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Western Region

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Region de l'Ouest

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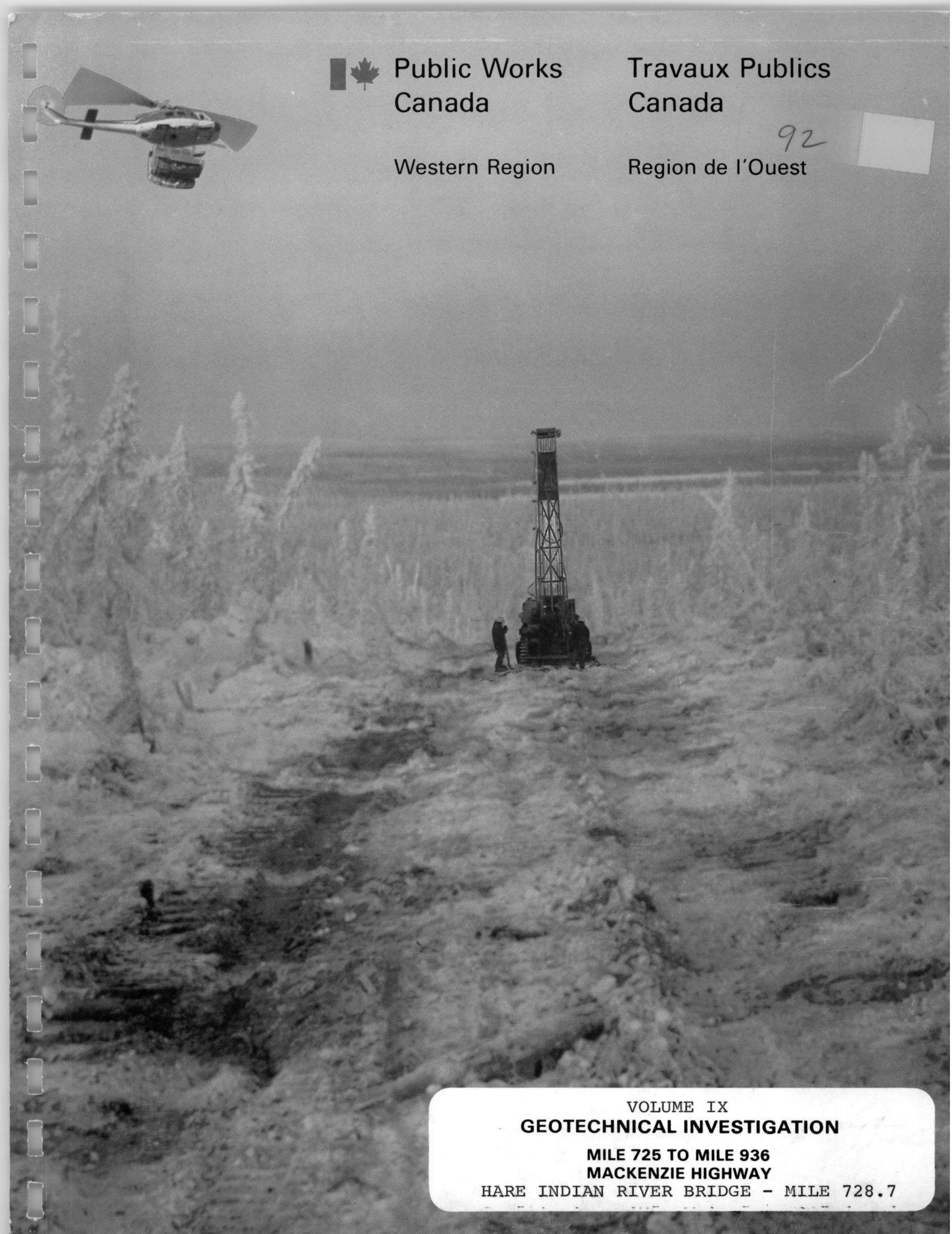

VOLUME IX

GEOTECHNICAL INVESTIGATION

MILE 725 TO MILE 936
MACKENZIE HIGHWAY

HARE INDIAN RIVER BRIDGE - MILE 728.7

000010

PUBLIC WORKS CANADA

WESTERN REGION

REPORT ON
GEOTECHNICAL INVESTIGATION
MILE 725 TO MILE 936
MACKENZIE HIGHWAY

VOLUME IX

FOUNDATION INVESTIGATION
HARE INDIAN RIVER CROSSING
MILE 728.7

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

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APPENDICES

I INTRODUCTION

The subsoil investigation at the Hare Indian 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. The Hare Indian River is the largest river within the study area, and is one of five major river crossings investigated in detail during the course of the field work. General terrain analysis and borrow evaluation along the Highway have 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 Hare Indian River crossing comprises Volume IX 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 DESCRIPTION

A. Location

The proposed bridge site is located approximately 8 miles upstream of where the Hare Indian River empties into the Mackenzie River, and is at approximately Mile 728.7 of the Mackenzie Highway. The geographic location of the River is

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shown on the 1" = 90 miles key plan, Drawing No. A-1, Appendix A, and the location of the crossing site is shown on the 1 : 50,000 plan, Drawing No. A-1a. Drawing No. A-2, Appendix A, outlines the upstream drainage area of the Hare Indian River and Drawing No. A-3 is a detailed 1" = 200' mosaic of the proposed crossing site.

B. Drainage Area

The Hare Indian River drainage basin encompasses approximately 6,000 square miles. In the upper reaches the River and its tributaries drain the western slopes of the Colville Hills physiographic area; the lower catchment area and the crossing site is located in the southern portion of the Anderson Plain physiographic zone. The Anderson Plain is a broadly dissected, undulating terrain, underlain in the South by Middle Devonian shales, primarily the Hare Indian formation. Cover, predominantly glacial till, is thin on uplands, with thicker deposits encountered in major depressions such as the Hare Indian Valley. Permafrost is continuous throughout both physiographic areas.

C. Crossing Site

In the lower six (6) miles the River is closely confined between steep scarps and a highway crossing along this portion would necessitate substantial approach cuts in potentially thaw unstable materials. Upstream, the valley floor widens to

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1/2-1 mile, with a flood plain consisting of sands, silts and clays over gravel, and fragmentary gravel terraces. The upstream section is preferred for a crossing site as the adjacent flood plain permits lower highway approach gradients and much shallow cuts in the valley walls.

Generalized stratigraphy of deposits exposed along scarps bounding the valley floor consists from bottom up of:
1) preglacial or interglacial gravel; 2) till; 3) glaciolacustrine silt and clay; 4) glaciofluvial sand and gravel. Both the till and the glaciolacustrine silt and clay are discontinuous. The scarp faces are mostly steep and stable, and approach cuts to a crossing may not be too detrimental providing the glaciolacustrine silt and clay is lacking in the cut areas, as the silt and clay is ice-rich and would be subject to retrogressive-thaw flow slides.

With reference to Drawing No. A-la in Appendix A, two crossing sites are shown - the original site located approximately 4 miles upstream from the mouth, and the revised site, investigated during this study, which is roughly 8 miles from the mouth. The original site was studied and reported on by hydrological consultants (FENCO) (3, 4)*, and data from that report is included in Appendix C. Cross-sections of the river valley are dis-similar at the two crossing sites - at the lower site the river is closely confined between steep scarps; at the upper site the river valley is approximately three times

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

as wide with a flood plain developed adjacent to the river channel. Gradients are low between the two sites and bed materials are similar, and, as the high water levels at both sites are governed by a back-water effect from the Mackenzie River, it is felt the hydrological data obtained at the lower site can generally be applied to the revised crossing site.

At the upper site, the river and the adjacent flood plain is roughly 100-130' below the level of the surrounding plain. Valley walls are steep on both sides, however the proposed bridge siting and orientation is such that there is room on the valley floor for route descent to bridge level - see Drawing No. A-3. On the south of the channel the valley floor is a low, wet flood plain marked by ponds, muskegs and drainage channels - on the north is the inside of a meander loop consisting in part of well drained, granular, alluvial terraces. Two alternate approaches are under consideration on the south - "A" is a direct descent into the valley at right angles to the scarp, which would necessitate a substantial cut; "B" is a curving approach along the flood plain from the west and a more gradual descent down the scarp. On the north the proposed approach curves across the granular terraces after a direct descent down the valley scarp which is significantly lower than on the south. Gradelines for the route have not been proposed as yet, however significant cuts and fills will be required on

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both sides of the valley.

At the original crossing site, a fifty year return design discharge of 64,000 cfs. was recommended by the hydrological consultants (3, 4). This discharge is influenced by a back water effect from the Mackenzie River such that the estimated velocity is only 1.5 feet per second. Elevation of the high water is estimated at elevation 157; and because of the back water effect it is assumed the high water level at the revised upstream crossing site will also be approximately elevation 157. Flood plain elevations at the revised site vary from approximately elevation 135' to 150', hence much of the valley floor will be inundated annually, the exception being higher gravel terraces.

An aerial photographic interpretation of the surficial geology of the general area of the revised crossing site is shown on Drawing No. A-3, and the terrain legend describing the symbols used is presented in Drawing No. A-3a. The immediate area of the crossing is shown in profile on Drawing No. A-4. Note that the borehole locations are slightly downstream of alternate B on Drawing A-3, as the test borings were carried out before the field survey lines were established. The profile along alternate B has been assumed along the line of boreholes and errors in elevation between the two lines are considered relatively minor.

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There are no conceptual bridge drawings available, however if a bridge-deck elevation of 175 is assumed, a bridge length approaching 1,000 feet will be required, and at least three stream channel piers will be required.

Photos #1, #2 and #3 in Appendix A are low angle oblique photographs of the crossing and illustrate the salient topographic features.

III EVALUATION OF SUBSOIL CONDITIONS

A. Field and Laboratory Analysis

A total of 14 test holes were drilled on the valley floor in the immediate vicinity of the crossing site. Hole locations are shown on Drawing No. A-3, Appendix A, and borehole logs are included in Appendix B.

Test borings were carried out with a Mayhew 1000 rotary drill rig using air circulation return. This rig performs well in permafrost soils but will not advance drill stem in unfrozen, wet subsoil, hence no borings were carried out in the thaw zone below the river channel. Disturbed samples were obtained from drill cuttings at frequent intervals in all holes for ice description, moisture content determinations, and material identification. Samples were returned to Edmonton for analysis in the Departmental Laboratory.

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B. Subsoil Profile

The boreholes and the inferred stratigraphic sections are shown on Drawing No. A-4 in Appendix A. This subsoil profile presents a generalized grouping of the soil types encountered and individual borehole logs should be consulted for detail.

Shale underlies the crossing site at an elevation of approximately 73.0, or roughly 50 feet below the stream bed, and 60 to 70 feet below the level of the adjacent flood plain. Overlying the shale are extensive deposits of sands and gravels, probably of pre-glacial origin. On the north side of the crossing site,sands and gravels extend very nearly to the ground surface and it is not possible to distinguish in the boreholes from the preglacial deposits and more recent granular alluvial terraces. On the south surficial flood plain deposits of clays and silts overlie the sands and gravels to depths of roughly 30 feet. Flood plain deposits are ice rich and are wet or exhibit free water on thawing; the cohesionless granular materials contain much less ice but also are wet or saturated on thawing at much lower moisture contents.

The shale bedrock was encountered in five test holes and the shale surface appears to be relatively uniform below the river channel. Maximum penetration into the shale was 20'

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(to elevation 53.0) in hole #5. Moisture contents of shale samples ranged between 5 and 8%, and although there was no visible ice detected during drilling, the shale was thought to be frozen in all drill holes.

The limits of the thaw zone below the river channel was not accurately determined due to limitations of the drilling equipment. Thawed subsoil was definitely encountered in only one hole - near 12' in hole #7 on the south edge of the channel. Possible thaw zones were indicated at depth in several other holes in gravels and gravelly sands, however these thaw zones were not confirmed. When hard drilling is encountered in permafrost soils, such as gravelly deposits, and bit advance is slow, a combination of heat generated by the drill bit, plus heat from the compressed air circulation, results in some thawing of the drill cuttings. With gravelly soils there is often sufficient thawing that the granular particles brought to the surface are wet, and it is not possible to determine if the deposits were frozen in-situ.

A sketch of the possible and probable thaw zones below the channel are shown on Drawing No. A-5 in Appendix A. Based upon drilling data obtained at several northern rivers, and experience of others (1, 2), it is the writer's opinion that the thaw zone extends vertically downward near the edges of the river and is confined below the present channel - i.e.,

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'probable thaw limits'. The lower limit of the thaw zone very likely extends below the shale surface. The 'possible thaw limits' indicate the approximate depths where wet drill cuttings were noted in the drill holes. In order for a thermal balance which would create a thaw zone indicated by the 'possible thaw limits' to be maintained, it is felt there would have to be a substantial flow of water in the granular deposits above the shale surface, and there was no evidence of abundant free water in the drill holes. Thus the thermal situation indicated by the 'possible limits' is considered most unlikely.

IV FOUNDATION SUPPORT OF BRIDGE STRUCTURE

A. General

In view of the magnitude of bridge structure required over the Hare Indian River, it is considered that the shale bedrock provides the logical bearing support for the foundation elements. A pile foundation employing either steel H-piles or steel pipe piles bearing in the shale is recommended.

At present the in-situ density or consistency of the shale has not been precisely established; nor have the thermal conditions of the shale or the overburden soils been accurately determined, thus only tentative pile designs or driving criteria can be provided at this time. It is considered that there is sufficient subsoil data available to permit bridge design, however it is

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recommended that additional borings be carried out once the foundation elements have been located, to confirm bearing assumptions, and to provide subsoil data for pile installation. At least one borehole is recommended at each pier and abutment to establish the thermal regime and the thaw zone below the channel, which will significantly affect pile installation. In addition, cores of the shale should be obtained for strength determinations.

Based upon available subsoil data it is considered probable that at least the abutments will be founded upon frozen shale, with the piers possibly founded upon unfrozen shale. Although there is no criteria for comparison of the bearing capacity of piles on frozen and unfrozen shale, construction on frozen shale is not considered detrimental. The shale contains low moisture (ice) content and there was no evidence of ice filled joints or cracks during test drilling.

Piles installed in frozen shale below frozen overburden,such as at abutments,should be seated directly upon the shale surface in a pre-bored hole before driving, in order that the full energy of the hammer can be utilized for pile penetration into the shale. Where there is a substantial thaw zone above the shale, or extending into the shale, such as piers within the river channel, pre-boring of piles will not be necessary.

