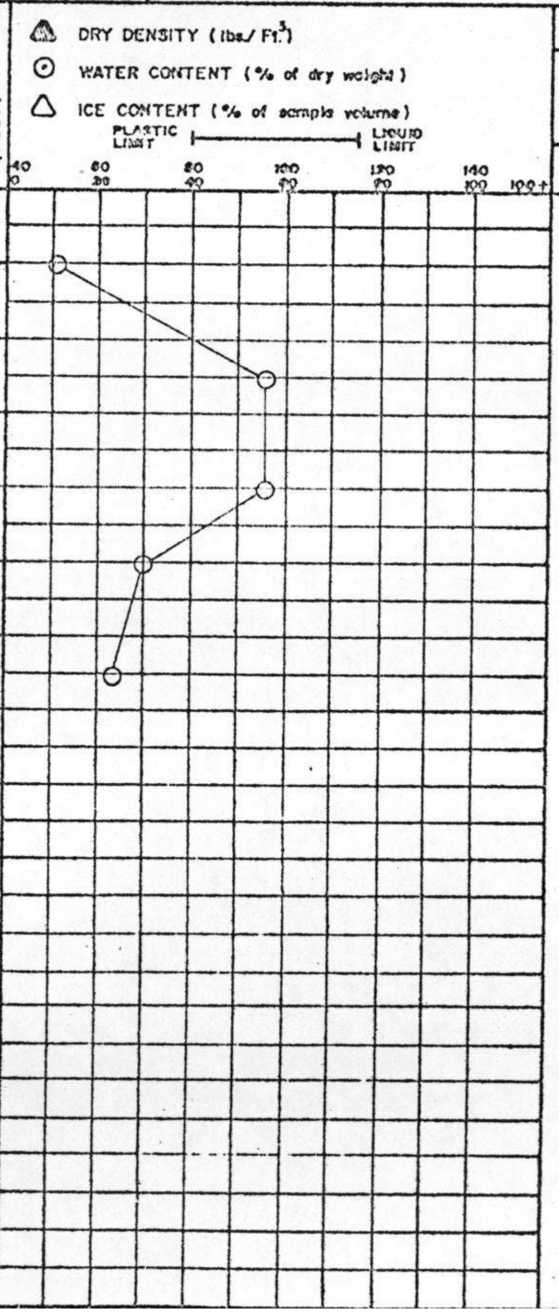


DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 29/1/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5125+00
OFFSET. ℄
TECH. JOHNSON
RIG. MAYHEW - #2
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 531
MILE 844



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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT		Low						
2						2'		Ice	-51-		47	2	Moist	
								Vx						
4									-61-		34	5		
								High					Free Water	
6								Ice						
8									-57-		43	0	Free Water	
					CL	CLAY -Sandy Pebbles Low plastic			-58-		36	6	Free Water	
10							F							
12								Vs						
									-57-		36	7	Sat.	
14														
						15'								
16						CLAY -Silty Pebbles								
18														
20						?								
22					CI									
24														
26														
28						Boulders 28'								
						30'								

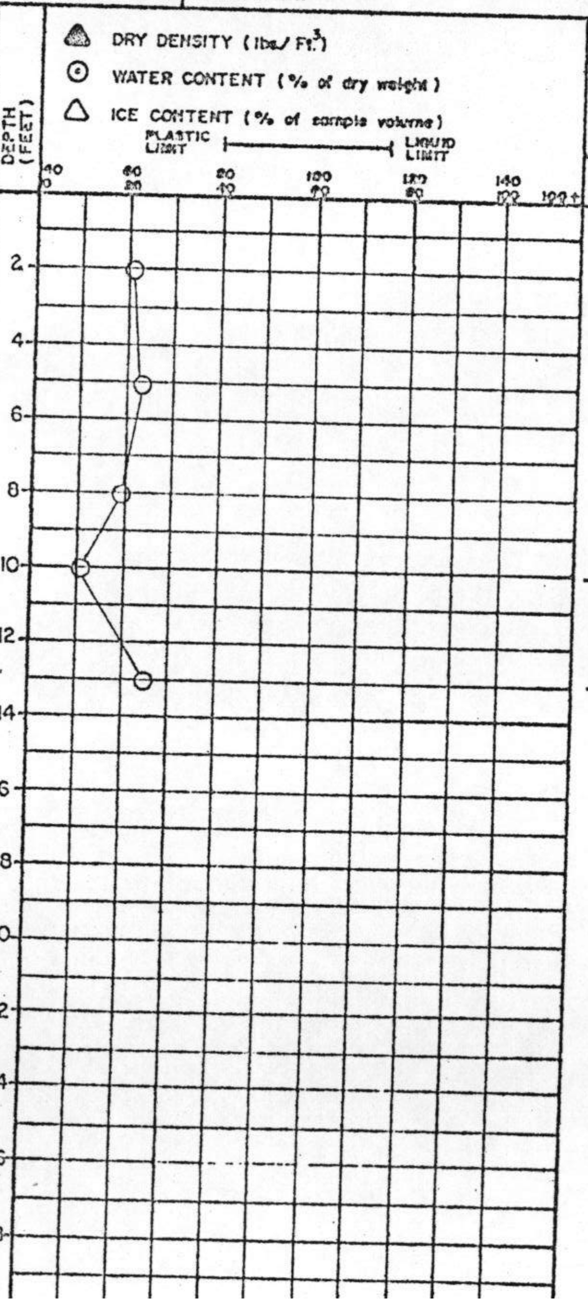
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 29/1/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5128+00
OFFSET. ¢
TECH. JOHNSON
RIG. MAYHEW - #2
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 532
MILE 844

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
2					Pt	PEAT — 2'		Moderate Ice Vc - Vr
4					CI	CLAY -Sandy, silty Med plastic — 4'		
6					GC	SAND -Clayey Pebbles		High Ice Vs
8								
10								
12							F	
14					CI	CLAY-Sandy Silty Pebbles — 13' – 15'		Moderate Ice Vc - Vr
16					GP	GRAVEL -Sandy		
18								
20								
22					CI	CLAY -Sandy Silty Pebbles — 21'		
24								
26								
28						30'		



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-69-		31	0	Moist	
-37-		61	2	Sat.	
-30-		69	1	Sat.	
-16-		71	13	Wet	
-82-		17	1	Wet	

THUNDER RIVER

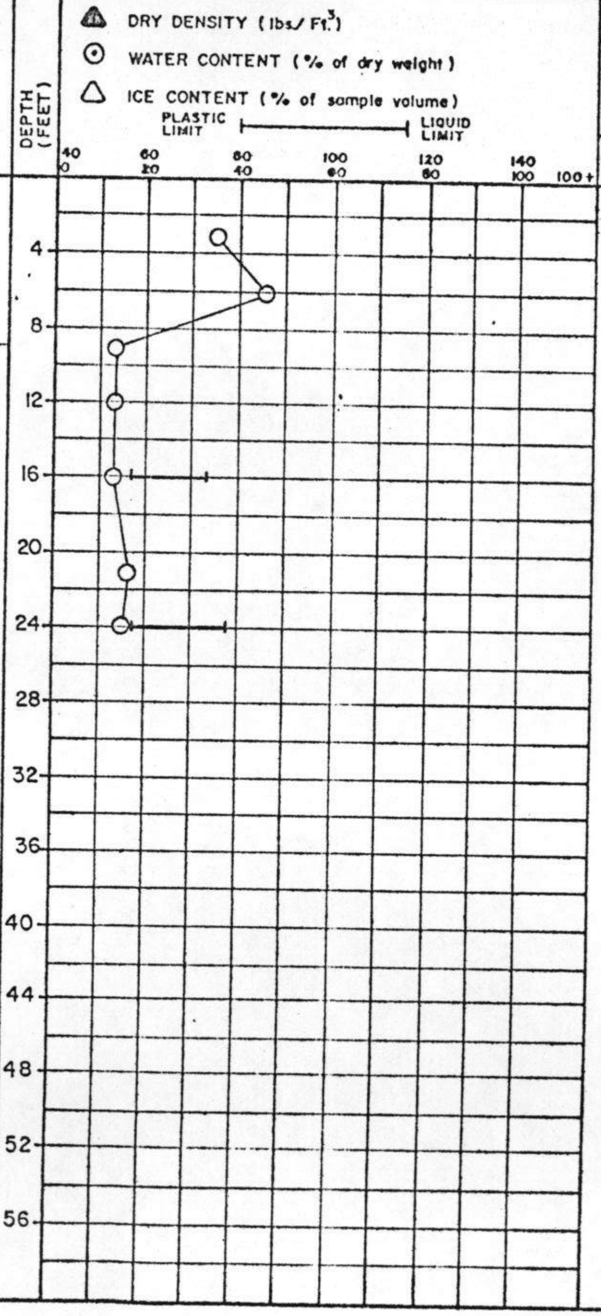
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.
TECH. W. Baine
DATE DRILLED. 2/2/74
RIG. Mayhew #1
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE. 5129+80
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 7
MILE 844

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					Pt	PEAT 1'		High
4					CL	SAND - CLAY MIX Pebbles Low plastic 7'		Ice Vs
8						CLAY - Sandy - Silty - Gravelly	F	Low
12					CL	- Pebbles		Ice
16					CI	Low-med. plastic		Vx
20								
24						Bottom of Hole - 25'		
28								
32								
36								
40								
44								
48								
52								
56								



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-44-		54	2	Free Water	
-57-		39	4	Free Water	
-17-		69	14	Sat.	
-32-		51	17	Wet	
-66-		31	3	Moist	
-81-		15	4	Moist	
-80-		16	4	Moist	

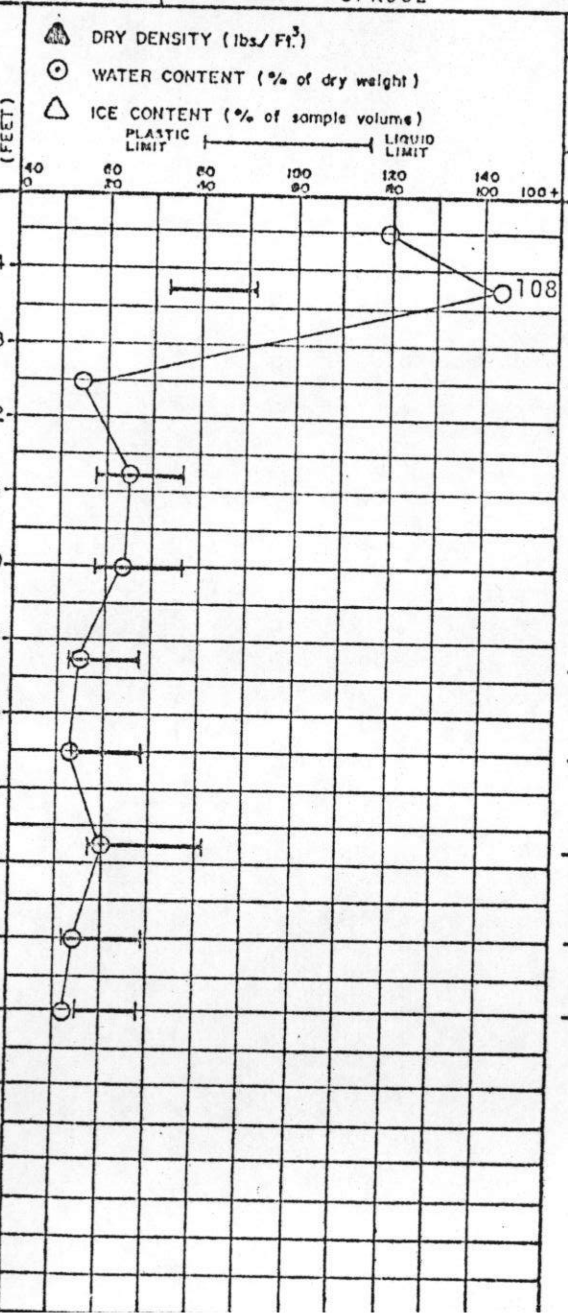
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5130+25
OFFSET. ȼ
TECH. PRONYCH
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION. SPRUCE
ELEV.
TEST HOLE 533
MILE 844