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B. H-piles

Steel H-piles are recommended at this site because of easier driving characteristics which will be advantageous in installing piles through the thawed or semi-thawed granular soils to shale. A heavy section pile - minimum 12BP53 - is recommended and, to prevent damage to the points of the piles during penetration of frozen shale or overburden, it is recommended the points be reinforced with flange plates for a distance equal to 1.5 times the size of the pile. The weight of pile driving hammer should be at least twice the weight of the pile being driven, except that in the case of a diesel hammer the weight of the hammer should be at least equal to the weight of the pile. Piles should be driven to practical refusal which may be assumed at 0.25 inches per blow measured over the last foot of driving. An allowable static design load in the order of 2/3 of the axial load permitted for the pile as a structural column may be assumed at practical refusal in shale.

Prebored holes for H-piles through frozen overburden soils should be the minimum diameter practically possible for pile installation. It is considered a pile penetration into frozen shale in the order of 8-10' can be realized if an adequate hammer is utilized - a Delmag D-12 diesel hammer or equivalent is recommended (approx. 22,000 ft. lbs. energy). Void spaces

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in pre-bored pile holes should be filled with dry, free-running sand following completion of driving.

At pier locations within the stream channel, it is anticipated it will be possible to drive steel H-piles to refusal in shale without pre-boring. Although additional borings have been recommended after bridge design to confirm permafrost limits, it is considered that the overburden soils here will be entirely thawed, or partially thawed with the lower portion 'high temperature permafrost' which can be penetrated with H-piling. Pile refusal below piers will occur at very shallow penetrations into the shale due to the frictional resistance to driving in the overburden soils.

Detailed driving records should be maintained for all piles.

C. Pipe Piles

Closed-end steel pipe piles are considered a viable alternative to steel H-piles, although they are less suited for penetrating overburden soils above shale than H-piles. Where overburden soils are frozen, preboring to the shale surface is recommended, with the hole size approximately 90-95% of the pile diameter to ensure a snug fit and lateral support. Piles should have a minimum nominal diameter of 10 inches

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and a minimum weight of 40 lbs. per foot, and should be driven with a fairly high energy hammer - Delmag D-12 or equivalent. Practical refusal may be assumed at a set of 0.25-0.4" per blow measured over the last foot of driving. A design load in the order of 2/3 of the axial load permitted for the pile as a structural column may be assumed at practical refusal.

The use of pipe piles for piers within the river channel is dependent upon the permafrost conditions below the channel. If permafrost is totally absent to the shale surface, pipe piles may be driven to practical refusal either on, or possibly somewhat above, the shale surface. If permafrost is present above the shale surface, pipe piles are not recommended as it is considered that pipe piles will have extreme difficulty in penetrating frozen or partially frozen granular overburden soils. Thus selection of pipe piles for the foundations will necessitate additional drilling at the location of foundation elements before final design. Pre-drilling for piles below the river channel is not considered practicable.

D. Bridge Approach Fills

Fill heights immediately adjacent to abutments will probably be in the order of 30' or more and will be placed in permafrost terrain. The permafrost table will undoubtedly rise

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into these fills and stability or settlement will not be a problem. Backfill immediately adjacent to the abutments should be well compacted granular material which is readily available near Ft. Good Hope in a large esker complex. Similarly, aggregate for concrete is abundant in the eskers. Field compaction control is recommended on all backfill associated with bridge piers and abutments.

Negative friction or frost heave forces on abutment piles will be insignificant at this site.

RDCook

R. D. Cook
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Western Region

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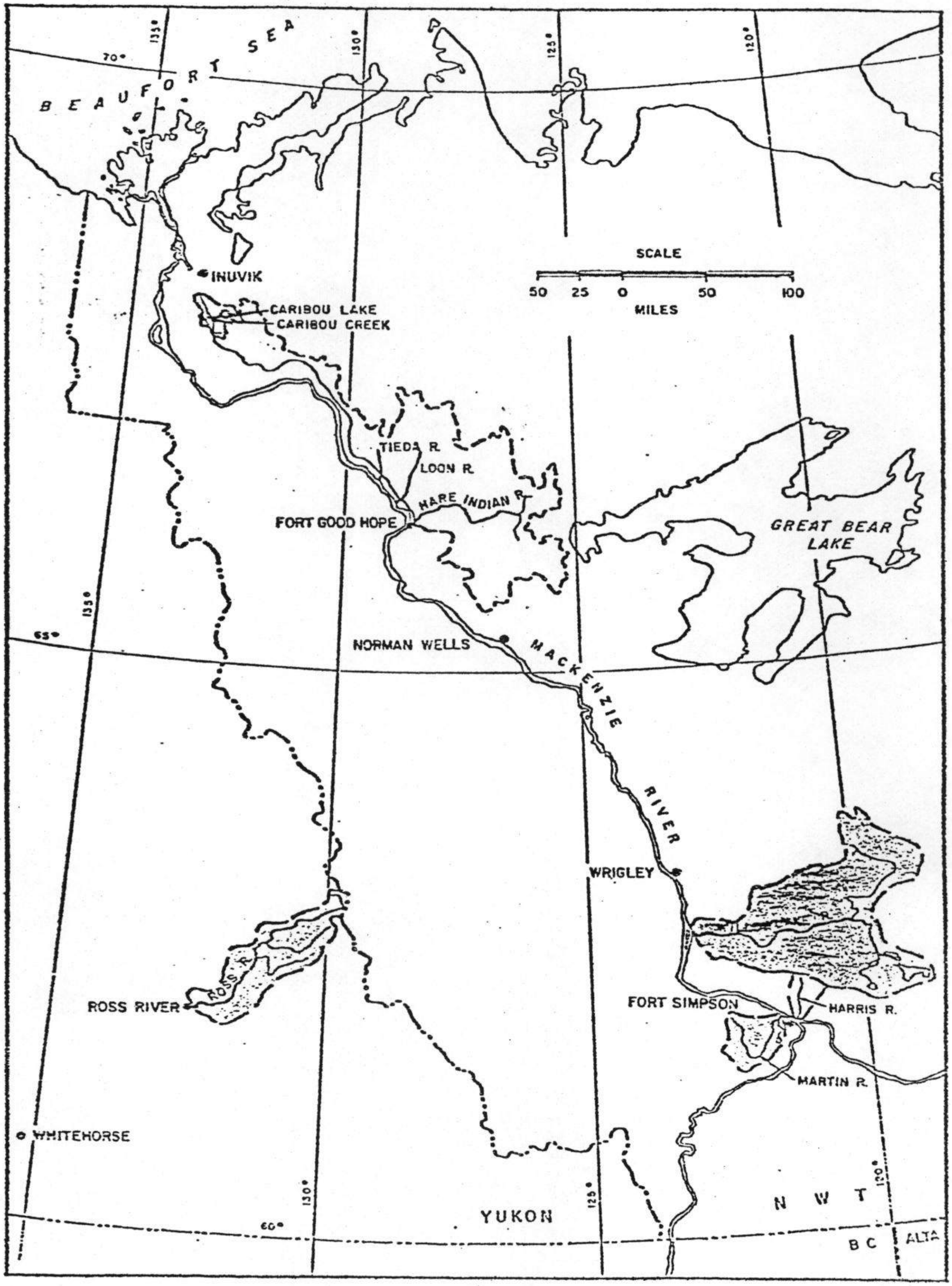
1. Brown, W. G. et al "Comparison of Observed and Calculated Ground Temperatures with Permafrost Distribution Under a Northern Lake", Canadian Geotechnical Journal, Vol. 1, No. 3, July 1964.

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.

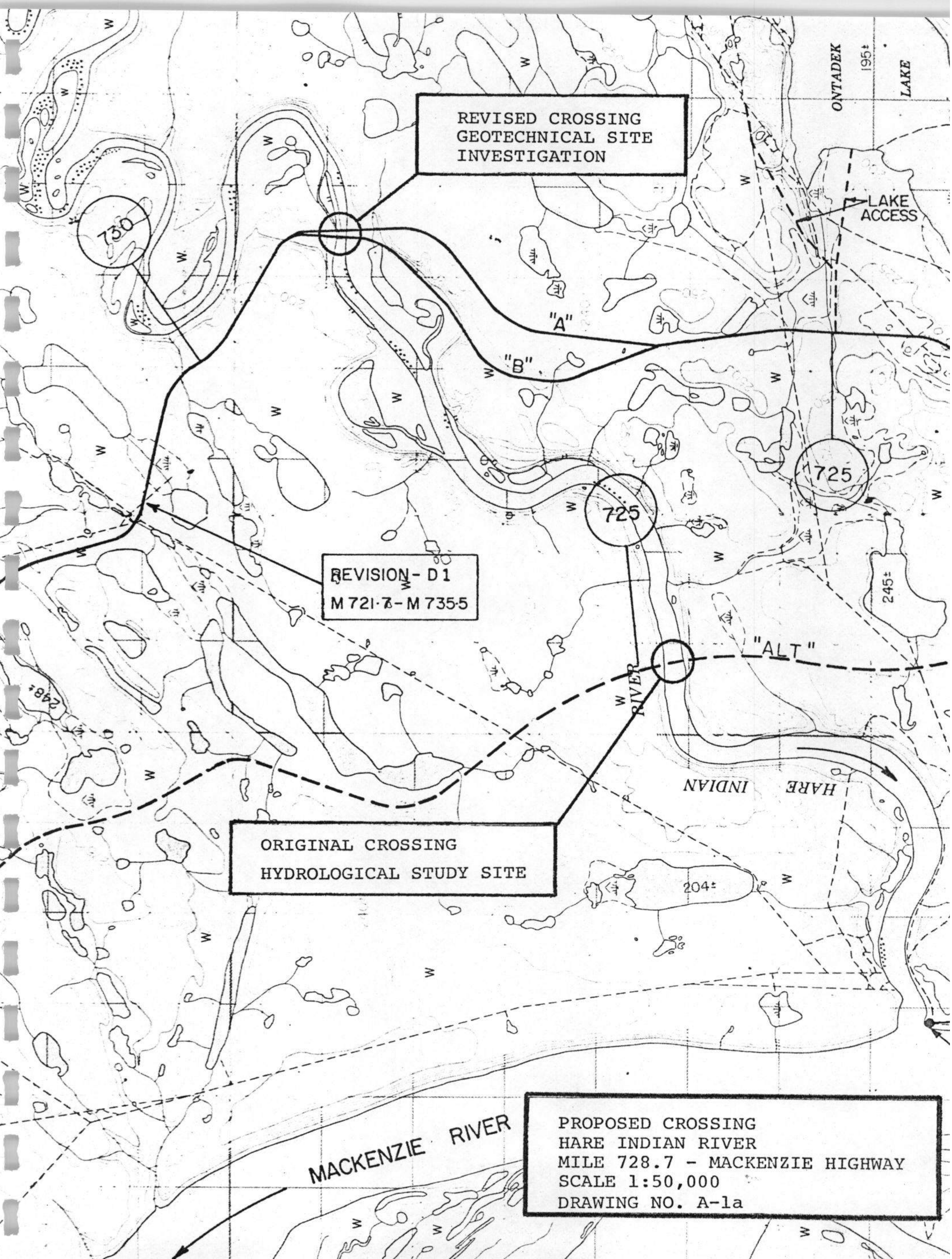


Dwg. No. A-1

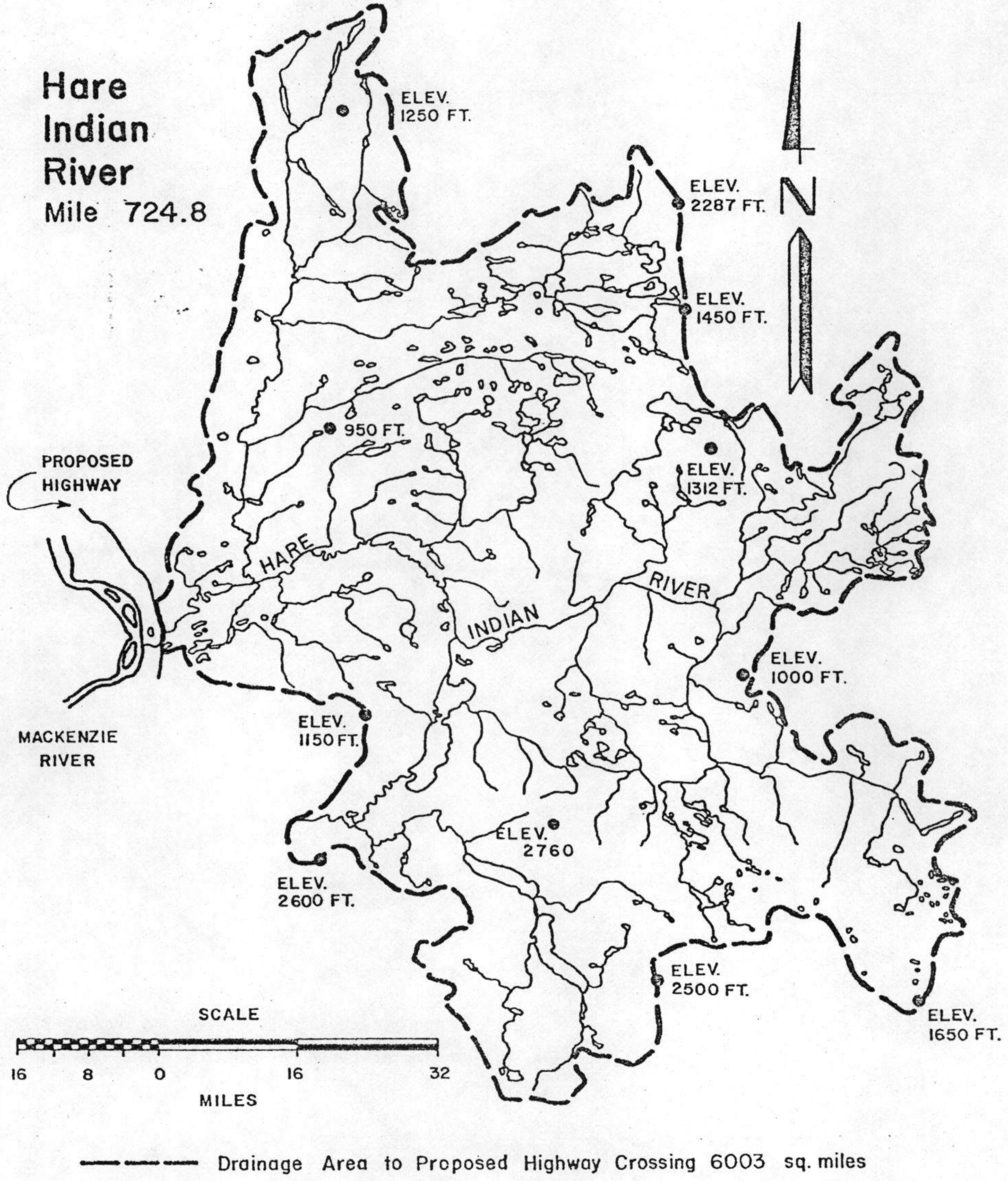
KEY PLAN

MACKENZIE RIVER, N.W.T.

1" = 90 MILES

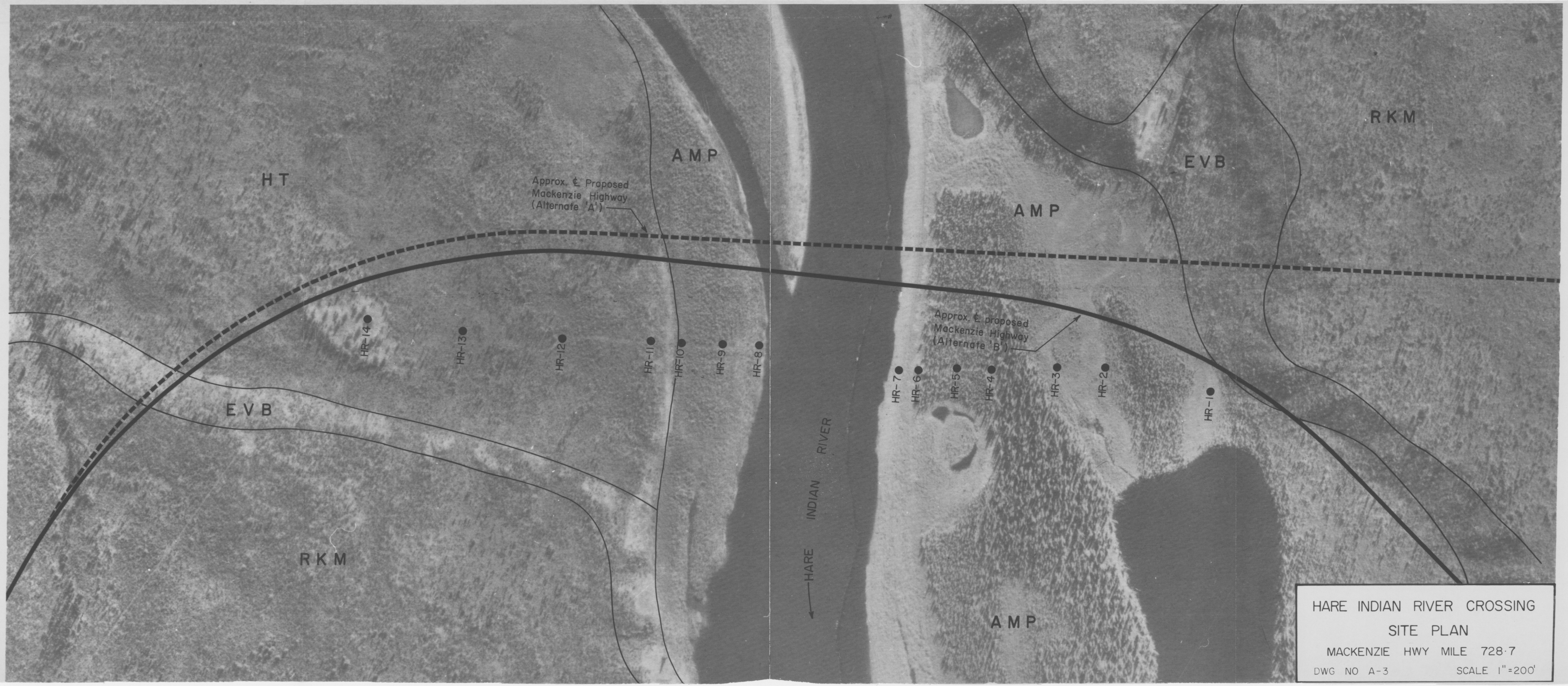


PROPOSED CROSSING
HARE INDIAN RIVER
MILE 728.7 - MACKENZIE HIGHWAY
SCALE 1:50,000
DRAWING NO. A-1a



Dwg. No. A-2

MAP Hare Indian River Basin



HARE INDIAN RIVER CROSSING
SITE PLAN
MACKENZIE HWY MILE 728·7
DWG NO A-3 SCALE 1"=200'

TERRAIN TYPING LEGEND

Symbol	Terrain Types
AMP	Alluvial meander plain: ice-rich stratified clay, silt, and fine sand over thin, discontinuous layer of sand and/or gravel over till or glaciolacustrine silt and clay
FFP	Fossil flood plain: ice-rich silty topstratum over sand and/or gravel below the inactive floodplain of relatively high-energy streams
HT	High terraces: silt-covered stratified fluvial and/or outwash sand and gravel along the sides of present river valleys and abandoned meltwater channels
RKM	Ridge-and-knoll moraine: largely rolling ground moraine with and without drumlinoid forms; low to medium plastic till with shallow peat and ponded sediments in depressions

PHASES AND FEATURES

Topographic and drainage features

DR	Drumlinoid forms, including fluting and glacial grooves with linear ridges
EVB	Eroding valley sides and escarpment slopes; mixed clay to boulders and/or bedrock

Topstratum phases associated with main terrain types

SL	Slopewash deposits and associated sheetwash drainage: top stratum of ice-rich, poorly sorted silty clay and silty sand layers with some gravel sizes and thin organic layers; generally less than 5 ft. thick but may reach 10 ft. locally

COMPLEXES

Complexes are shown as combinations of two terrain types, with or without phases that pertain to the parent type.

Drawing No. A-3a

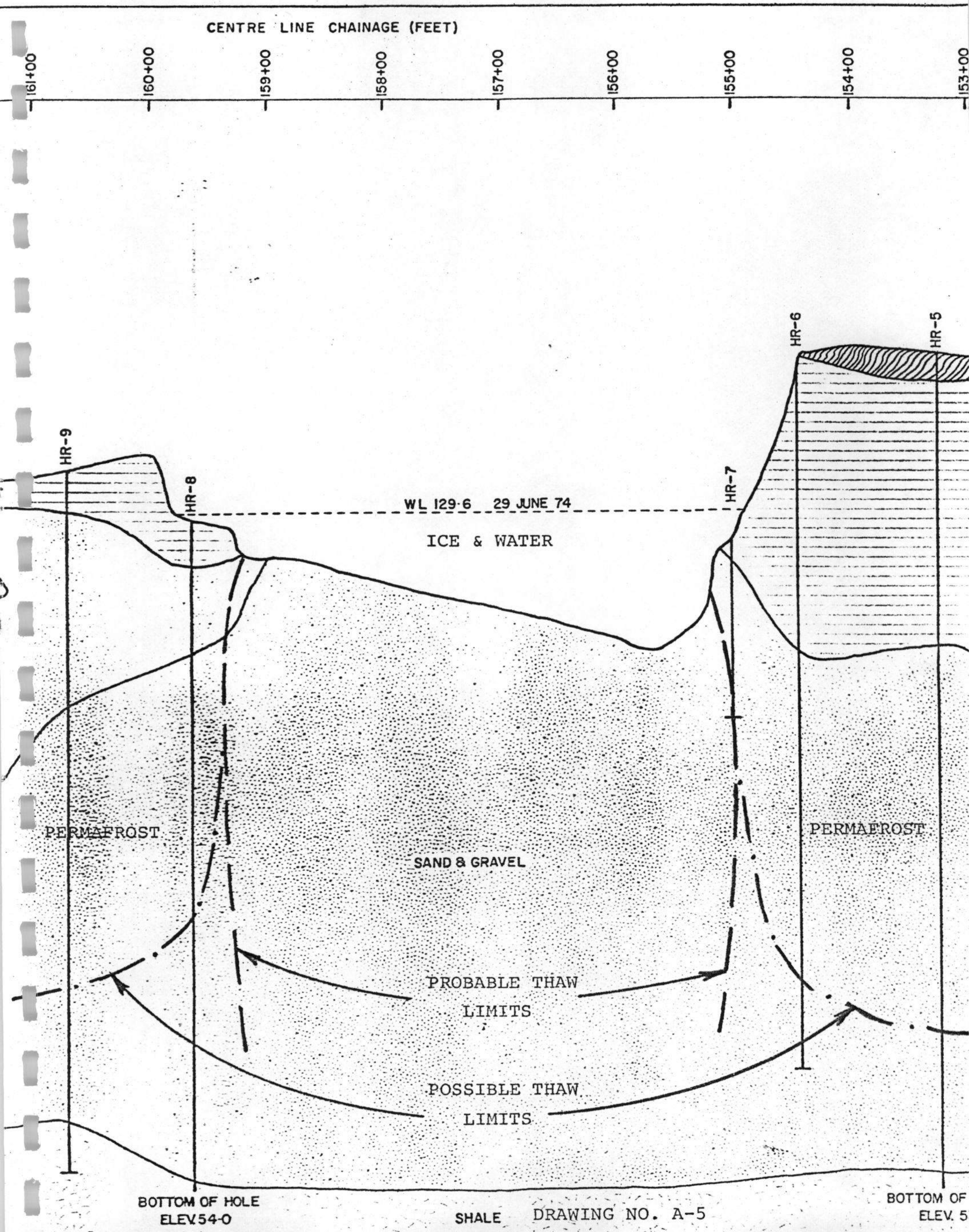
NOTE: STRATIGRAPHY BETWEEN BOREHOLES HAS BEEN ASSUMED.

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

PUBLIC WORKS CANADA
WESTERN REGION

HARE INDIAN RIVER CROSSING
℄ PROFILE & STRATIGRAPHY

DWG. NO A-4



DRAWING NO. A-5

PHOTO No. 1

Hare Indian River Valley looking easterly. Crossing site indicated by Black Line.

PHOTO No. 2

Hare Indian River looking southeasterly. Proposed crossing slightly upstream (left) of vehicle tracks.

PHOTO No. 3

Hare Indian River looking northerly. Proposed crossing slightly upstream (right) of vehicle tracks.

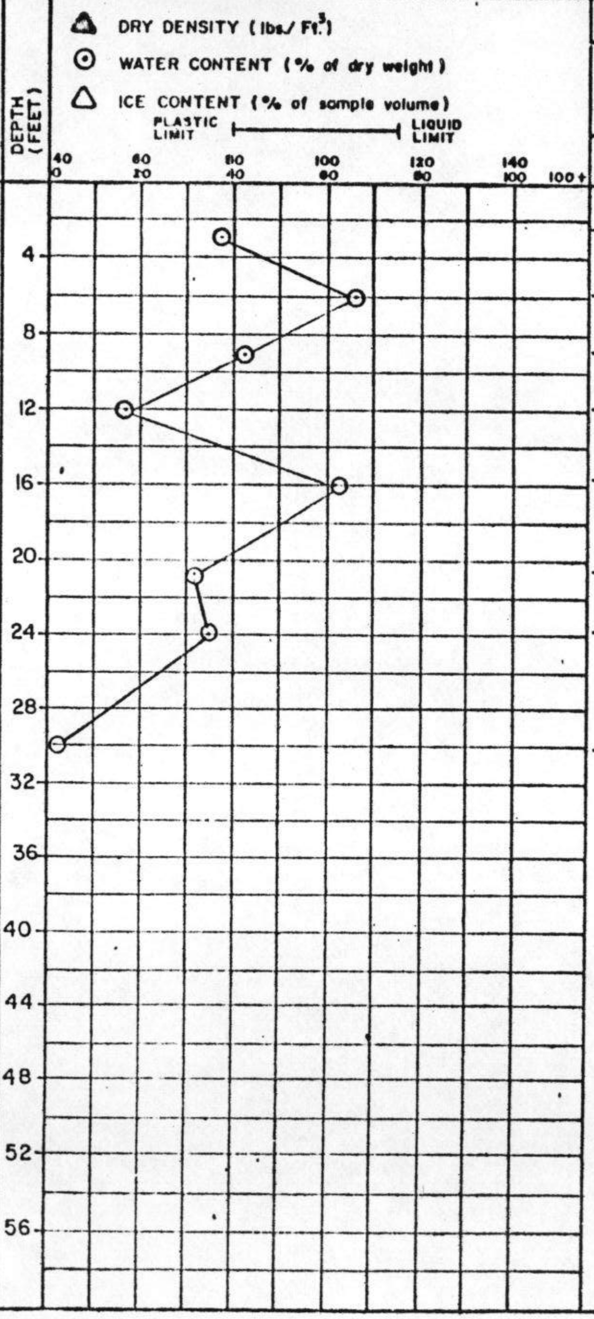
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
DATE DRILLED. 8/4/74
AIRPHOTO NO.
CHAINAGE.
OFFSET.
TECH. W. Baine
RIG. 1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 1
MILE

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
						Clay - Silty		High	-94-		6	0	Moist	
4					CI	Organic		&						
						Med. Plastic			-91-		9	0	Sat.	
8						8'		Moderate						
					ML	Silt - Clayey	F		-68-		32	0	Wet	
12						Sandy		Ice	-63-		37	0	Damp	
					OL	Organic		V_s						
16									-93-		7	0	Wet	
						17'								
						Clay - Silty		V_c - V_r						
20					CL				-94-		.6	0	Wet	
24					CI	Sandy			-66-		34	0	Sat.	
28						Low - Med. Plastic 28'								
						Gravel - Sandy			- 8-		24	68	Moist	
32						Bottom of Hole - 30'								
36														
40														
44														
48														
52														
56														



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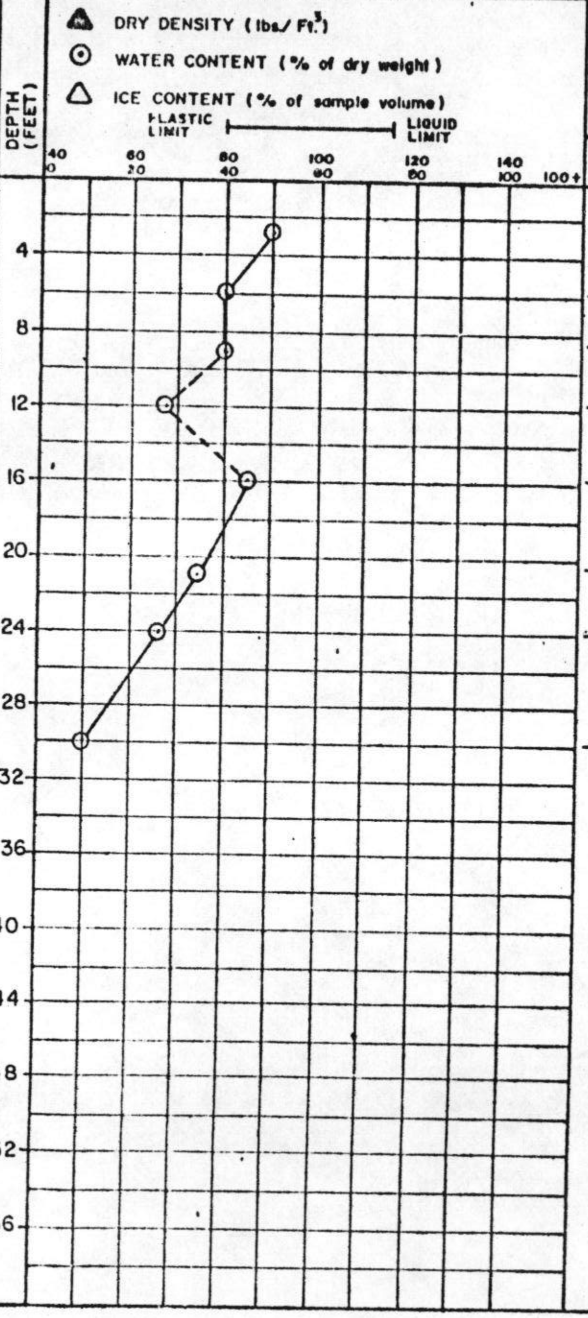
EPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