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–3'					Pt	PEAT		High Ice Vs
3'–10					CI	CLAY -Sandy Silty Med plastic Organics to 6'		
10–14'					SC	SAND-Clayey Gravelly	F	Moderate Ice Vc - Vr
14'–25'					CI CL	CLAY -Silty Low-med plastic Pebbles-Sandy		
25'–44'					CL CI CL	CLAY -Sandy Silty Low-med plastic Pebbles Gravelly	F	Moderate To Low Ice Vc - Vr Vx
44'						BOTTOM OF HOLE - 44'		



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-96-		4	0	Wet	Hole in Bag
-92-		8	0	Free Water	
-15-		75	10	Sat.	
-97-		2	1	Wet	
-95-		5	0	Moist	
-68-		28	4	Moist	
-66-		26	8	Damp	
-86-		13	1	Moist	
-61-		32	7	Moist	
-59-		29	12	Damp	

NORTH SIDE ABUTMENT THUNDER RIVER

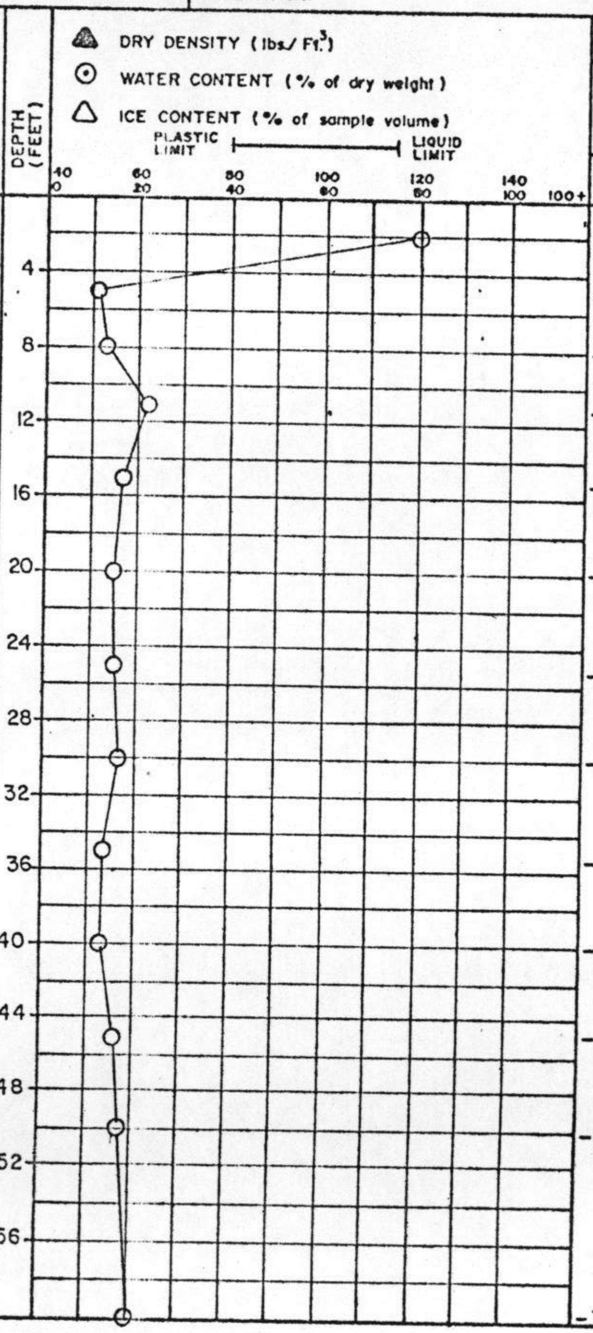
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.
DATE DRILLED. 1/2/74
AIRPHOTO NO.
CHAINAGE. 5130+75
OFFSET.
TECH. W. Baine
RIG. Mayhew #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 1
MILE 844

UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
Pt	PEAT .... 1.5'		High Ice Vs
CL CI	CLAY - Organic - Silty 4'		
SP	SAND - Gravelly, - Silty 7'		Moderate Ice
SC	SAND - Clayey, silty, - pebbles 11'		
SM SP	SAND - silty - fine - medium		Vc-Vr
SP	Pebbles SAND - fine - medium	F	Moderate Ice
	Pebbles Partially frozen? 40' - 43' Silty Fine - coarse		High Ice Vs
	Bottom of Hole - 60'		



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-70-		30	0	Wet	
-33-		54	13	Moist	
-20-		67	13	Moist	
-47-		53	0	Sat.	
-21-		79	0	Wet	
-26-		74	0	Moist	
-16-		82	2	Moist	
-11-		89	0	Moist	
- 9-		91	0	Moist	
- 6-		91	3	Moist	
-14-		79	7	Wet	
-13-		79	8	Wet	
-12-		88	0	Free Water	

THUNDER RIVER

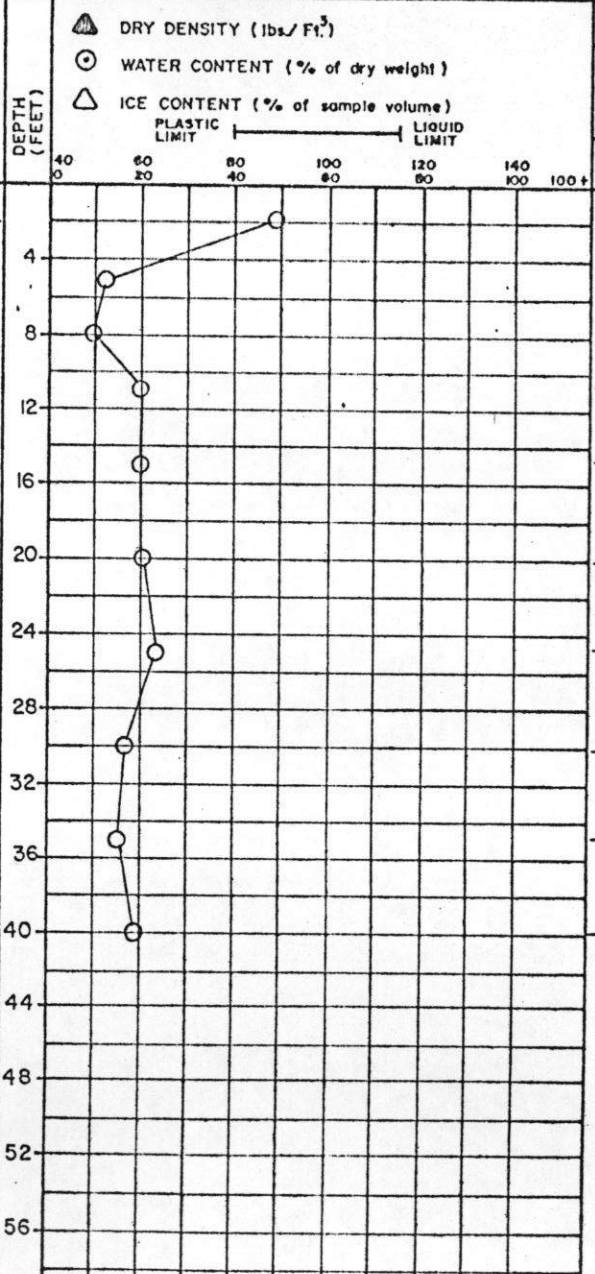
DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.
DATE DRILLED. 2/2/74
AIRPHOTO NO.
CHAINAGE. 5131+2
OFFSET.
TECH. W. Baine
RIG. mayhew #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 6
MILE 844

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						ICE 2'		ICE
4					CI GW	CLAY - Sandy, silty med. plastic 4' - Sand - Boulders		Moderate Ice Vc-Vr
8					SW	- Silty 8'		
					SW	SAND - Gravelly - Silty 11'		
12						SAND - Silty	F	
16					SP			
20						Fine-medium		
24								
28						SAND - Fine-medium		Moderate
32								Ice
36					SP SM	Silty Medium-coarse	F	Vc-Vs
40								
44						44'		
48						Bottom of Hole - 44'		
52								
56								



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-71-		29	0	Sat.	
-19-		69	12	Wet	
-12-		73	15	Wet	
-23-		77	0	Free Water	
-27-	1	73	0	Free Water	
- 8-		92	0	Sat.	
-10-		90	0	Wet	
- 8-		92	0	Wet	
- 9-		90	1	Wet	
-16-		84	0	Wet	

D3·14·5·74 a

THUNDER RIVER

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

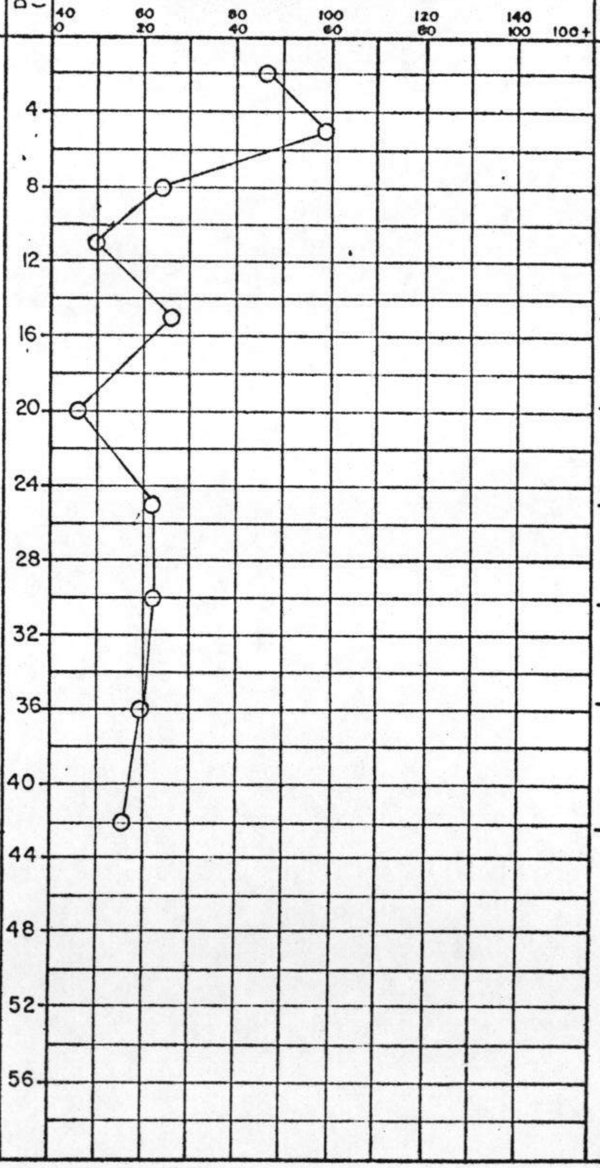
DRILL HOLE REPORT

SITE:

FIELD ENG.
DATE DRILLED. 2/2/74
AIRPHOTO NO.
CHAINAGE. 5131+55
OFFSET.
TECH. W. Baine
RIG. Mayhew #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 5
MILE 844

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT & SAND 2'		High	-51-		49	0	Free Water	
4					ML	SILT - Clayey, sandy 4'		Ice	-36-		63	1	Free Water	
					SM	SAND - Silty - Pebbles		Vs						
8						10'	F		-15-		80	5	Free Water	
12						Boulders			-17-		69	14	Sat.	
					SP	SAND - Gravelly 13'								
16						SAND - Fine-medium			- 9-		87	4	Sat.	
20					SP	Boulders Gravelly, coarse			- 7-		83	10	Sat.	
24						Fine-medium			- 7-		89	4	Free Water	
28														
32					SM	SAND - Silty - Fine-medium		Moderate to	-30-		70	0	Sat.	
36					SP	Pebbles		High	-10-		89	1	Wet	
40								Ice Vc-Vr						
						42'		Vs	- 9-		90	1	Wet	
44						Bottom of Hole - 42'								
48														
52														
56														

▲ DRY DENSITY (lbs/Ft^3)
⊙ WATER CONTENT (% of dry weight)
△ ICE CONTENT (% of sample volume)
PLASTIC LIMIT ├──┤ LIQUID LIMIT



THUNDER RIVER

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.

DATE DRILLED. 2/2/74

AIRPHOTO NO.

CHAINAGE. 5131+40

OFFSET.

TEST HOLE 6A

TECH. W. Baine

RIG. Mayhew #1

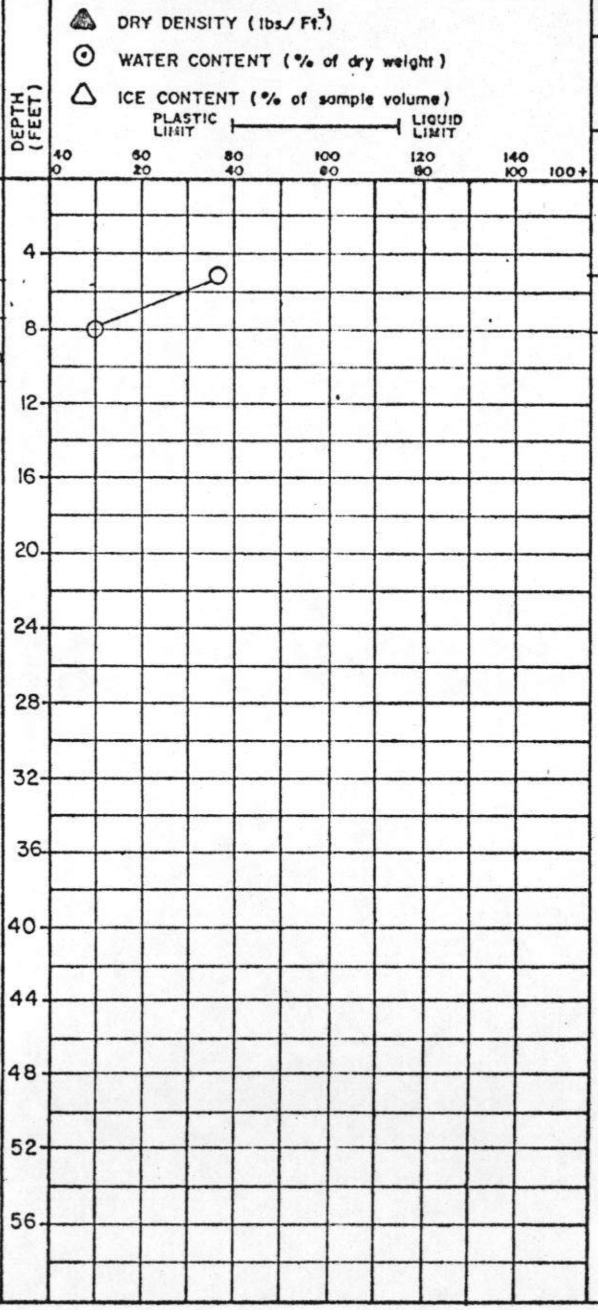
SURFACE DRAINAGE.

VEGETATION.

ELEV.

MILE 844

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
4						ICE		ICE						
						5 - Sand - Silty, gravelly	F	Frozen	22		65	13	Free Water	
8						GRAVEL - Sandy	UF	Not frozen	6		45	49	Free Water	
						11								
12						Bottom of Hole - 11'								
16						Water in thawed gravel								
20						zone - hole abandoned.								
24														
28														
32														
36														
40														
44														
48														
52														
56														



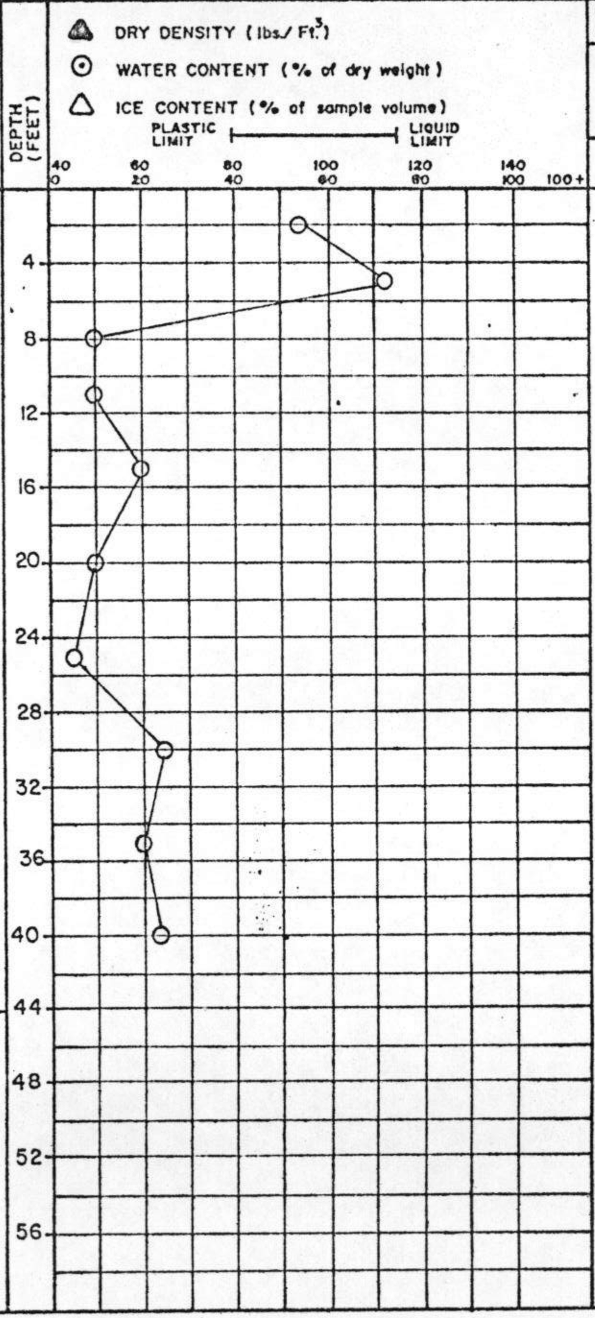
THUNDER RIVER

DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.
DATE DRILLED.
AIRPHOTO NO.
CHAINAGE. 5131+67
OFFSET.
TECH.
RIG.
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 4
MILE 844



DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT 1.5		High						
4						SILT - Sandy - Clayey 4'		Ice	-57-		43	0	Free Water	
					ML SC	SAND - Silty, clayey 7'		Vs	-45-		54	0	Free Water	
8					GW SW	SAND - Gravelly - Silty 11'			-14-		60	26	Sat.	
12													Moist	
16					SW	SAND - Silty, gravelly - coarse	F	Moderate Ice	-10-		89	1	Wet	
20								Vc-Vr	- 9-		84	7	Wet	
24						Gravelly			- 7-		68	25	Sat.	
28														
32						SAND - Silty - fine - med. - few pebbles		High Ice	-10-		90	0	Free Water	Free Water
36					SM	from 27'-44'	F	Vs	-11-		84	5	Free Water	to bottom of hole
40									-16-		84	0	Free Water	
44						44'								
48						Bottom of Hole - 44'								
52														
56														

D3:14:5:74 a

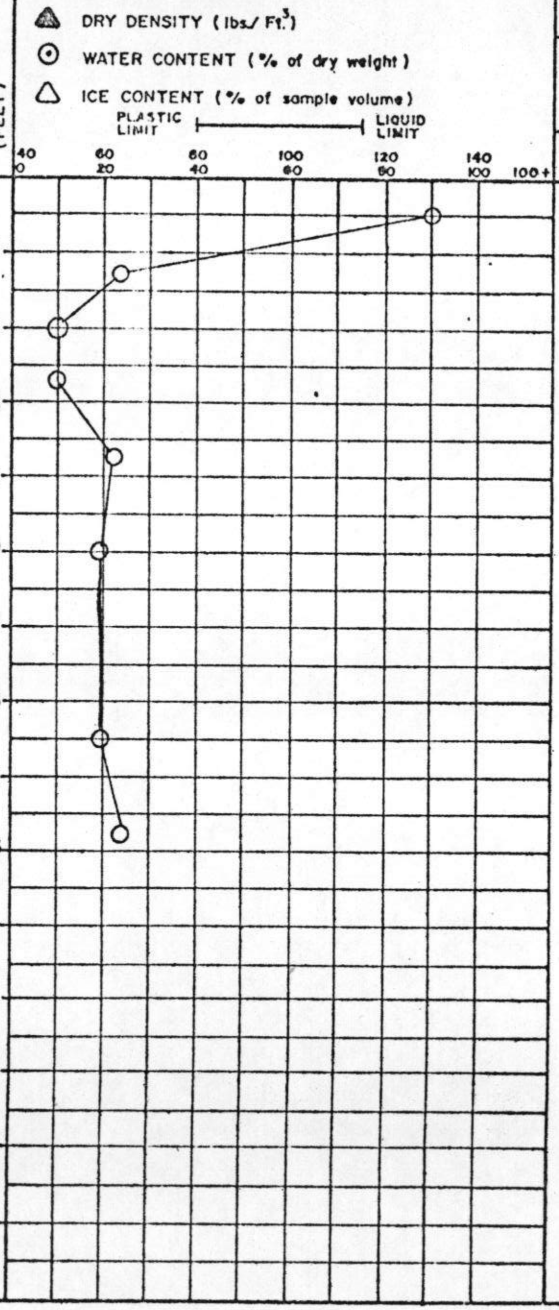
THUNDER RIVER

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.	DATE DRILLED. 1/2/74	AIRPHOTO NO.	CHAINAGE. 5131+80	OFFSET.	TEST HOLE 3
TECH. W. Baine	RIG. Mayhew #1	SURFACE DRAINAGE.	VEGETATION.	ELEV.	MILE 844



DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT 1'		High Ice Vs	-	26-	74	0	Free Water	
4					SC	SAND - Clayey, silty - Pebbles Low plastic 7'			-	12-	76	12	Sat.	
8					SC	SAND - Clayey - Gravelly 11'	F		-	15-	58	27	Sat.	
12					SM	SAND - Silty			-	19-	78	3	Free Water	
16						- Pebbles Fine - medium		Low Ice	-	10-	89	1	Free Water	
20					SP	Fine - coarse		Vx	-	13-	82	5	Free Water	
24						Fine - medium								
28														
32									-	11-	89	0	Wet	
36									-	9-	91	0	Free Water	
40														
44						Bottom of Hole - 45'								
48														
52														
56														

SOUTH SIDE ABUTMENT THUNDER RIVER

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.

TECH. W. Baine

DATE DRILLED. 1/2/74

RIG. Mayhew #1

AIRPHOTO NO.

SURFACE DRAINAGE.