LD ENG.
H. W. Baine
DATE DRILLED. 8/4/74
RIG. 1
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 2
MILE

UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
PT	Peat 2'		
	Clay - Silty		High
	Silt - Clayey		
CL	Organic		Ice
OL			
ML		F	V_s
	Sandy		
ML	Silt - Sandy 22'		
SM	Sand - Silty Pebbles		
	Bottom of Hole - 30'		



CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
- 86	- 14		0	Sat.	
- 96	- 4		0	Moist	
- 94	- 6		0	Wet	
- 96	- 4		0		Hole in Bag
- 93	- 7		0	Wet	
- 72	- 28		0	Sat.	
- 57	- 43		0	Sat.	
- 20	- 75		5	Moist	

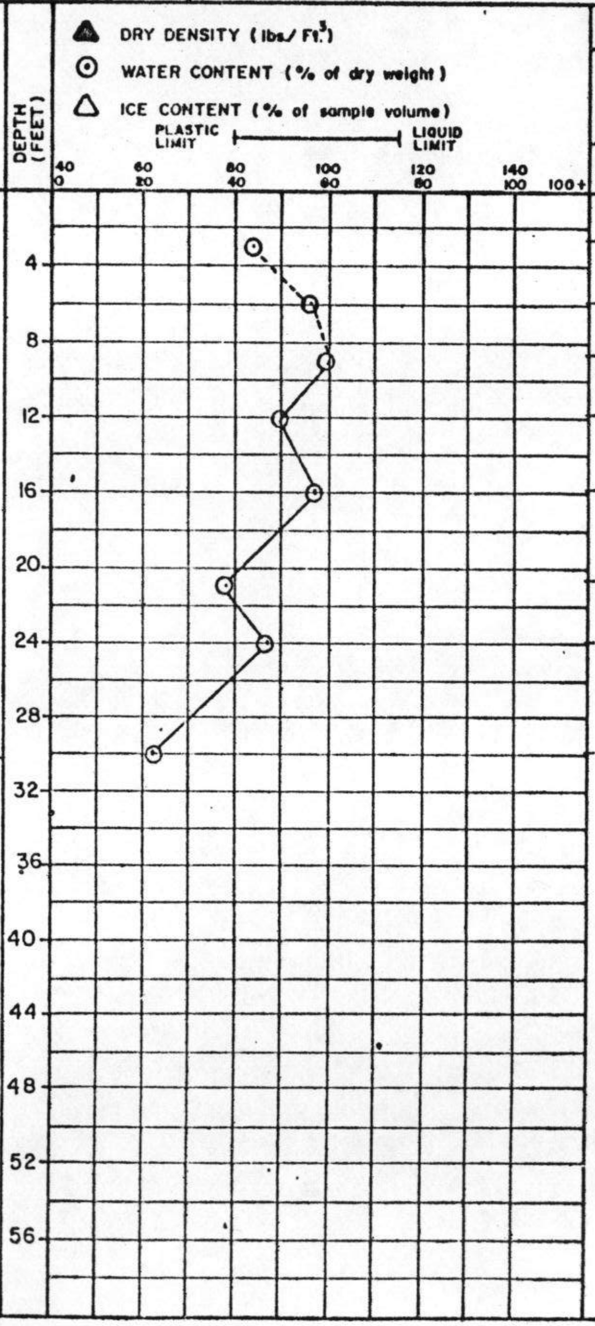
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
DATE DRILLED. 8/4/74
AIRPHOTO NO.
CHAINAGE.
OFFSET.
TECH. W. Baine
RIG. 1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 3
MILE

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'								
4						Clay - Silty Silt - Clayey		High	93	-	7	0		Hole in Bag
					CL	Organic		Ice	88	-	12	0		Hole in Bag
8					OL	To 25'			96	-	4	0	Sat.	
12					ML		F	Vs	92	-	8	0	Wet	
16									95	-	5	0	Sat.	
20									92	-	8	0	Sat.	
24									78	-	22	0	Sat.	
28						Silt - Sandy								
					ML	Clayey Gravelly			48	-	37	15	Sat.	
32						Bottom of Hole 30'								
36														
40														
44														
48														
52														
56														



1 of 1

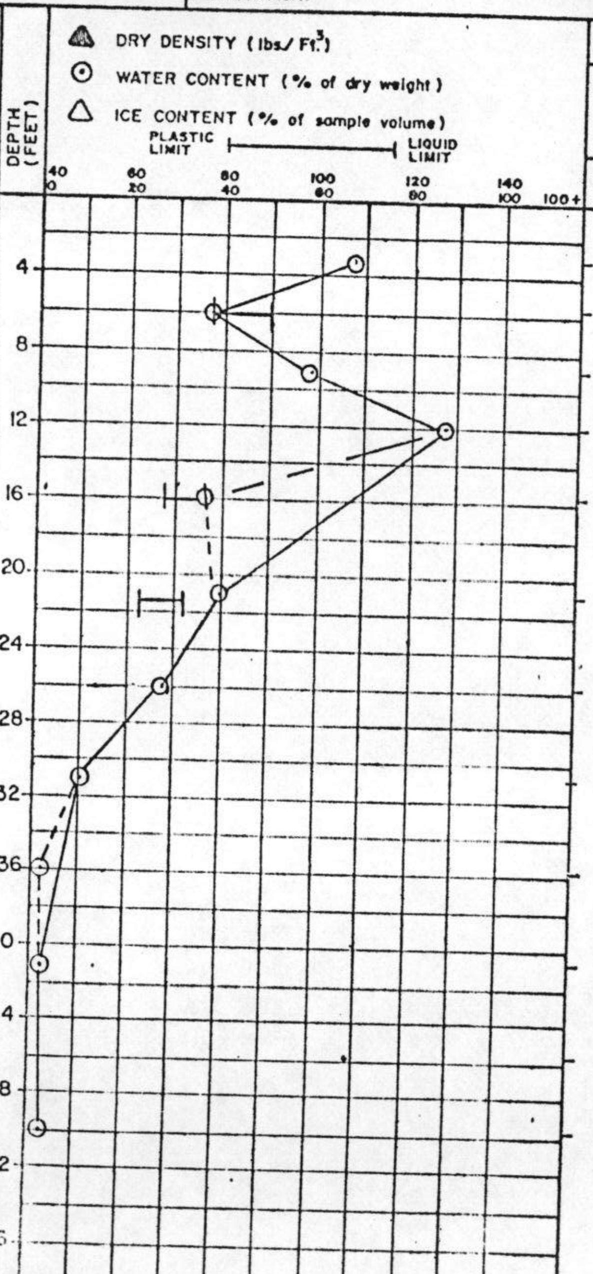
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
DATE DRILLED. 7/4/74
AIRPHOTO NO.
CHAINAGE.
OFFSET.
TECH. L. Johnson
RIG. 1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
TEST HOLE 4
MILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–14'					ML OL	Silt - Organics Organics To 14' Clayey	F	High Ice V_s
–35'					SM	Sand - Silty Gravelly	F	Moderate Ice V_c-V_r
35'–45'					GP	Gravel - Sand Mixture	F	Low Ice V_x
45'–55'					GP	Gravel - Sandy		
55'						Bottom of Hole - 55'		



CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
90	-	6	4	Wet	
94	-	6	0	Moist	
94	-	6	0	Wet	
92	-	8	0	Free Water	
82	-	18	0		Hole in Bag
74	-	26	0	Sat.	
45	-	55	0	Sat.	
16	-	54	30	Wet	
5	-	48	47		Hole in Bag
7	-	51	42	Damp	
4	-	20	76		Hole in Bag
5	-	28	67	Damp	

1 of 2

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
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DATE DRILLED. 8/4/74
RIG. 1
AIRPHOTO NO.
SURFACE DRAINAGE.
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VEGETATION.
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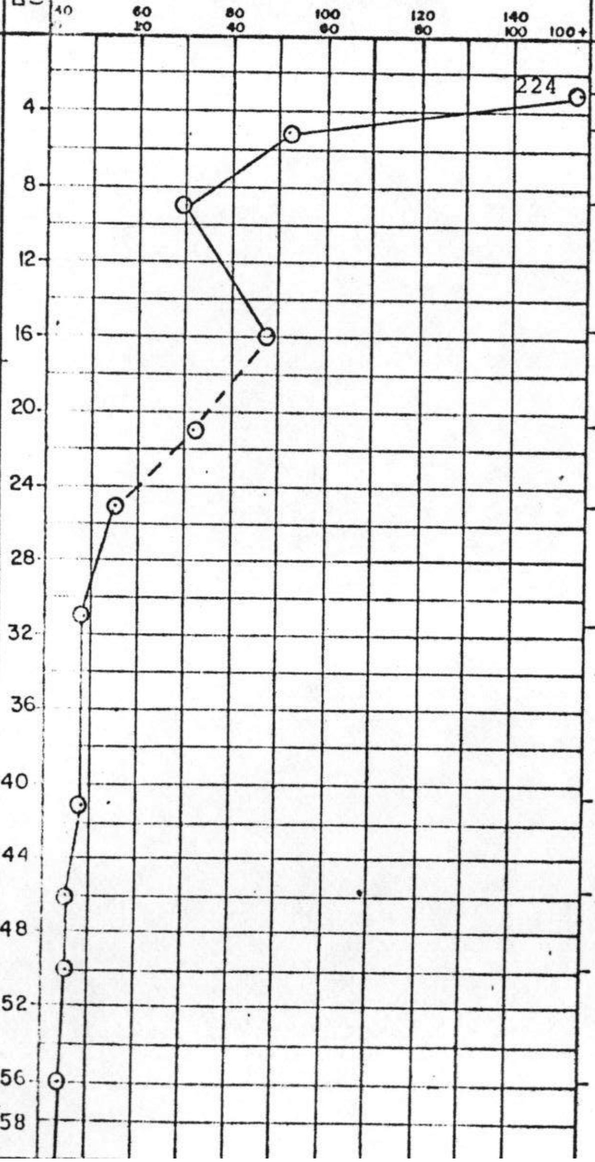
TEST HOLE 5
MILE

DEPTH (FEET)	SAMPLE	TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2					PT	Peat — 2'	F	High Ice V_s
2–24					ML	Silt - Clayey Sandy Organic		High Ice V_s (to 17) Moderate Ice $V_c - V_r$
24–57					SP	Sand - Silty Gravelly Pebbles Sand - Pebbles Gravelly Frozen to 57'	F	Moderate To Low Ice $V_c - V_r$ V_x Low Ice V_x



DEPTH (FEET)	CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
4	90	-	10	0	Free Water	
5	89	-	11	0	Wet	
9	95	-	5	0	Free Water	
16	83	-	16	1	Sat.	
21	94	-	.6	0		Hole in Bag
25	37	-	53	10	Wet	
31	8	-	45	47	Wet	
41	9	-	67	24	Wet	
46	12	-	82	6	Moist	
50	11	-	82	7	Moist	
56	7	-	49	44	Moist	

2 of 2

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

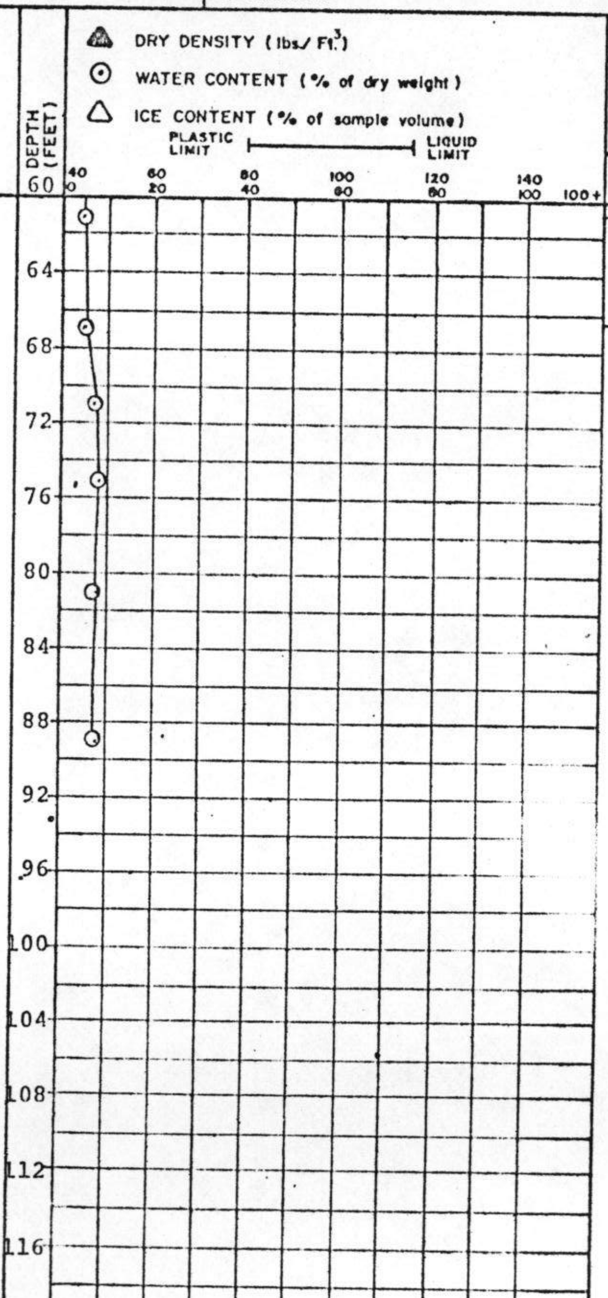
SITE: HARE INDIAN RIVER

FIELD ENG.	DATE DRILLED. 8/4/74	AIRPHOTO NO.	CHAINAGE.	OFFSET.
TECH. W. Baine	RIG. 1	SURFACE DRAINAGE.	VEGETATION.	ELEV.