CHAINAGE. 5131+80

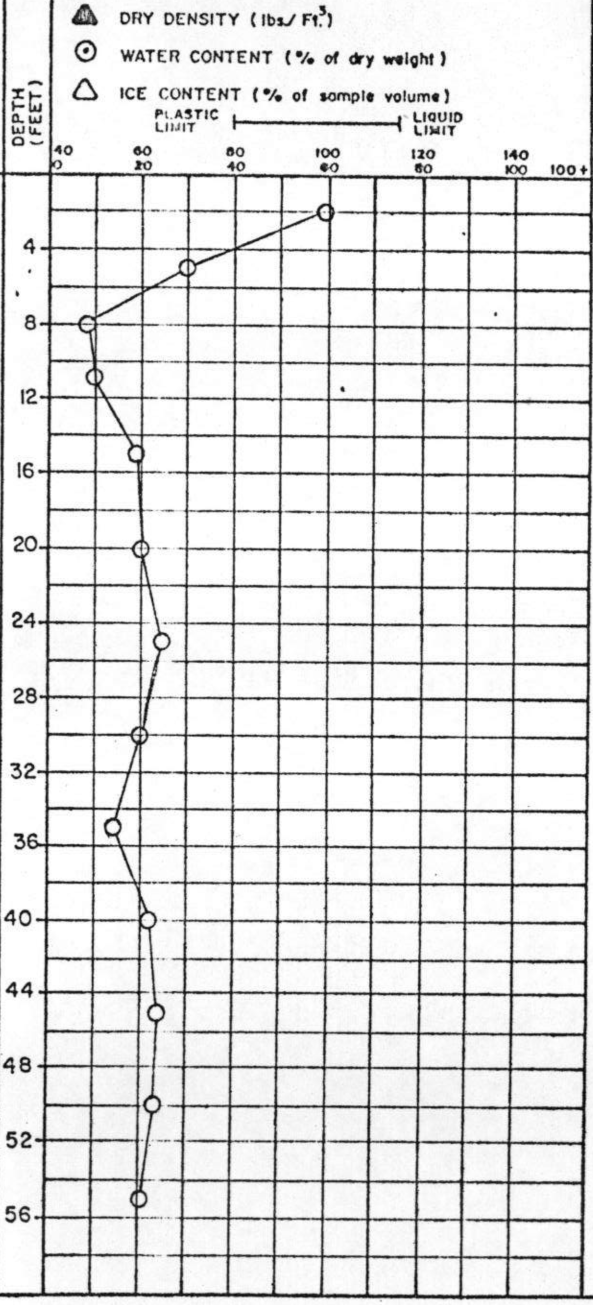
VEGETATION.

OFFSET. 25' Rt. of ȼ

ELEV.

TEST HOLE 2

MILE 844



DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT 1'								
					SC	SAND		Vs	-50-		50	0	Free Water	
4						- Clayey - Silty		High	-31-		41	28	Free Water	
						5'		Ice						
8						GRAVEL - Clayey - Sandy		Moderate	-11-		39	50	Sat.	
12					GW		F	Ice	-16-		36	48	Sat.	
						- Sandy 14'		Vc-Vr						
16						SAND - Fine-medium - Pebbles			-8-		88	4	Moist	
					SP	19'								
20					ML	SILT - SANDY			-78		20	2	Wet	
24						24'								
					SM	SAND -Silty			-9-		91	0	Sat.	
28						SAND								
32					SP	- Fine-coarse			-6-		94	0	Sat.	
36									-4-		93	3	Sat.	
					SM	Silty Pebbles	F							
40									-16-		84	0	Free Water	
44									-11-		87	2	Free Water	
48						Fine-medium								
52									-11-		89	0	Free Water	
56									-16-		84	0	Wet	
						Bottom of Hole - 57'								

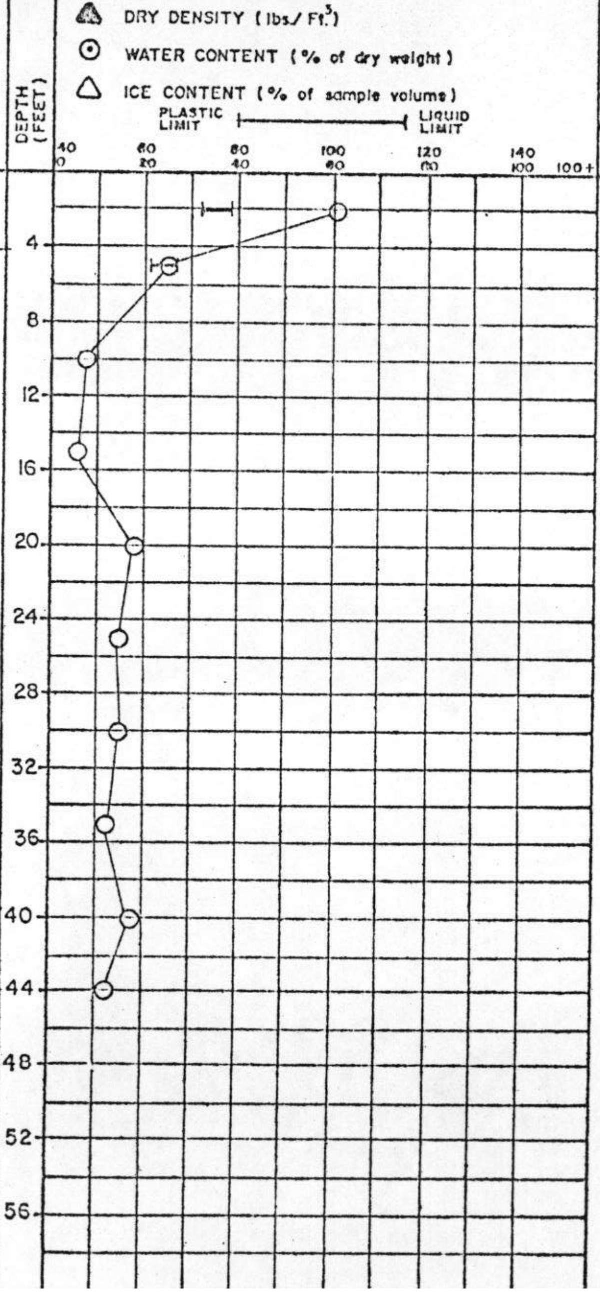
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5132+00
OFFSET. ¢
TECH. PRONYCH
RIG. MAYHEW - #1
SURFACE DRAINAGE. POOR
VEGETATION. SPRUCE
ELEV.
TEST HOLE 534
MILE 844

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION		LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					Pt	PEAT	2'		High Ice Vs
4					OL	ORGANICS -Clayey, sandy	6'		
8					GC	GRAVEL -Clayey Sandy	10½'		Moderate Ice
12					SC	SAND-Clayey Pebbles	14'		Vc - Vr
16					ML	SILT-Sandy, clayey Gravelly	18'		
20					ML	SILT -Sandy	21'		
24					SM	SAND -Fine	25'		
28 32 36 40 44					SM	SAND -Silty fine Fine Pebbles Gravelly	44'	F	Moderate Ice Vc - Vr
48 52 56						BOTTOM OF HOLE- 44'			



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-79-		21	0	Wet	
-48-		51	1	Moist	Hole in Bag
-11-		45	44	Wet	Hole in Bag
-64-		19	17	Wet	Hole in Bag
-67-		33	0	Wet	Hole in Bag
-8-		91	1	Wet	Hole in Bag
-10-		90	0	Wet	Hole in Bag
-5-		93	2	Wet	Hole in Bag
-6-		94	0	Wet	Hole in Bag
-9-		72	19	Wet	Hole in Bag

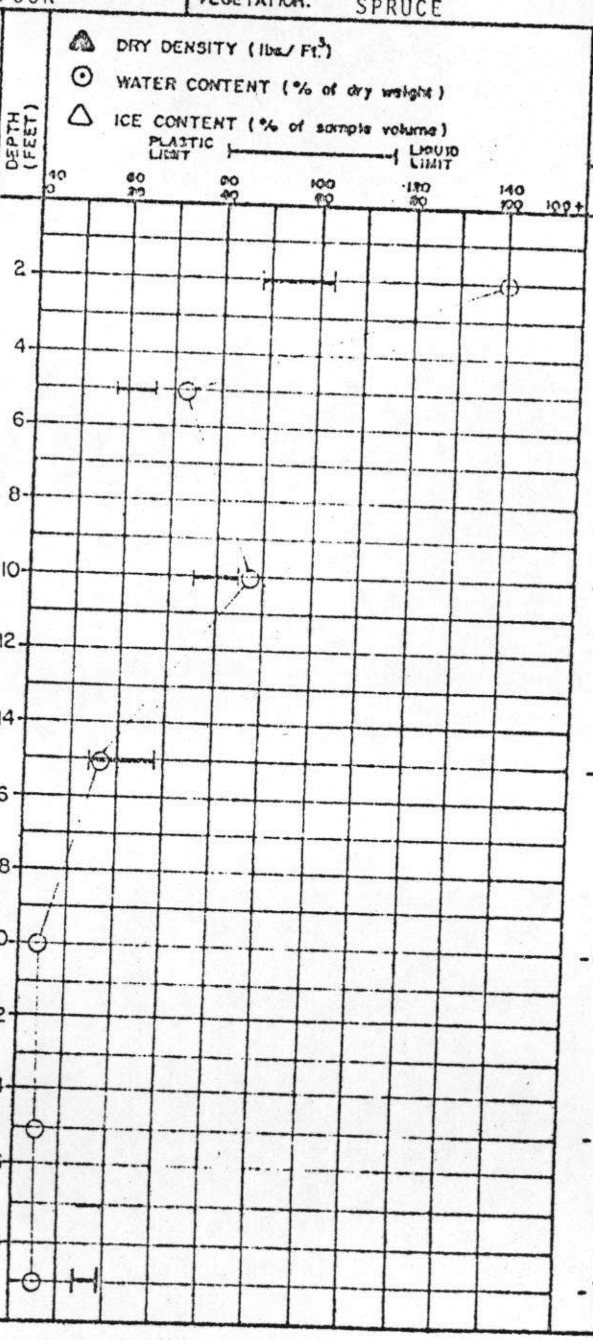
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5133+00
TECH. PRONYCH
RIG. MAYHEW - #1
SURFACE DRAINAGE. POOR
VEGETATION. SPRUCE
OFFSET. ℄
ELEV.
TEST HOLE 535
MILE 843

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
2					Pt	PEAT — 3'	F	High Ice	-91-		9	0	Sat.	
4 6					SC	SAND -Clayey Silty — 5'			-51-		49	0	Sat.	
8 10 12					CI	CLAY -Silty Sandy Low-med Plastic Organic		Vs	-77-		23	0	Moist	
14 16					CL	Gravelly — 17'		Moderate Ice	-43	41	16		Wet	
18 20 22 24					GC	GRAVEL -Clayey Sandy		Vc - Vr	-4-	27	69		Wet	
26									-8-	40	52		Wet	
28						— 29'			-7-	31	62		Wet	



BOTTOM OF HOLE - 29'

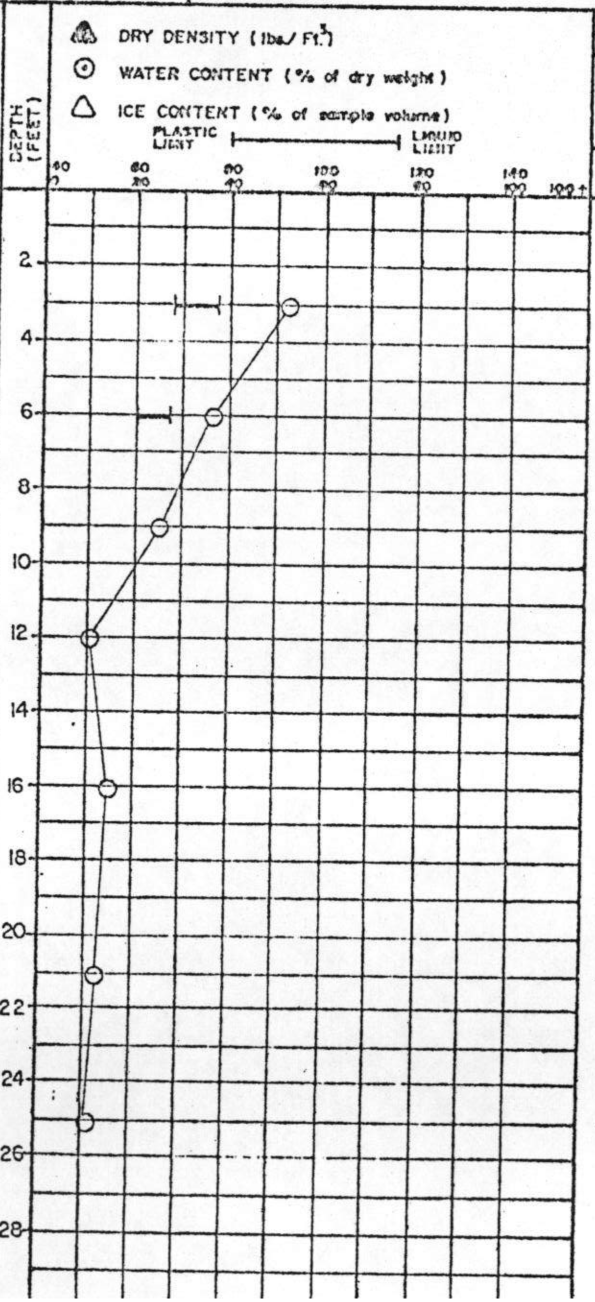
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5134+00
OFFSET. ℓ
TECH. BAINE
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 536
MILE 843

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT —— 1'		High						
2						CLAY -Organic to 10' Silty Sandy Low-med plastic		Ice	-50-		50	0	Sat.	
4														
6					CL			Vs	-31-		69	0	Sat.	Hole in Bag
8					CI	Gravelly from 8'		Low						
10							F	Ice	-12-		65	23	Wet	
						—— 11'								
12						SAND -Silty Pebbles Gravelly Boulders 13-15'			-5-		80	15	Wet	
14														
16								Vx	-1-		97	2	Wet	
18					SM	Gravelly								
20														
22									-1-		84	15	Wet	
24						Gravelly								
26									-1-		.83	16	Wet	Hole in Bag
						—— 27'								
28						BOTTOM OF HOLE - 27'								



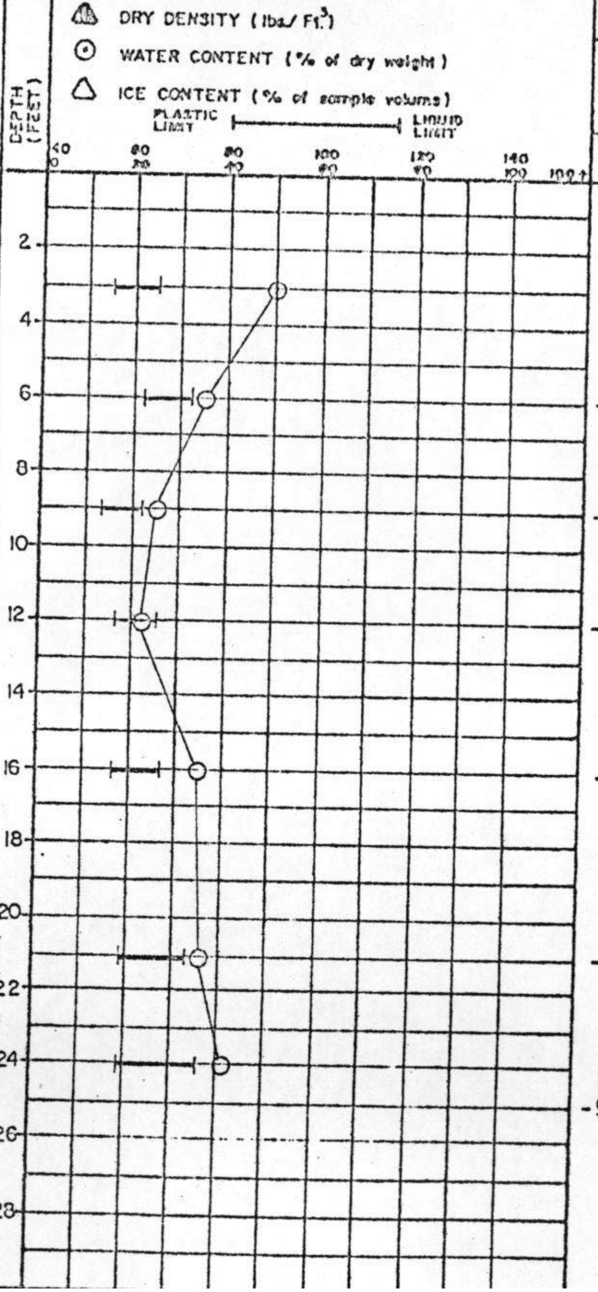
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 2/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5138+00
OFFSET. ₫
TECH. BAINE
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 537
MILE 843

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT 1'								
2						CLAY -Silty Sandy		Moderate	-75-		25	0	Free Water	
4								&						
6									-88-		12	0	Sat.	
8						Pebbles 8'-10' Sand - clayey Low-med plastic		High						
10					CL		F	Ice	-24-		68	8	Free Water	
12									-78-		22	0		Hole in Bag
14					CI			Vc - Vr						
16								.	-83-		17	0	Sat.	
18								Vs						
20						Silty							Wet	
22									-97-		3	0		
24													Sat.	
26									-99-		.1	0		
28						29'								



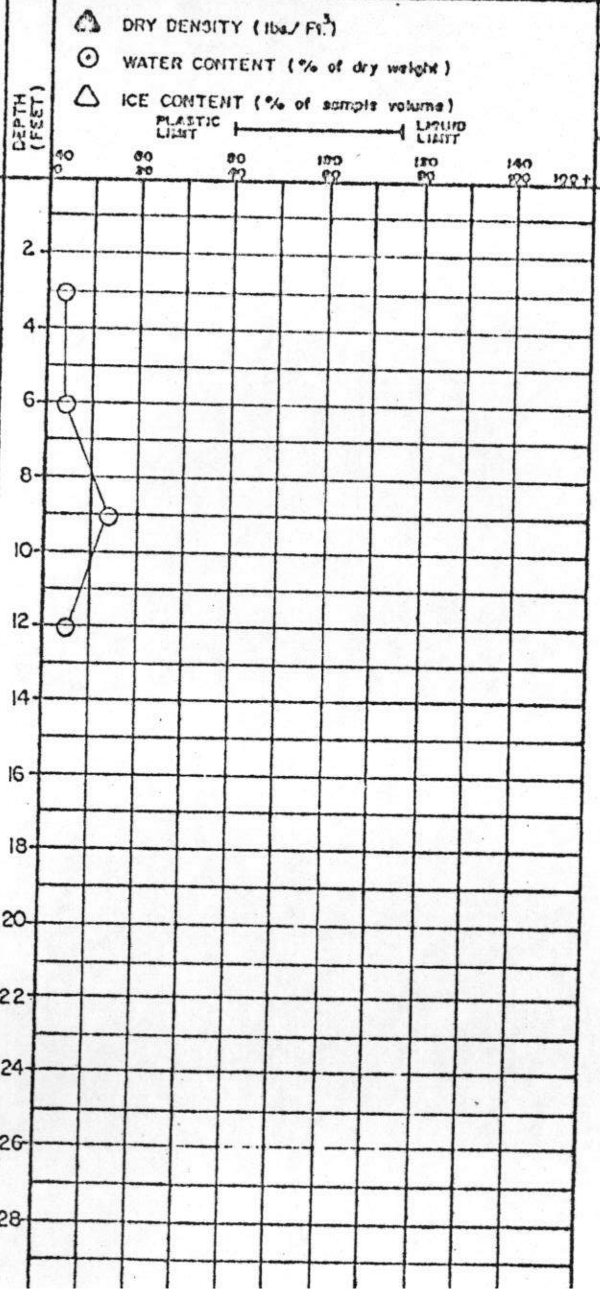
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5141+20
OFFSET. ¢
TECH. BAINE
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 538
MILE 843

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT ½'								
2					GP	GRAVEL-SAND MIXTURE		Low	-1-		51	48	Himid	
4						4'		Ice						
6					SP	SAND -Gravelly	F		-1-		72	27	Damp	
8														
10					SC	Gravelly-clayey		Vx	-2-		87	12	Wet	
12									-9-		47	44	Moist	
14						14'								
16						BOTTOM OF HOLE - 14'								
18														
20														
22														
24														
26														
28														



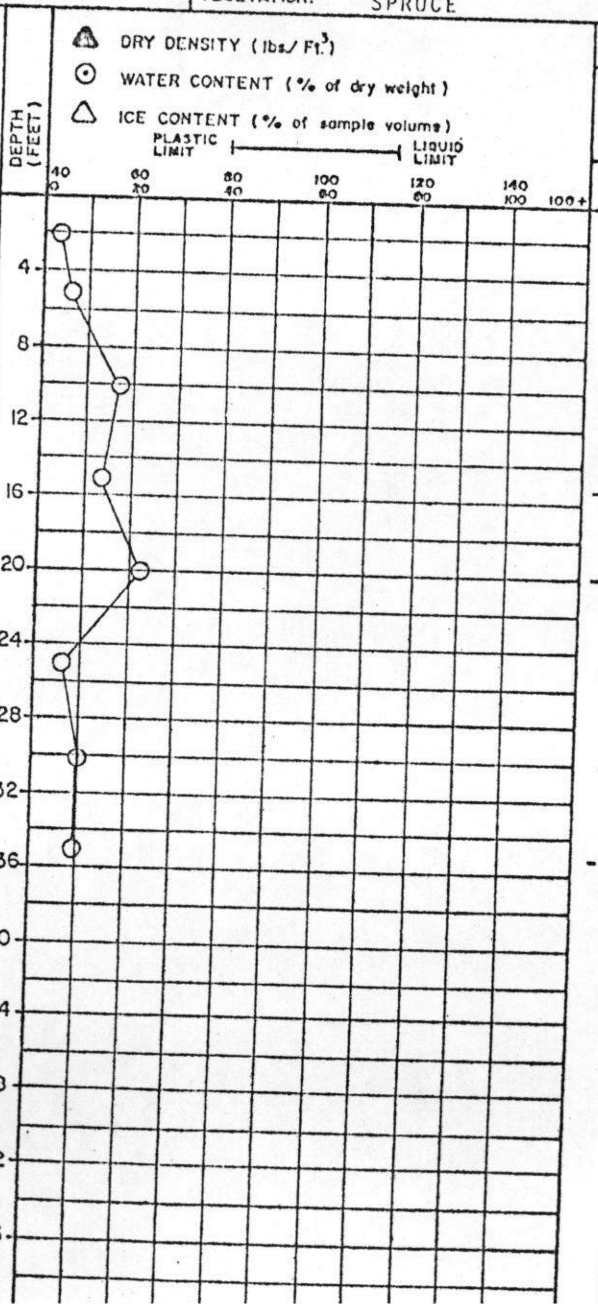
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 2/1/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5141+20
OFFSET. 45 Rt ℄
TECH. PRONYCH
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION. SPRUCE
ELEV.
TEST HOLE 538-R1
MILE 843