TEST HOLE 5

MILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
						-Wet Gravel @ 57'		
4						-Unable to Determine if Frozen Below 57'		
8								
12						70'		
						Shale - Silty		
16								
20								
24								
28								
32						90'		
						Bottom of Hole - 90'		
36								
40								
44								
48								
52								
56								



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
10	-	73	17	Damp	
9	-	71	20	Moist	
				Damp	
				Damp	
				Damp	
				Damp	

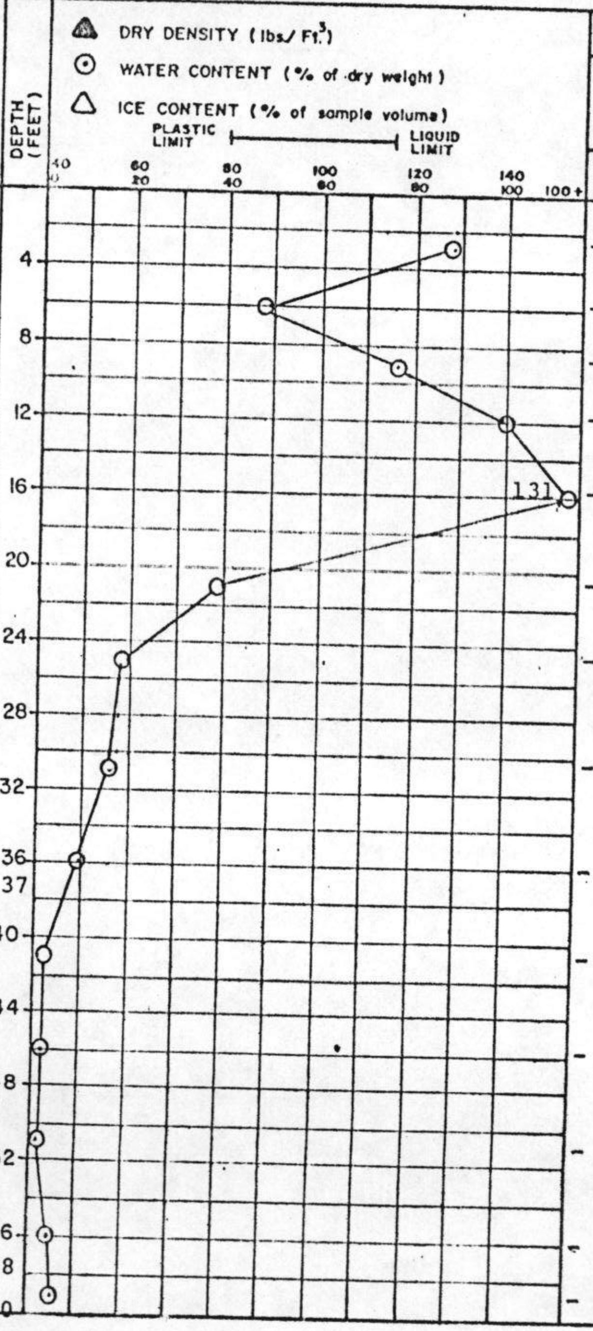
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
DATE DRILLED. 8/4/74
AIRPHOTO NO.
CHAINAGE.
TECH. W. Baine
RIG. 1
SURFACE DRAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 6
MILE

DEPTH (FEET)	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–32'	ML OL	Silt - Sandy Pebbles Clayey Organic	F	High Ice V_s
32'	GW	Gravel - Sandy		Moderate Ice V_c - V_r
				Low Ice Vx
	GW	Gravel - Sandy		Moderate To Low Ice Vx V_c - V_r
58'	SP	Sand - Gravelly		
60'		Bottom of Hole - 60'	Not Frozen-?	



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE, THAWED MOISTURE CONTENT
-	75 -	25	0	Freewater
-	56 -	37	7	Freewater
-	78 -	22	0	Freewater
-	81 -	19	0	Freewater
-	78 -	22	0	Freewater
-	80 -	.20	0	Moist
-	39 -	48	13	Moist
-	8 -	68	24	Wet
-	2 -	25	73	Wet
-	3 -	25	72	Moist
-	1 -	19	80	Moist
-	4 -	35	61	Wet
-	6 -	47	47	Wet
-	9 -	70	21	Wet

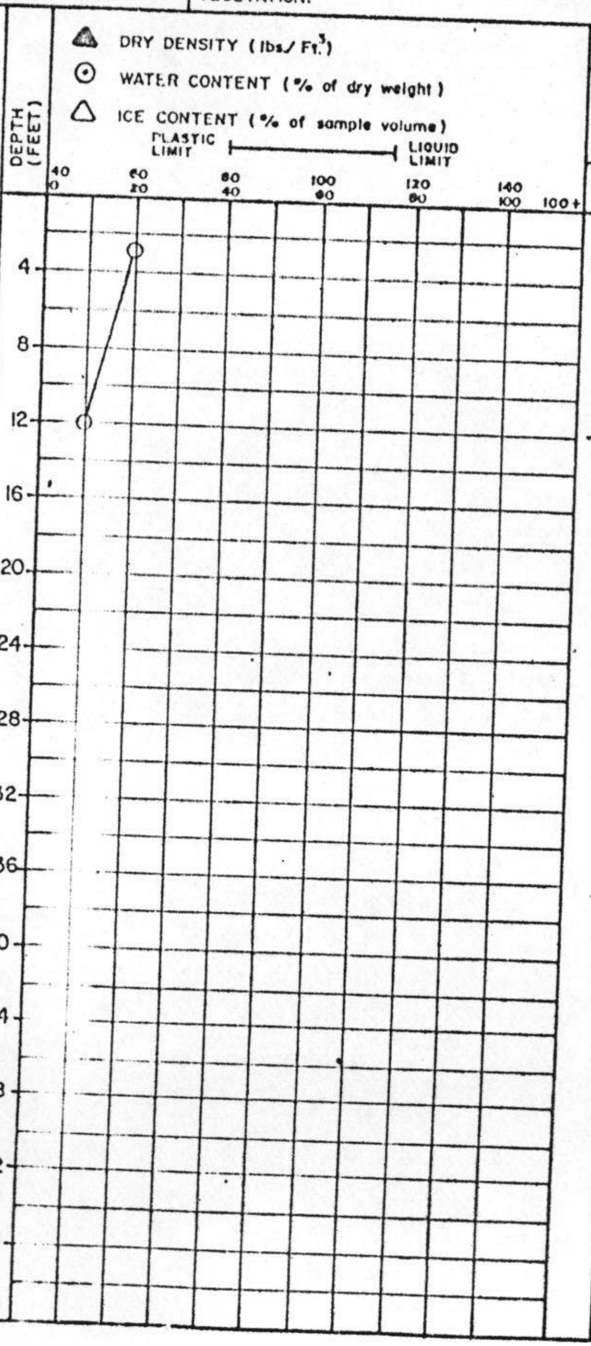
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
TECH. W. Baine
DATE DRILLED. 8/4/74
RIG.
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 7
MILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					ML	Silt - Sandy 4'		
					SP	Sand - Silty Gravelly 15'		
						Bottom of Hole - 15' Water Blowing from Hole Unable to Drill		



DEPTH (FEET)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
4	-	55 -	45	0	Damp	
12	-	11 -	54	35	Wet	

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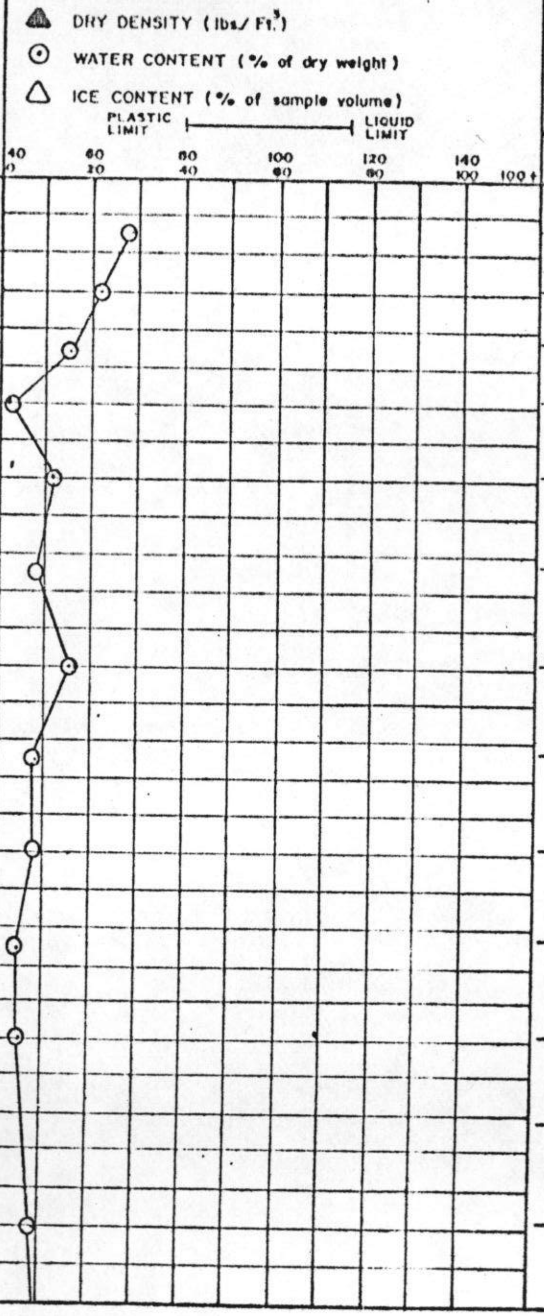
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
TECH. W. BAINE
DATE DRILLED. 8/4/74
RIG. 1
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 8
MILE



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 %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
4					SM ML	Sand - Silt Mixture	4'		Moderate	4	-	55 -	45	0	Damp	
						Sand - Silty			Ice		-	29 -	71	0	Sat.	
8						Gravelly		F	$V_c - V_r$	8	-	8 -	78	14	Sat.	
12										12	-	2 -	25	73	Wet	
16					SM					16	-	7 -	57	36	Sat.	
20						Pebbles				20	-	9 -	85	6	Wet	
24										24 25						
28						Sand - Silty Pebbles			Moderate	28	-	20 -	74	6	Moist	
32					SM	Gravelly		F	Ice $V_c - V_r$	32	-	10 -	71	19	Sat.	
36					GM	Gravel - Silt - Sand Mix Clayey	35'			36 37	-	20 -	41	39	Damp	
40					GP	Gravel - Sandy	40'			40	-	7 -	40	53	Sat.	
44						- Wet from 37' to 57' - Appears Unfrozen				44	-	7 -	45	48	Moist	
48										48 50						
52					GP	Gravel - Sandy				52	-	4 -	32	64		Hole in Bag
56					ML	Silt - Sandy Gravelly	55' 57'			56	-	41 -	25	24	Moist	
						Shale				60						

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DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.

TECH. W. BAINE

DATE DRILLED. 8/4/74

RIG. 1

AIRPHOTO NO.

SURFACE DRAINAGE.

CHAINAGE.

VEGETATION.

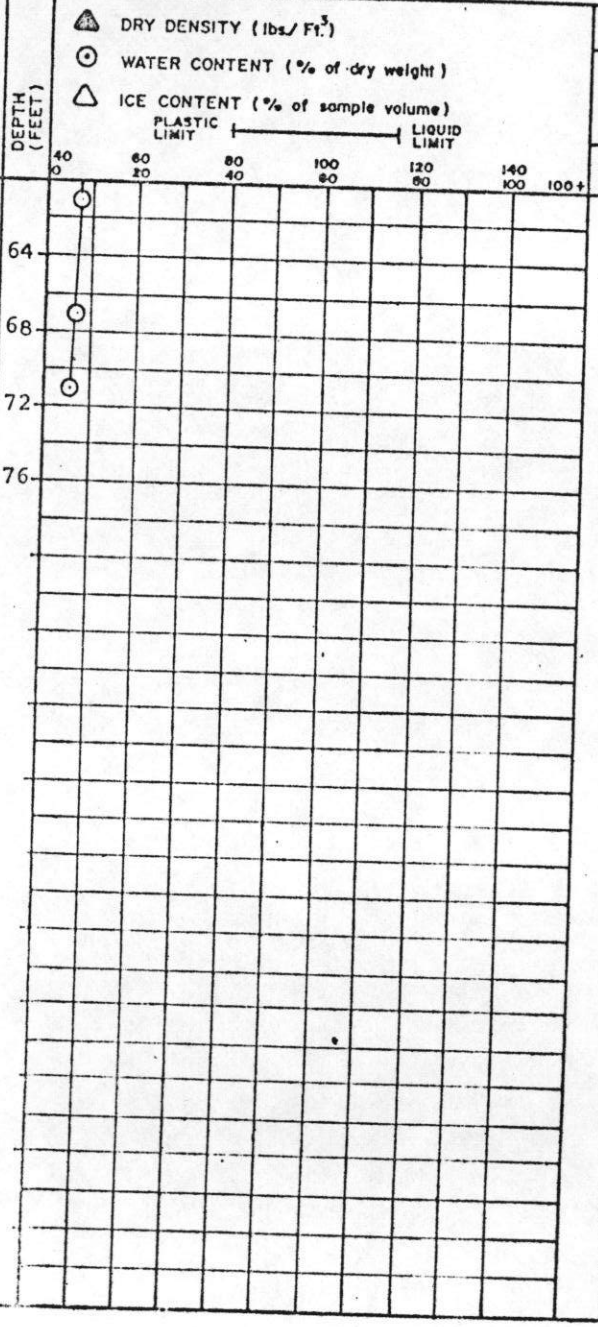
OFFSET.

ELEV.