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					Pt	PEAT — 4"		
4					SP / SW	SAND -Gravelly Pebbles Silty		Moderate Ice
12							F	Vc - Vr
28					SC	Gravelly-Clayey		
36						—35' BOTTOM OF HOLE - 35'		



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-0-		48	52	Humid	
-7-		88	5	Moist	
-11-		88	1	Wet	
-14-		82	4	Wet	
-16-		75	9	Sat.	
-6-		64	30	Wet	
-3-		75	22	Wet	
-4-		67	29	Wet	

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

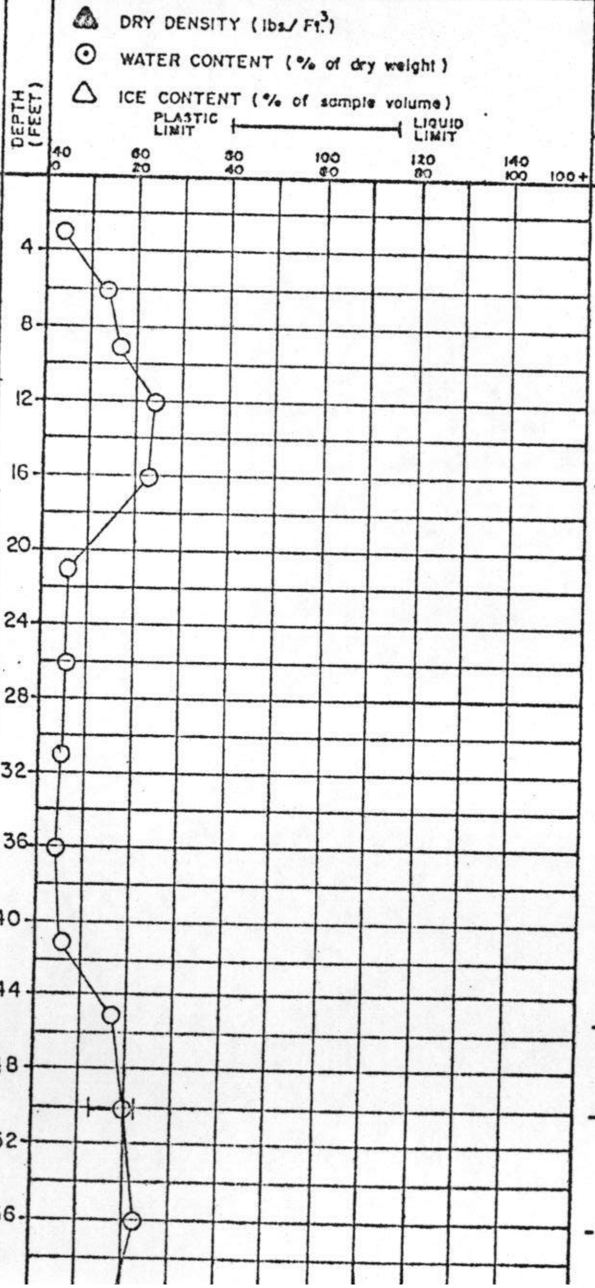
DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5141+20
OFFSET. 100 Rt OF ¢
TECH. BAINE
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 538-R2
MILE 843

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION
					Pt	PEAT —½'
4					SP	SAND -Gravelly Pebbles
8					SC	Clayey, silty Pebbles
16					SM	Silty Pebbles —20'
24					GC	GRAVEL -Clayey Sandy
28						GRAVEL -Sandy Clayey
32					GC	—45'
48					CL	CLAY -Silty, sandy Pebbles low plastic —50'
52					ML CL	CLAY- -Silty, sandy Pebbles Low plastic
56						SILT -Clayey Gravelly 60'

LIMITS OF FROZEN GROUND	ICE DESCRIPTION
F	Moderate Ice Vc - Vr
	High Ice Vs
F	Moderate Ice Vc - Vr Low Ice Vx
	Moderate To High Ice Vc - Vr
	Vs Moderate To High Ice Vc - Vr Vs



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-1-		70	29	Damp	
-11-		86	3	Wet	
-8-		90	2	Wet	
-12-		85	3	Free Water	
-17-		78	5	Sat.	
-9-		34	57	Wet	
-7-		32	61	Sat.	
-6-		36	58	Wet	
-4-		18	78	Humid	
-9-		42	49	Wet	
-53-		41	6	Sat.	
-65-		26	8	Sat.	
-73		25	2	Sat.	

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

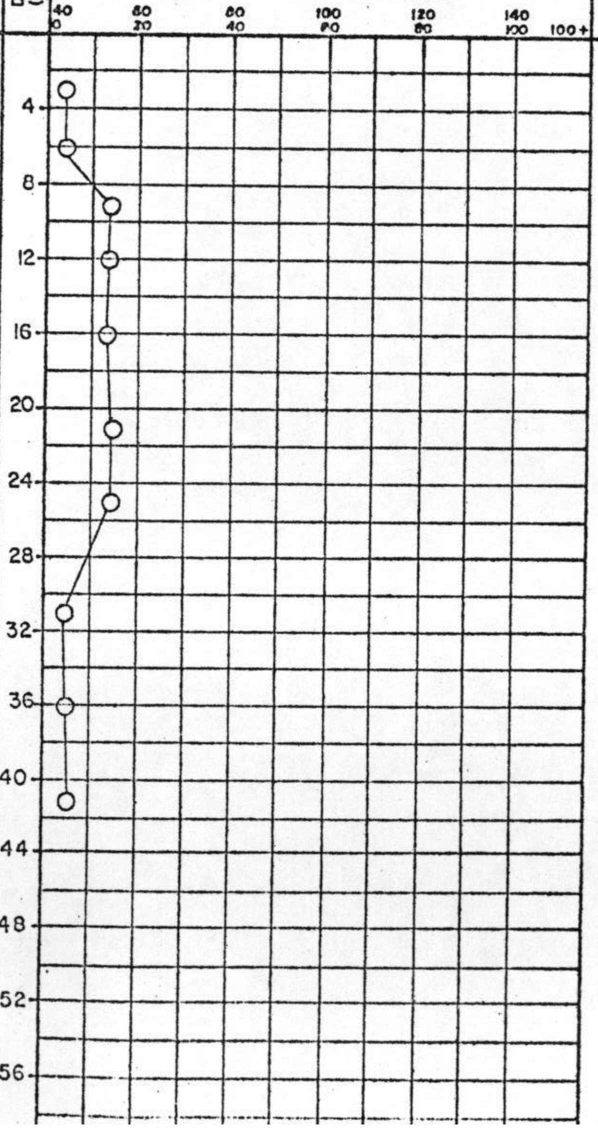
DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 1/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5141+20
OFFSET. 50' Lt ℄
TECH. BAINE
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 538-L
MILE 843

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT 1'								
4					SP	SAND -Gravelly Pebbles		Moderate Ice	-4-		55	41	Humid	
8									-3-		85	12	Damp	
									-5-		93	2	Wet	
12							F	Vc - Vr	-8-		92	0	Wet	
16					SC	Clayey			-26-		74	0	Wet	
20					SP	Medium Pebbles			-6-		91	3	Wet	
24						Gravelly SAND -Med grained Gravelly 30'			-8-		82	10	Wet	
28								Moderate						
32						GRAVEL -Clayey Sandy		To	-4-		43	53	Sat.	
36					GC			Low Ice	-7-		42	51	Wet	
40						42'		Vc - Vr Vs	-5-		39	56	Wet	
44						BOTTOM OF HOLE - 42'								
48														
52														
56														

▲ DRY DENSITY (lbs/Ft.^{3})
⊙ WATER CONTENT (% of dry weight)
△ ICE CONTENT (% of sample volume)
PLASTIC LIMIT ├──┤ LIQUID LIMIT



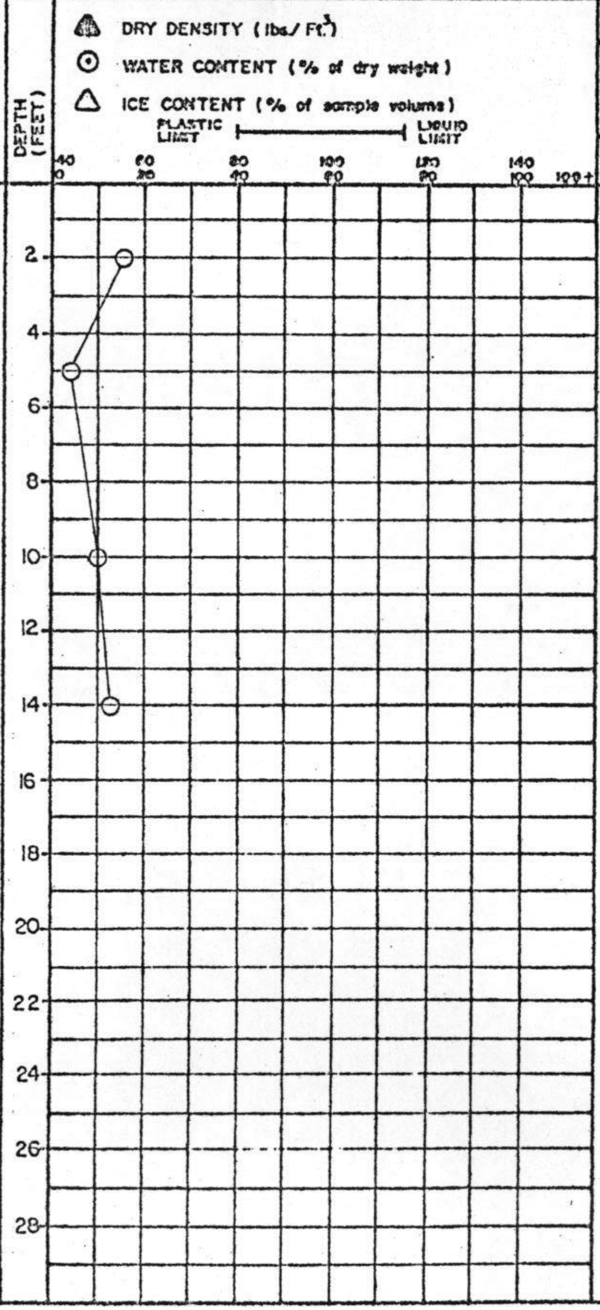
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG. A. HANNA
DATE DRILLED. 2/2/74
AIRPHOTO NO. A 23329-168
CHAINAGE. 5145+00
OFFSET. ℄
TECH. PRONYCH
RIG. MAYHEW - #1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 539
MILE 843

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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
					Pt	PEAT —2"								
2						SAND -Gravelly Clayey		Moderate	-12	-	74	14	Wet	
4								Ice						
					SC	Gravelly Throughout			-3	-	70	27	Moist	
6														
8							F	Vc - Vr						
10									- 6	-	72	22	Wet	
12														
14						Med - Fine —14'			-7	-	74	19	Wet	
						BOTTOM OF HOLE - 14'								
16														
18														
20														
22														
24														
26														
28														



DEMPSTER HIGHWAY, Y.T.
EAGLE RIVER BRIDGE SITE

Initial Ground Temperatures at installation of thermistors- June 7, 1974.