TEST HOLE 8

MILE

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
						Shale - Silty Soft							Damp	
4														
8													Damp	
12													Damp	
16						75' Bottom of Hole - 75'								
20														
24														
28														
32														
36														
40														
44														
48														
52														
56														



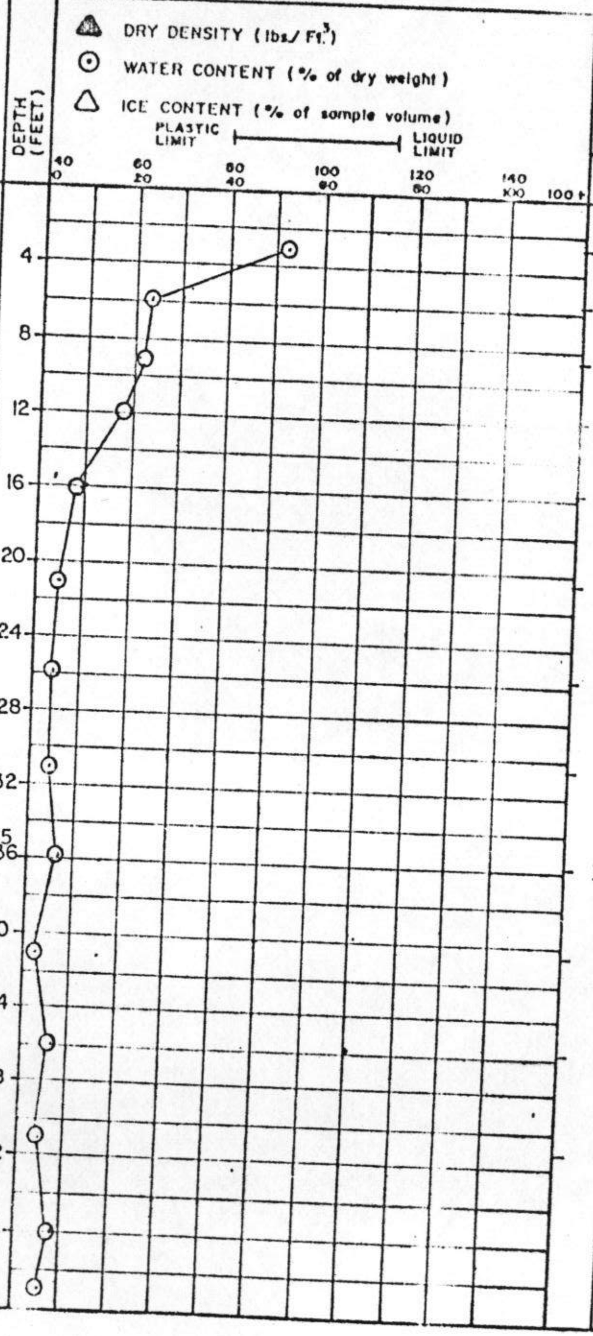
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
TECH. W. BAINE
DATE DRILLED. 8/4/74
RIG. 1
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 9
MILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
4					CL	Clay - Silty Sandy Low Plastic Organic 4'		High Ice
8						Sand - Fine		V_s
12					SP	Pebbles	F	
16								Moderate Ice
20						Gravelly		$V_c - V_r$
24					SP	Sand - Gravel Mix		
28					GP		F	Low Ice
32								V_x
36						- Wet @ 35' - Unable to Determine if Frozen below 35'		
40								
44								
48								
52					GP SP	Gravel - Sand Mix		
56						56' Shale - Silty Soft - Hard Bottom of Hole 60'		



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
86	-	14	0	Sat.	
7	-	93	0	Sat.	
6	-	94	0	Wet	
6	-	87	7	Freewater	
9	-	82	9	Wet	
7	-	70	23	Wet	
9	-	50	41	Wet	
7	-	61	32	Wet	
11	-	58	31	Wet	
7	-	57	36	Moist	
8	-	59	33	Wet	
9	-	57	34	Wet	
				Moist	
				Damp	

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

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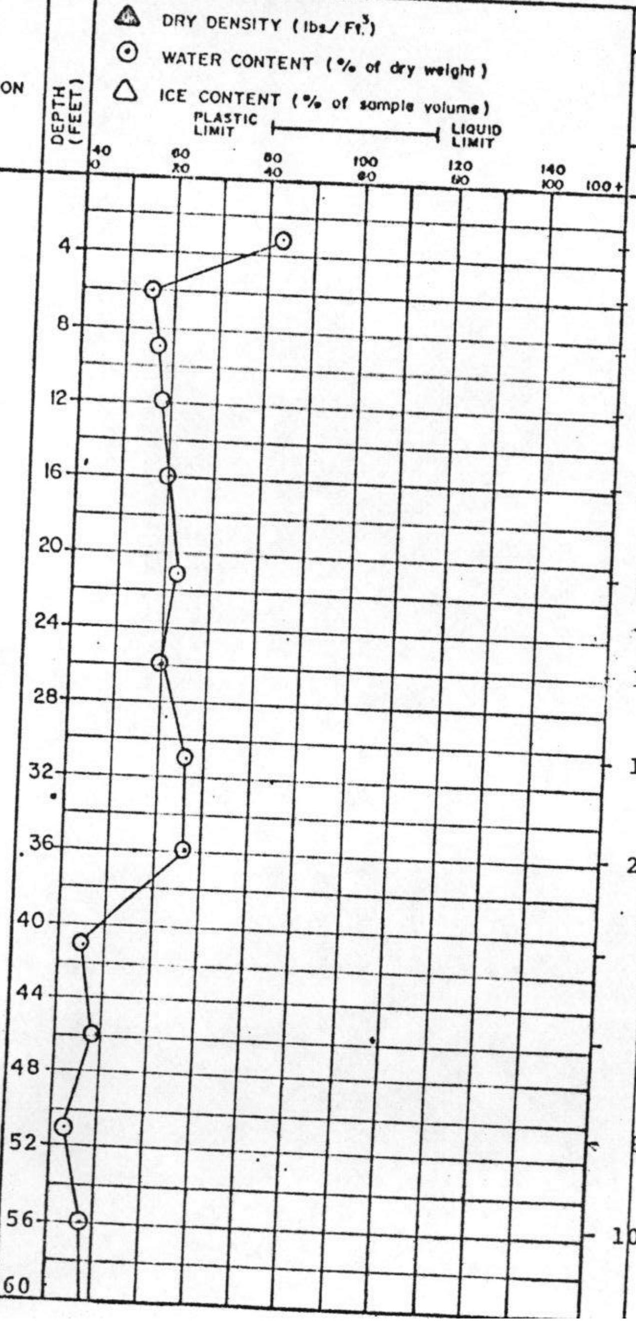
DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
TECH. W. BAINE
DATE DRILLED. 8/4/74
RIG. 1
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 10
MILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–4					CL	Clay - Silty Sandy Low Plastic — 4'		High Ice V_s
4–24					SM	Sand - Silty Pebbles	F	
24–40					SM	Sand - Silty	F	Moderate Ice V_c - V_r
40–52						Gravelly		
52–58					SM	Sand - Silty Fine Gravelly -Wet @ 55' -Unable to Determine if Frozen Below 55' — 58'		Moderate Ice V_c - V_r
58–						Shale		



GRAIN-SIZE ANALYSIS

CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT
79	-	21	0	Freewater
29	-	67	4	Sat.
9	-	81	10	Wet
25	-	75	0	Wet
10	-	87	3	Freewater
21	-	79	0	Freewater
14	-	86	0	Wet
15	-	85	0	Sat.
23	-	77	0	Sat.
8	-	59	33	Wet
9	-	71	20	Wet
8	-	65	27	Wet
10	-	52	38	Sat.

REMARKS

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DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.

DATE DRILLED. 8/4/74

AIRPHOTO NO.

CHAINAGE.

OFFSET.

TECH. W. BAINE

RIG. 1

SURFACE DRAINAGE.

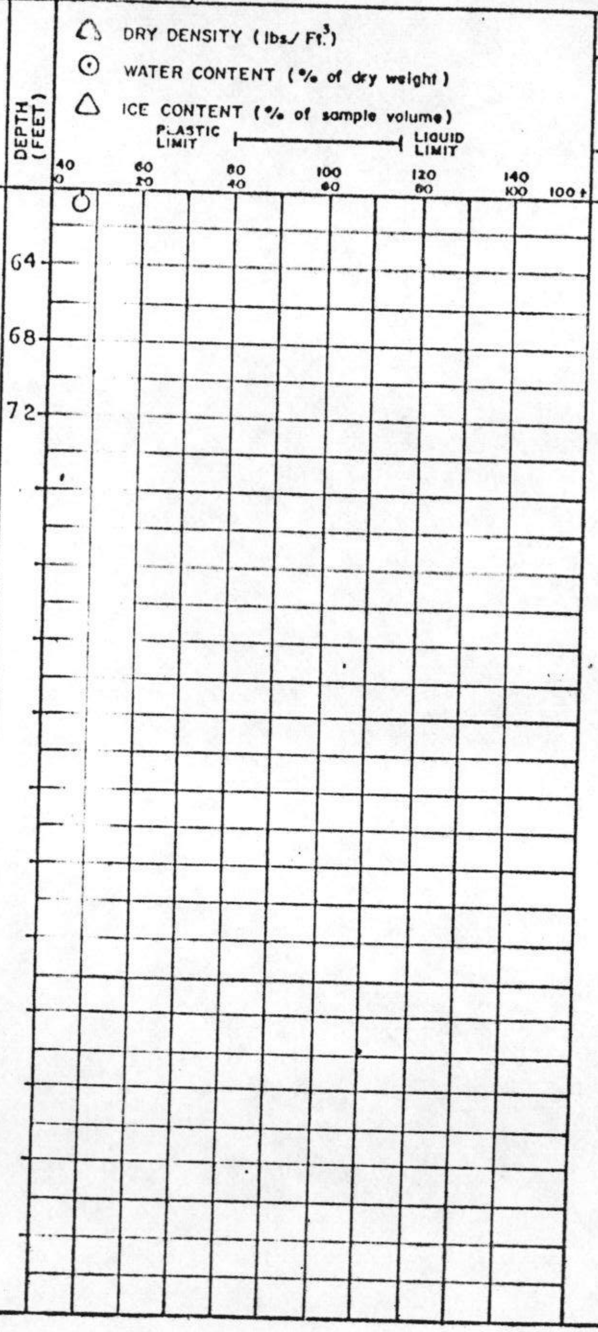
VEGETATION.

ELEV.

TEST HOLE 10

MILE

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
						Shale - Silty							Moist	
64						Soft								
						65'								
						Bottom of Hole - 65'								
68														
72														
16														
20														
24														
28														
32														
36														
40														
44														
48														
52														
56														



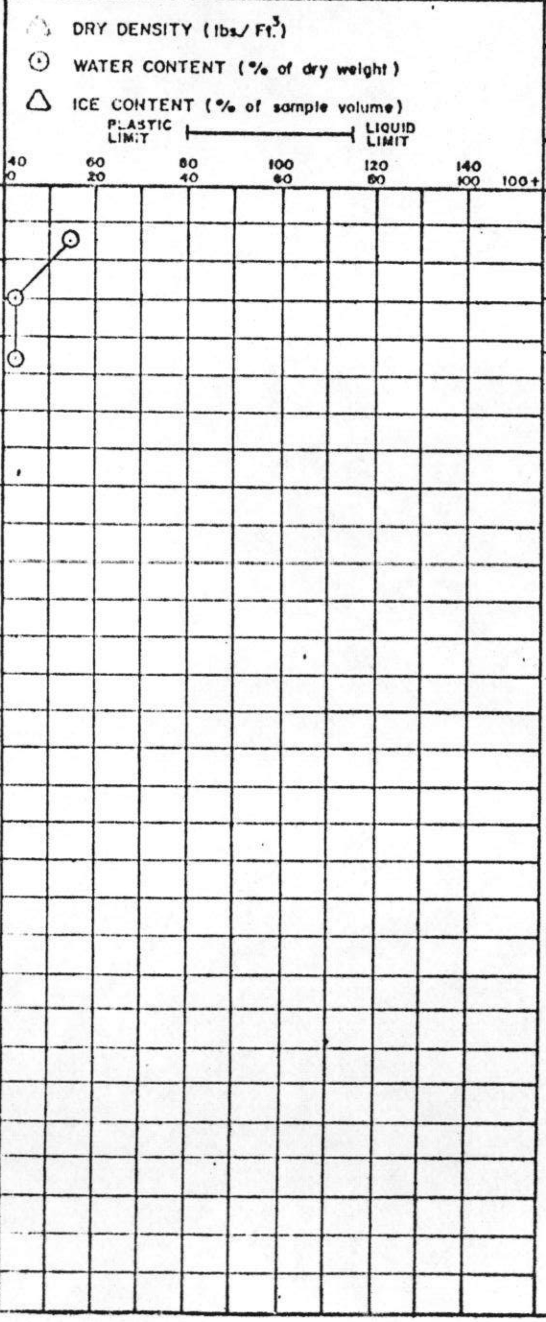
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
DATE DRILLED. 8/4/74
AIRPHOTO NO.
CHAINAGE.
OFFSET.
TEST HOLE 11
TECH. W. BAINE
RIG. 1
SURFACE DRAINAGE.
VEGETATION.
ELEV.
MILE

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 2'		Moderate							
4					SM	Sand - Gravelly Silty		Ice	4	-	15 -	73	12	Sat.	
					GP	Gravel - Sandy	F	V_c - V_r		-	4 -	37	59	Wet	
8					SW	Sand - Gravelly 10'	.		8	-	5 -	59	36	Wet	
12						Bottom of Hole 10'			12						
16						Very Hard			16						
20						Unable to Drill			20						
24						Past 10'			24						
28									28						
32									32						
36									36						
40									40						
44									44						
48									48						
52									52						
56									56						



DS-14-5-74 a

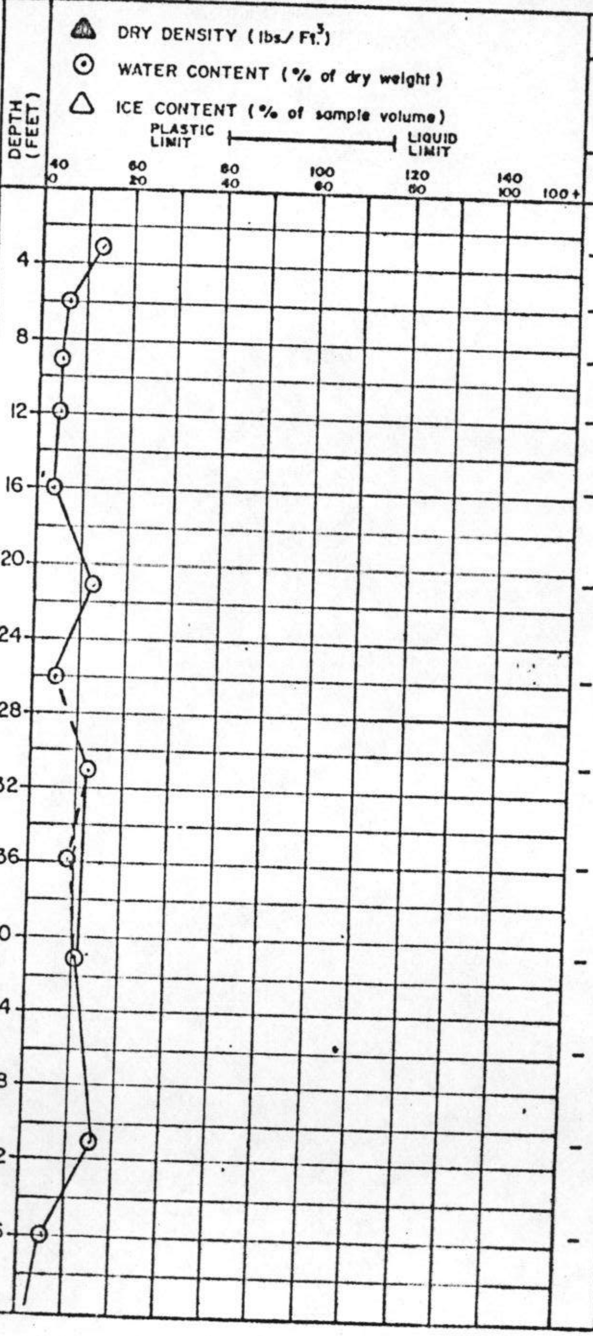
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.
TECH. W. BAINE
DATE DRILLED. 8/4/74
RIG. 1
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET. 60' North of 11
ELEV.
TEST HOLE 11A
FILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					ML	Silt - Clayey		
4					GW SW	Gravel - Sand Mixture 2'		Moderate Ice
8							F	$V_c - V_r$
12								
16								
20						18' Sand - Silty Gravelly		
24								
28								Moderate Ice
32					SM	Pebbles		$V_c - V_r$
36								
40								
44								
48						Sand - Silty		
52					SM			Moderate To
56						Gravelly		Low Ice



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
-	8	68	24	Wet	
-	7	67	26	Wet	
-	6	47	47	Wet	
-	4	42	54	Wet	
-	6	46	48	Wet	
-	17	61	22	Sat.	
-	17	72	11		Hole in Bag
-	9	56	35	Sat.	
-	14	78	8		Hole in Bag
-	14	78	8	Wet	
-	15	79	6		Open Bag
-	13	87	0	Wet	
-	10	59	31	Wet	

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DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE:

FIELD ENG.

DATE DRILLED. 8/4/74

AIRPHOTO NO.

CHAINAGE.

TECH. W. BAINE

RIG. 1

SURFACE DRAINAGE.

VEGETATION.

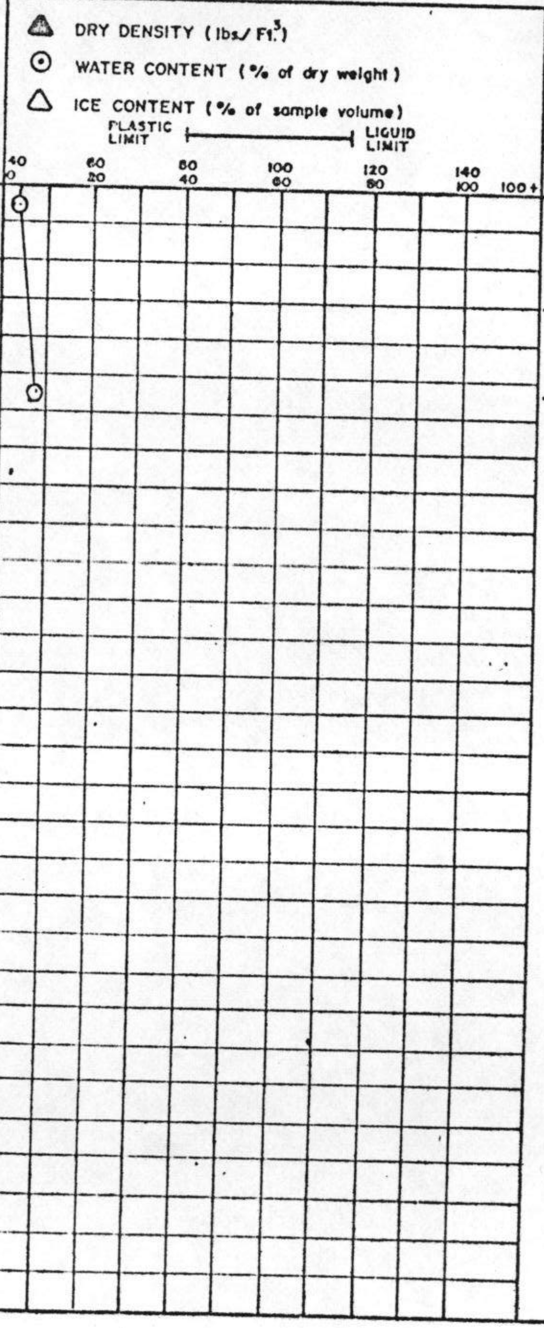
OFFSET. 60' North of 11

ELEV.

TEST HOLE 11A

MILE

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
						SAND - SILTY - GRAVELLY		Vc - Vr	60	-	11 -	55	34	Moist	
4									64						
8								Vx	68	-	19 -	65	16		Hole in Bag
12					SC	Clayey			72	-	10 -	56	34	Wet	
16						Bottom of Hole - 75'			76						
20									80						
24															
28															
32															
36															
40															
44															
48															
52															
56															



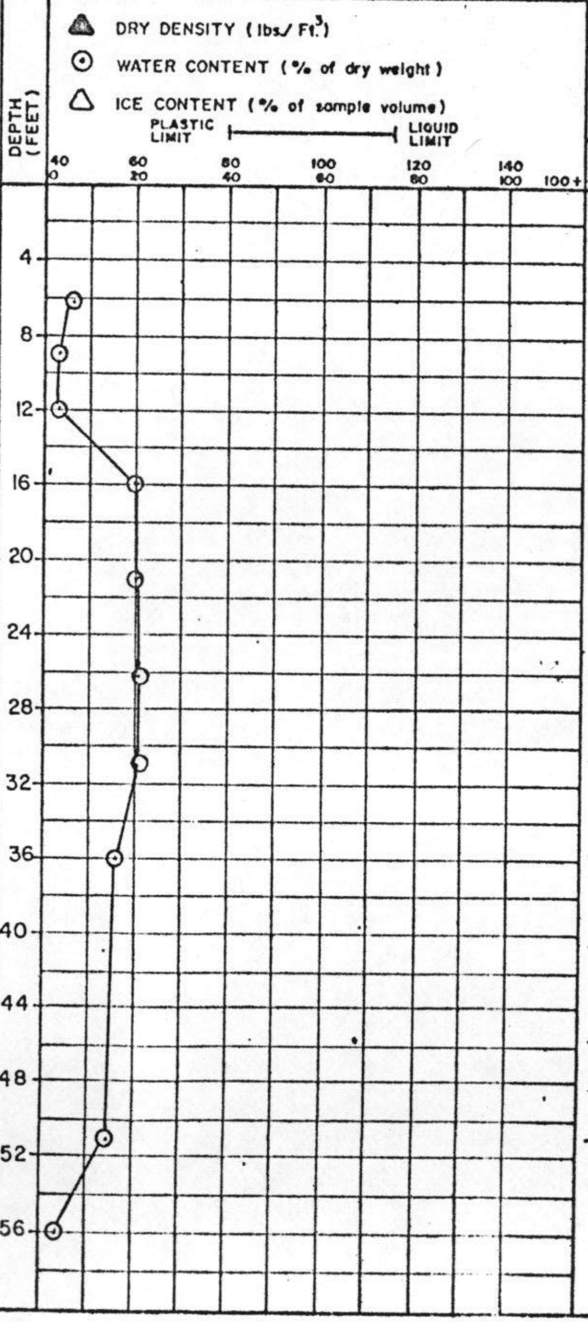
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
TECH. W. BAINE
DATE DRILLED.
RIG.
AIRPHOTO NO.
SURFACE DRAINAGE.
CHAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 12
MILE

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'								
4					SW	Sand - Gravelly Fine to Coarse			-	14 -	75	11		Hole in Bag
								Moderate	-	7 -	73	23	Wet	
8							F	Low Ice	-	7 -	54	39	Wet	
12						14'		$V_c - V_r$	-	7 -	69	24	Moist	
16					SP	Sand - Fine		V_x	-	7 -	93	0	Moist	
20									-	8 -	92	0	Moist	
24														
28					SP	Sand Fine - Medium			-	10 -	90	0	Wet	
32								Moderate Ice	-	7 -	93	0	Wet	
36							F	$V_c - V_r$	-	5 -	95	0	Wet	
40									-	7 -	93	0	Wet	
44														
48						Pebbles			-	6 -	86	8	Wet	
52					SP	Sand Fine - Medium	F	Moderate Ice $V_c - V_r$	-	6 -	94	0	Wet	
56					GW	55' Gravel - Sandy -Wet @ 55' -Unable to determine if Frozen Below 55' Bottom of Hole - 60'							Damp	



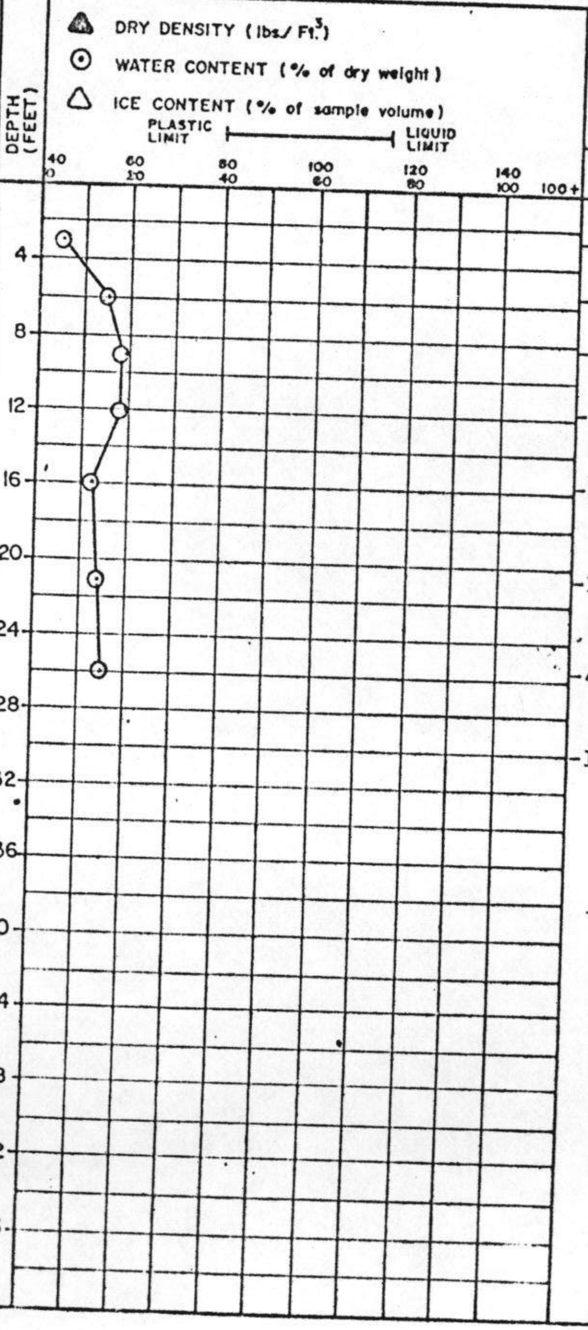
DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.
DATE DRILLED. 8/4/74
AIRPHOTO NO.
CHAINAGE.
TECH. W. BAINE
RIG. 1
SURFACE DRAINAGE.
VEGETATION.
OFFSET.
ELEV.
TEST HOLE 13
MILE

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
					PT	Peat		
						2'		Moderate
4						Gravel - Sandy		
								To
8						8'		High
						Sand - Silty		Ice
12							F	
					SM			V_c - V_r
16						Pebbles 15' - 17'		
								V_s
20								
24								
28								
32						Bottom of Hole - 30'		
36								
40								
44								
48								
52								
56								



GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	RELATIVE THAWED MOISTURE CONTENT	REMARKS
4	-	41	55	Wet	
9	-	29	62	Sat.	
8	-	91	1	Wet	
7	-	93	0	Wet	
12	-	82	6	Moist	
19	-	81	0	Wet	
46	-	54	0	Sat.	
12	-	88	0	Sat.	

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DRILL HOLE REPORT

SITE: HARE INDIAN RIVER

FIELD ENG.

TECH. W. BAINE

DATE DRILLED. 8/4/73

RIG. 1

AIRPHOTO NO.

SURFACE DRAINAGE.

CHAINAGE.

VEGETATION.

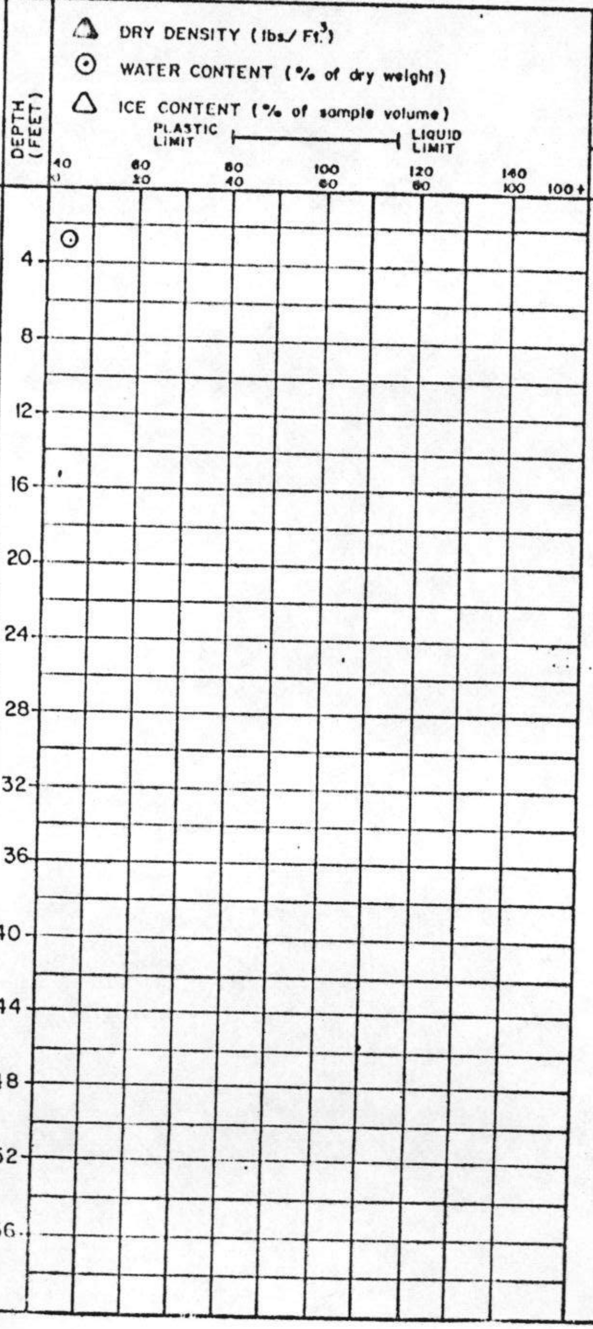
OFFSET.

ELEV.