DEPTH	TEMPERATURE ^oF	
	SOUTH BANK STA 5091+80	NORTH BANK STA 5094+35
5	30.6	26.0
10	30.7	22.9
20	31.95	24.4
30	32.06	27.0
40	32.2	28.2
50	32.2	28.5
60	32.1	28.6
70	32.1	28.8
80	32.0	28.7
90	32.3	29.0
100	32.1	29.1

DEMPSTER HIGHWAY, Y.T.
EAGLE RIVER BRIDGE SITE

Ground Temperatures - Sept. 29, 1974

Observer - G.H. Johnst
DBR/NRC

(1) Thermistor Cable No. 1 - North Side - Sta. 5094 + 35 (B.H. #74-BH-Da)

Point No.	Depth Ft.	Temperature	
		°C	°F
1	5	-0.77	30.6
2	10	-1.71	28.9
3	20	-2.55	27.4
4	30	-2.62	27.3
5	40	-2.35	27.7
6	50	-2.08	28.2
7	60	-1.91	28.6
8	70	-1.79	28.8
9	80	-1.86	28.7
10	90	-1.64	29.0
11	100	-1.72	28.9

(2) Thermistor Cable No. 2 - South Side - Sta. 5091 + 80 (B.H. #74-1)

Point No.	Depth Ft.	Temperature	
		°C	°F
1	5	-0.14	31.7
2	10	-0.44	31.2
3	20	-0.10	31.8
4	30	+0.06	32.1
5	40	+0.12	32.2
6	50	+0.15	32.2
7	60	+0.02	32.0
8	70	+0.04	32.1
9	80	-0.10	31.8
10	90	+0.15	32.2
11	100	-0.10	31.8

NATIONAL RESEARCH COUNCIL CANADA DIVISION OF BUILDING RESEARCH

DEMPSTER HIGHWAY, Y.T.
EAGLE RIVER BRIDGE SITE

Ground Temperatures - March 21, 1975

Observers -
J.C. Plunkett, DBR/
T. Thompson, AES/DO

Point No.	Depth Ft.	Cable #1 (North)		Cable #2 (South)	
		°C	°F	°C	°F
1	5	-5.53	22.0	-0.34	31.4
2	10	-3.78	25.2	-0.37	31.3
3	20	-2.15	28.1	-0.19	31.7
4	30	-2.03	28.3	-0.05	31.9
5	40	-2.11	28.2	+0.04	32.1
6	50	-2.06	28.3	+0.09	32.2
7	60	-1.95	28.5	-0.16	31.7
8	70	-1.80	28.8	0.0	32.0
9	80	-1.84	28.7	-0.23	31.6
10	90	-1.64	29.0	+0.10	32.2
11	100	– *	–	– *	–

Snow Cover - Range 27" - 39" 32" - 36"
- Avge. (~20 obser.) 32" 34"

Air Temperature - 0°C

* Unable to obtain stable reading.

5. Thunder River

The drainage area is 116 square miles. No major lake on the main channel effects the peak discharge. A discharge of 980 c.f.s. has been computed from ice marks which is approximately a seven year return period flow rate. A fifty year return period discharge of 1,410 c.f.s. is used for design with and average velocity estimated at 3.4 feet per second. The average slope of the river is 0.62%.

III.5 THUNDER RIVER

5.1 Bridge Crossing

In case a bridge turns out to be the best solution for the crossing, a bridge lenght of 220 feet is recommended, as shown on Fig. 14.

On the west side of the river, the bridge approach is built on a flood plain that will be slightly inundated by the fifty year design high water.

5.2 Scour Computation

The mean size of bed material observed is 50 m.m. The water depth and velocity at design discharge of 1,410 cfs were estimated to be 8.9 feet and 3.04 fps respectively (Table 1). Based on this bed material size and water depth, a velocity of 8.9 fps is required to move the bed material; this value is much higher than the mean velocity of 3.04 fps. The minimum required channel width of 67 feet computed by Lacey's equation(8) is less than the natural channel width of 69 feet under fill condition as shown in Fig. 14. Thus, no general scour is expected.

The local scour depths around piers were calculated to be 5 feet, 6 feet and 8 feet for the piers with widths of 4 feet, 6 feet and 8 feet respectively (Appendix II). 3 inch diameter stones will be sufficient to insure protection against local scour. 12 inch mean size riprap is recommended for protection. (Table 2).

5.3 Ice Considerations

Very few ice marks were found along the river banks, except below a sharp bend slightly upstream of the crossing. Schultz measurements on March 14, 1974 found that the river was frozen solid to the bottom. Ice was 6 feet deep. We feel that, due to the excessive amount of debris on the Thunder River combined with some ice floes or high water, a bridge will be safer and more maintenance-free than a culvert.

I.5 THUNDER RIVER

Design discharge: 1,410 cfs

Elevation corresponding to design discharge: 283.9 feet

Natural channel width at design discharge: 88 feet

Riverbed material: small boulder, D_{50} = 50 m.m.

Channel width at bridge site under fill condition at design discharge: 69 feet

Average water depth at design discharge: 8.9 feet

Channel cross-section area at bridge site corresponding to design discharge: 465 sq. ft.

Velocity at design discharge: 3.04 fps

The competent velocity suggested(7) for bed material size of 50 m.m. and water depth of 8.9 feet is:

$$V_c = 8.9 \text{ fps}$$

which is much greater than the mean velocity of 3.04 fps

The water opening width required for stable channel estimated by Lacey's equation is:

$$W = 1.8 \times (1,410)^{0.5} = 67 \text{ feet}$$

which is less than the channel width even under fill condition.

Therefore, no general scour is expected.

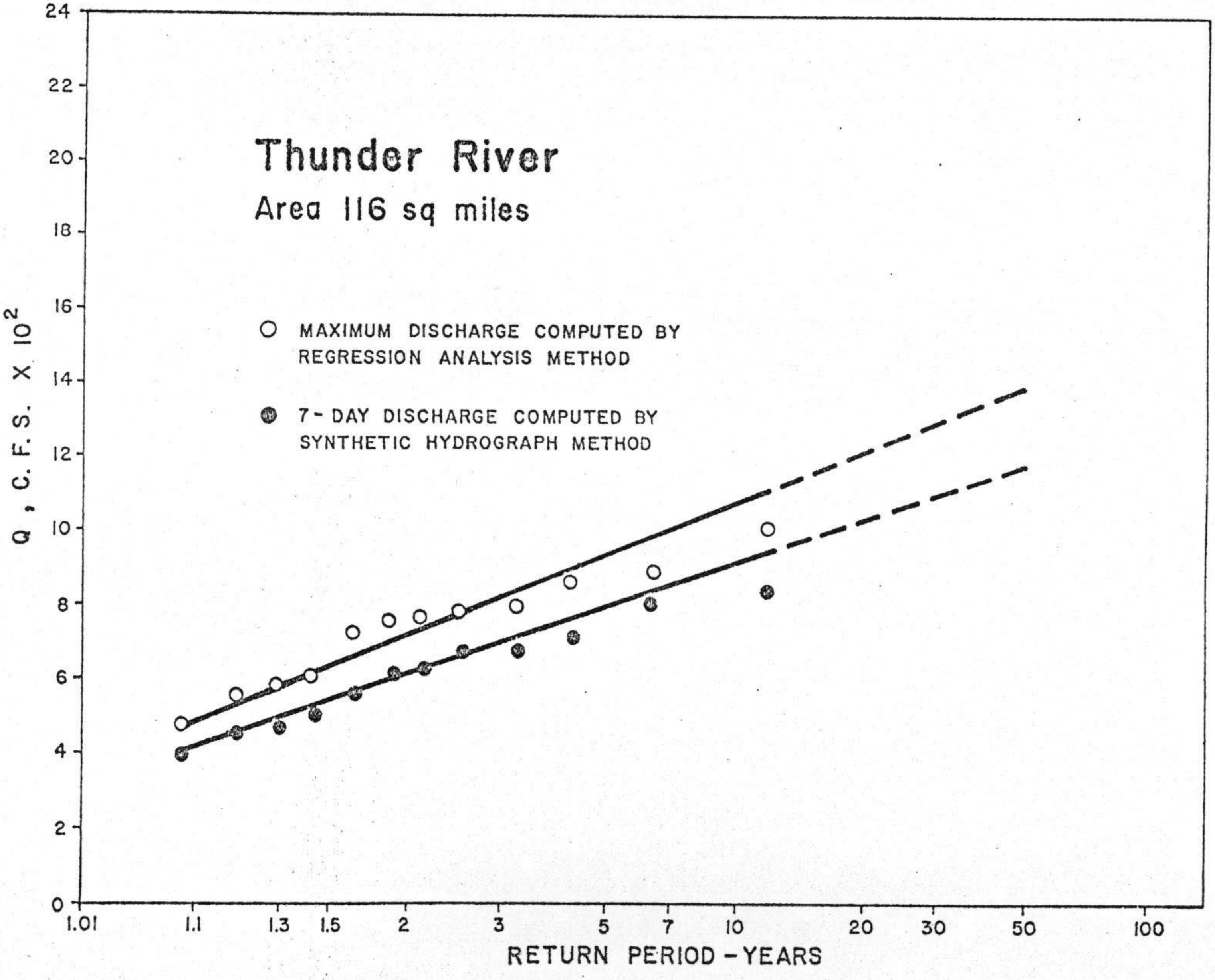


FIGURE 16 Peak and 7-day discharges of the Thunder River

THUNDER RIVER BASIN

TOTAL DRAINAGE AREA TO HWY 116 SQ MI

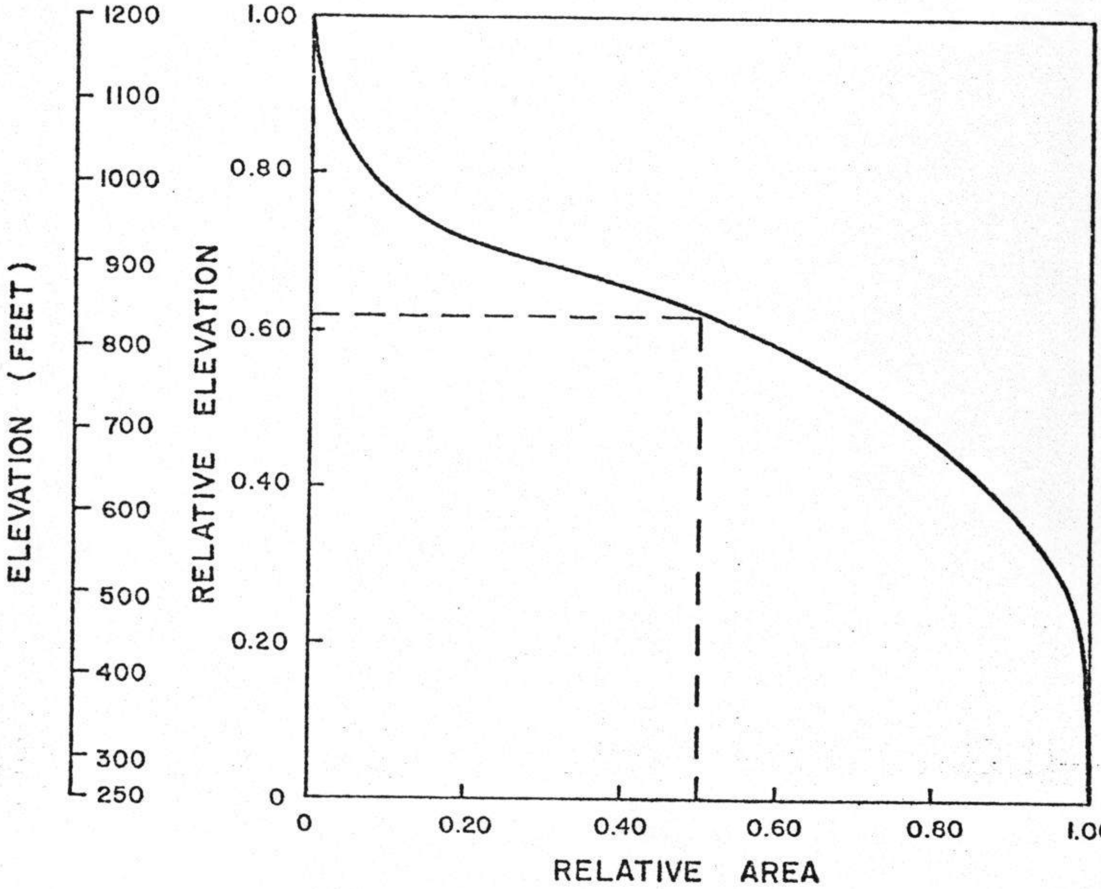


FIGURE 34

FENCO

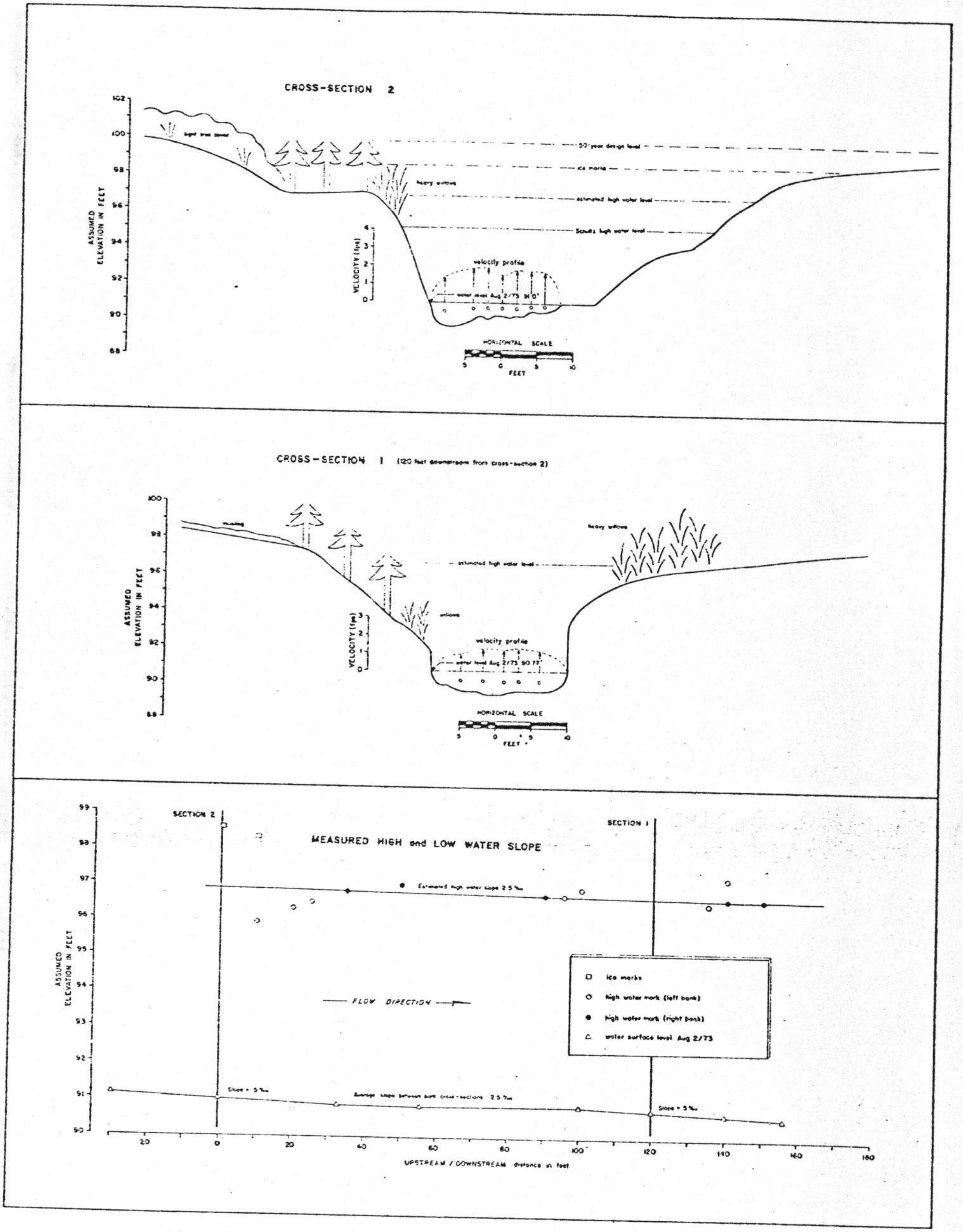


FIGURE 42 Thunder River Hydraulic Data

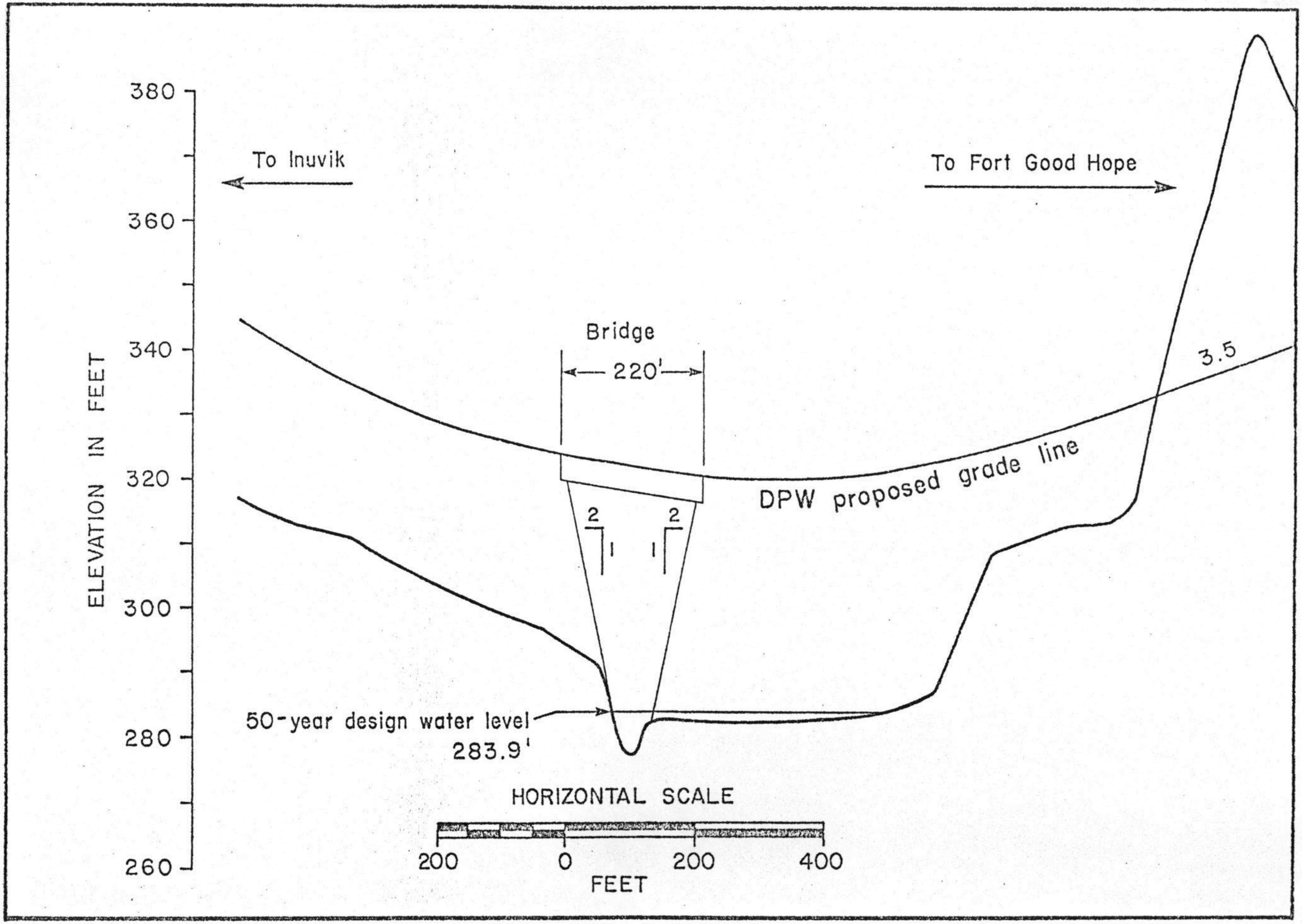


FIGURE 14 THUNDER RIVER BRIDGE
Preliminary Profile

Table D

Local Scour Depth Around Piers
at Thunder River Crossing

	Scour Depth in Feet		
	Width of Pier in Feet		
Equation Used	4	6	8
Blench	4.3	5.7	6.8
Shen	4.3	5.5	6.6
Larras	5.6	7.6	9.5
Depth Recommended	5.0	6.0	8.0

APPENDIX III

THUNDER RIVER - CULVERT DESIGN

I FIRST TRY: 26.9 x 18.7 foot culvert with 4.5 feet of fill at the bottom

I.1 MAXIMUM VELOCITY COMPUTATION

$S = 0.004$

$n = 0.045$ for a culvert bottom filled with rocks$^{(2)}$

$$A\,R_{50}^{2/3} = \frac{nQ}{1.49\,S^{\frac{1}{2}}} = \frac{0.045 \times 1{,}410}{1.49 \times 0.0632} = 673$$

Therefore $D_{N_{50}} = 9.05$ feet

The tailwater depth is 10.0 feet (natural channel depth) and the backwater curve is of the M1 type.

The maximum velocity occurs at the normal depth section if the pipe is long enough.

$A_{N_{50}} = 225\ ft^2$

$$V_{N_{50}} = \frac{1{,}410}{225} = 6.26 \text{ fps}$$

I.2 7 DAY DELAY VELOCITY COMPUTATION

$$A\,R_{50\text{-}7\text{-}day}^{2/3} = \frac{0.045 \times 1{,}190}{1.49 \times 0.0632} = 568.6$$

depth, $D_{N_{50\text{-}7\text{-}day}}$ = 7.95 Backwater curve of M1 type

Area, $A_{N_{50\text{-}7\text{-}day}}$ = 198

$$V_{N_{50\text{-}7\text{-}day}} = \frac{1,190}{198} = 6.01 \text{ fps}$$

With a total fill depth of 45 feet, the length of the culvert is 34 + 3 x 45 = 169 feet.

Assuming that the M1 curve is horizontal the depth at the entrance of the culvert is found to be:

$$D = 9.4 - 169 \times 0.004 = 8.72$$

corresponding to an Area of 217 ft^2 and therefore a 7 day delay velocity of:

$$V = \frac{1,190}{217} = 5.48 \text{ fps}$$

Currents are too fast. A bigger culvert has to be tried.

II SECOND TRY: 28.3 x 20.5 foot culvert with 4.5 feet of fill at the bottom

II.1 MAXIMUM VELOCITY COMPUTATION

$S = 0.004$

$n = 0.045$ with bottom filled with rocks

$A\ R_{50}^{2/3} = 673$

Now $D_{N_{50}}$ becomes equal to 7.7 feet. There is backwater effect in the culvert since the tailwater depth is 10 feet.

Assuming horizontal slope, the depth at the entrance is:

$D = 10 - 169 \times 0.004 = 9.32$ feet corresponding to a culvert area of 265 ft^2 and a 50 year maximum velocity of:

$V_{50} = 5.32$ fps

II.2 7 DAY DELAY VELOCITY COMPUTATION

$A\ R_{50\text{-}7\text{-}day}^{2/3} = 568$

$D_{N_{50\text{-}7\text{-}day}} = 6.7$ feet

$D_{entrance} = 9.4 - 169 \times 0.004 = 8.72$

corresponding to an area of:

$A = 248\ ft^2$

and a 50 year, 7 day delay velocity of 4.79 fps which is below 5 fps.

This type of culvert can be retained.