TEST HOLE 14

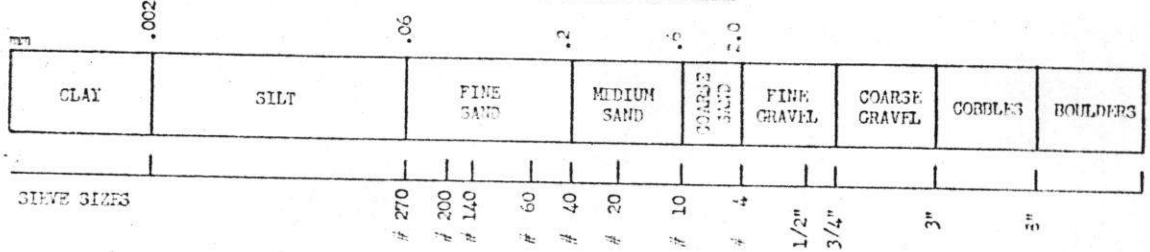
MILE

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 5								
4					SP	Sand - Fine - Medium		Nil Ice Nbn	-	8 -	92	0	Damp	
8						Bottom of Hole 8' 8'								
12						Very Dry Hole Caving In								
16														
20														
24														
28														
32														
36														
40														
44														
48														
52														
56														



TERMS USED IN THE REPORT

CLASSIFICATION BY PARTICLE SIZE



DESCRIPTIVE SOIL TERMS

Glacial Till	An unstratified Glacial deposit of clay, silt, sand, gravel, cobbles, and boulders in any combination.
Peat	A fibrous mass of organic matter in various stages of decomposition.
Well-Graded	Having wide range of grain sizes and substantial amounts of all intermediate sizes.
Poorly Graded	Predominantly of one grain size.
Stratified	Containing layers of different soil types.
Desiccated	Dried by moisture evaporation - desiccated clays are sometimes described as fissured or as having nugget structure.
Sensitive	Exhibiting loss of strength on remolding.
Slickensided	Refers to a clay that, following shear movements, exhibits planes that are slick and glossy in appearance.

DENSITY OF SANDS & GRAVELS

Descriptive Term	Relative Density	Standard Penetration Test
Very Loose	0 - 20%	0 - 4 blows per foot
Loose	20 - 40%	4 - 10 blows per foot
Medium Dense	40 - 70%	10 - 30 blows per foot
Dense	70 - 90%	30 - 50 blows per foot
Very Dense	90 - 100%	Over 50 blows per foot

CONSISTENCY OF CLAYS AND SILTS

Descriptive Term	Unconfined Compressive Strength - Kips/ft.^{2}	Standard Penetration Test Blows Per Foot	Remarks
Very Soft	Less than 0.5	Less than 2	Can Penetrate with Fist
Soft	0.5 - 1.0	2 - 4	Can Indent with Fist
Firm	1.0 - 2.0	4 - 8	Can Penetrate with Thumb
Stiff	2.0 - 4.0	8 - 15	Can Indent with Thumb
Very Stiff	4.0 - 8.0	15 - 30	Can Indent with Thumb-Nail
Hard	Over 8.0	Over 30	Difficult to Indent with Thumb-Nail

NOTE: Standard Penetration Test employs 140 lb. weight, 30 inch drop, 2" O. D. Sampler. All Shelby Tube Samples are 2" O. D.

CONSISTENCY LIMITS

Descriptive Term	Plasticity Index
Non Plastic	0 - 3
Low Plastic	4 - 9
Medium Plastic	9 - 30
Highly Plastic	Over 30

1. Hare Indian River

This is the river with the largest drainage basin in this study area. The drainage area measured is 6003 square miles. Lakes and ponds are scattered throughout the basin. Large lakes on the main channel do not materially effect peak discharge at the highway crossing. Discharge and water elevation are influenced by a back water effect from the Mackenzie River. The peak discharge estimated by former high water marks is 54,000 c.f.s. in which the backwater from the Mackenzie is considered. The design discharge recommended is 64,000 c.f.s. which is calculated by regression analysis method for fifty year return period. The average velocity estimated for that discharge is 1.5 feet per second. This reduced velocity is due to the backwater effect of the Mackenzie.

III BRIDGE CROSSINGS

III.1 HARE INDIAN RIVER

1.1 Bridge Setting

The grade line, as illustrated on Fig. 10, takes a profound sag as it crosses the river valley, the lowest elevation of the bridge being 100 feet below the edge of the plateau. A bridge length of 1,080 feet is derived by employing a 2:1 slope on the north bank and daylighting the south bank at grade level.

Notwithstanding the sag in the highway grade, which lowers the bridge as much as practical considerations would allow, there is more than adequate vertical clearance above high water level. The lowest point of the bridge superstructure will be more than 15 feet above the 50 year design high water level.

The proposed grade line will require excavations of 48 feet and 37 feet in the North and South banks respectively. Cuts of this magnitude in permafrost would be a formidable task. Furthermore, the grade line was placed on a sharp vertical curve in order to get the bridge lower in the river valley. Due to the above problems at this site an alternative crossing is proposed at a location 3.5 miles upstream. A preliminary field reconnaissance of the second site was carried out and it appears feasible. Further studies are warranted.

1.2 Scour Computations

The bed material of the Hare Indian River is sand with an average diameter of 1 m.m. observed by the FENCO field team. The computed water depth and velocity at design discharge are 38 feet and 2.03 fps. respectively (Table 1). For this combination of water depth and material size, the minimum velocity to erode the riverbed is 6 fps suggested by Neill.(8) Besides the velocity at design discharge being low, the channel top width of 920 feet is also much greater than the minimum width of 675 feet as suggested by Lacey (8), for which scour starts to take place for a design discharge of 64,000 cfs. Therefore, no general scour is expected.

The local scour depths around piers are calculated to be 5 feet, 7 feet and 10 feet corresponding to pier widths of 4 feet, 6 feet and 8 feet respectively (Appendix II). The local velocity around the pier is estimated to be 3 fps. Therefore, 3 inch diameter stones will be sufficient to insure protection against local scour. 12 inch mean size riprap is recommended for the protection apron (Table 2), because nothing smaller than 12 inches is considered for riprap.

1.3 Ice Considerations

Ice scour marks were found very distinctly on the gravel part of the right bank some 1500 feet upstream of centreline. From these marks it was possible to estimate the slope and elevation of ice levels. Few ice marks have been found on the trees due to the scarcity of trees at the level of the high water marks. The edge of the line of trees is found some 35 feet above the summer water level.

Because of a low average flow velocity at design discharge due to backwater effect, it is thought that the ice would not be a very serious problem at the present crossing.

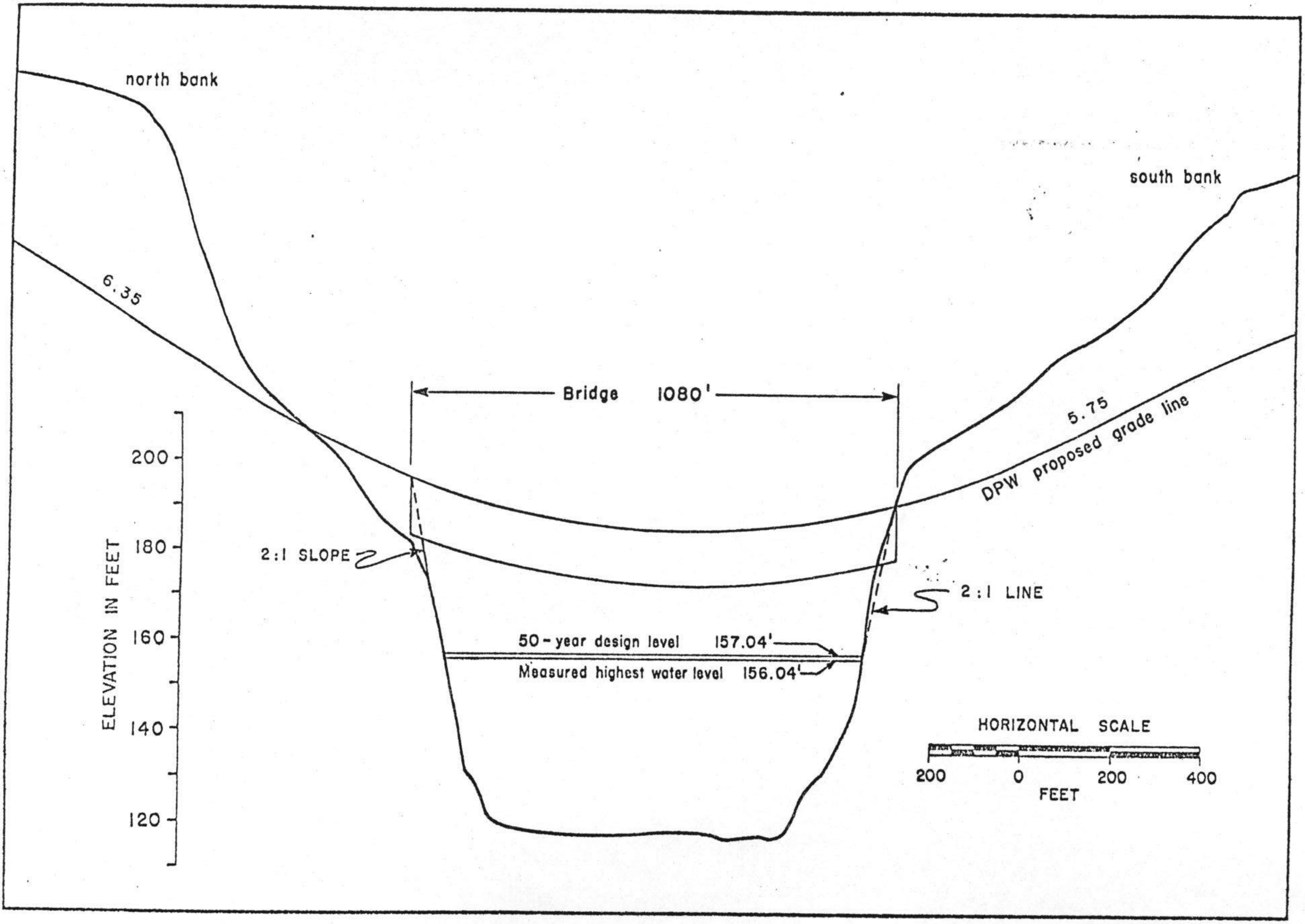


FIGURE 10 HARE INDIAN RIVER BRIDGE
Preliminary Profile

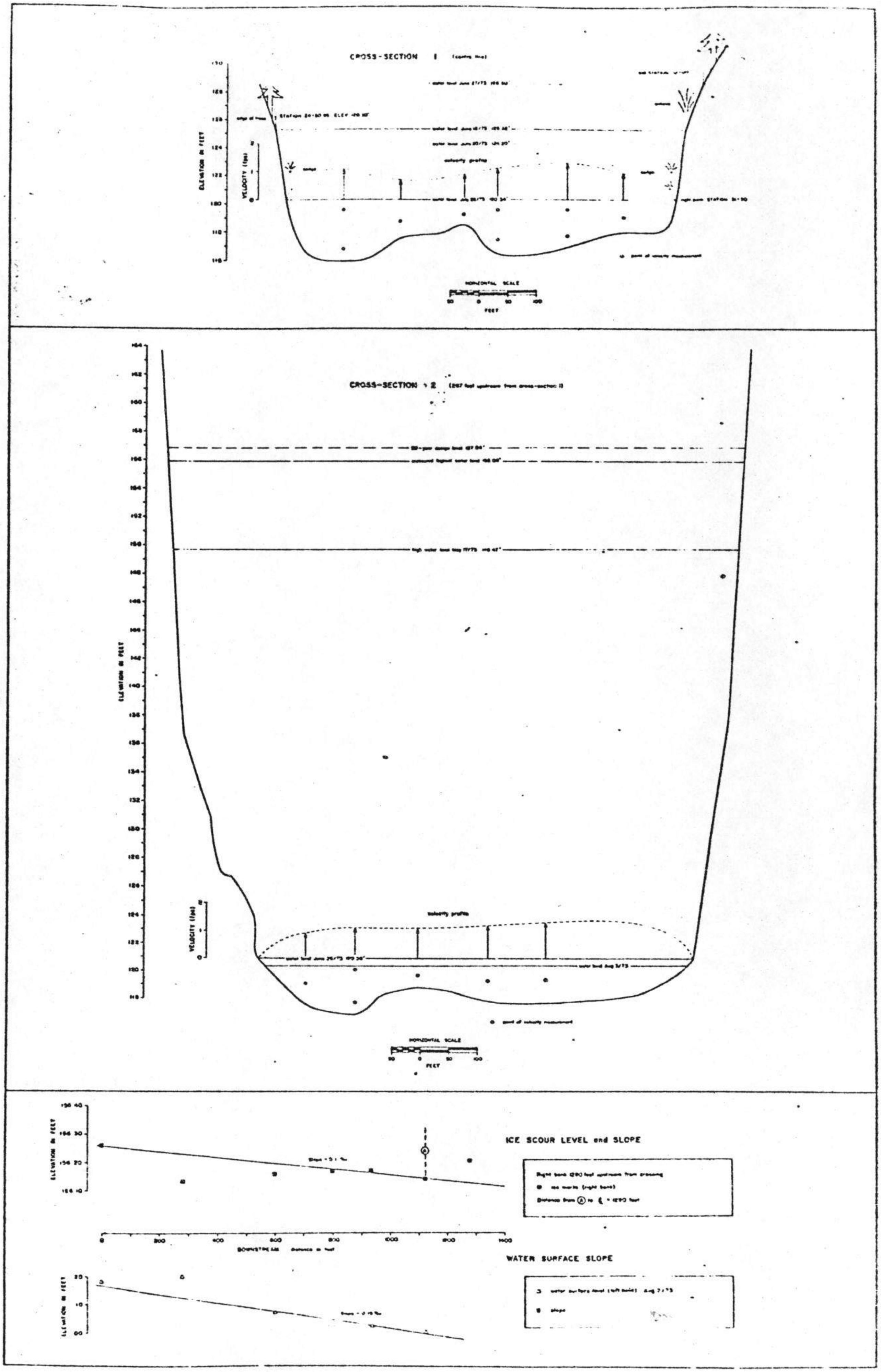


FIGURE 38 Hess Indian River Hydraulic Data

APPENDIX I

GENERAL SCOUR

I.1 HARE INDIAN RIVER

Design discharge: 64,000 cfs

Elevation corresponding to design discharge: 157.04 feet

Natural channel width at design discharge: 920 feet

Elevation at low discharge: 120.36 feet

Riverbed material: Sand, D_{50} = 1 m.m.

Average water depth at design discharge: 38 feet

Cross-section area at bridge site corresponding to design discharge: 31,400 sq. ft.

Velocity at design discharge: 2.03 fps

Competent velocity suggested by Neill(7) for bed movement under conditions of bed material size = 1 m.m. and water depth = 38 feet,

$$V_c = 6 \text{ fps}$$

which is much greater than the mean velocity of 2.03 fps

The required water opening, W, is estimated by Lacey's equation,(6)

$$W = C\,Q^{0.5}$$

where Q = discharge in cfs, and

C = a constant ranged from 1.8 to 2.67 depending on the characteristics of bed material.

In the case of Hare Indian River, the required water opening

$$W = 2.67 \times (64,000)^{0.5} = 675.46 \text{ feet}$$

which is less than the natural channel width of 920 feet. Thus, no general scour is expected.

Table A

Local Scour Depth Around Piers at Hare Indian River Crossing

Equation Used	Scour Depth Calculated in Feet Width of Pier in Feet 4	6	8
Blench	1.0	5.1	8.4
Shen	3.3	4.3	5.1
Larras	5.6	7.6	9.5
Depth Recommended	5.0	7.0	9.0

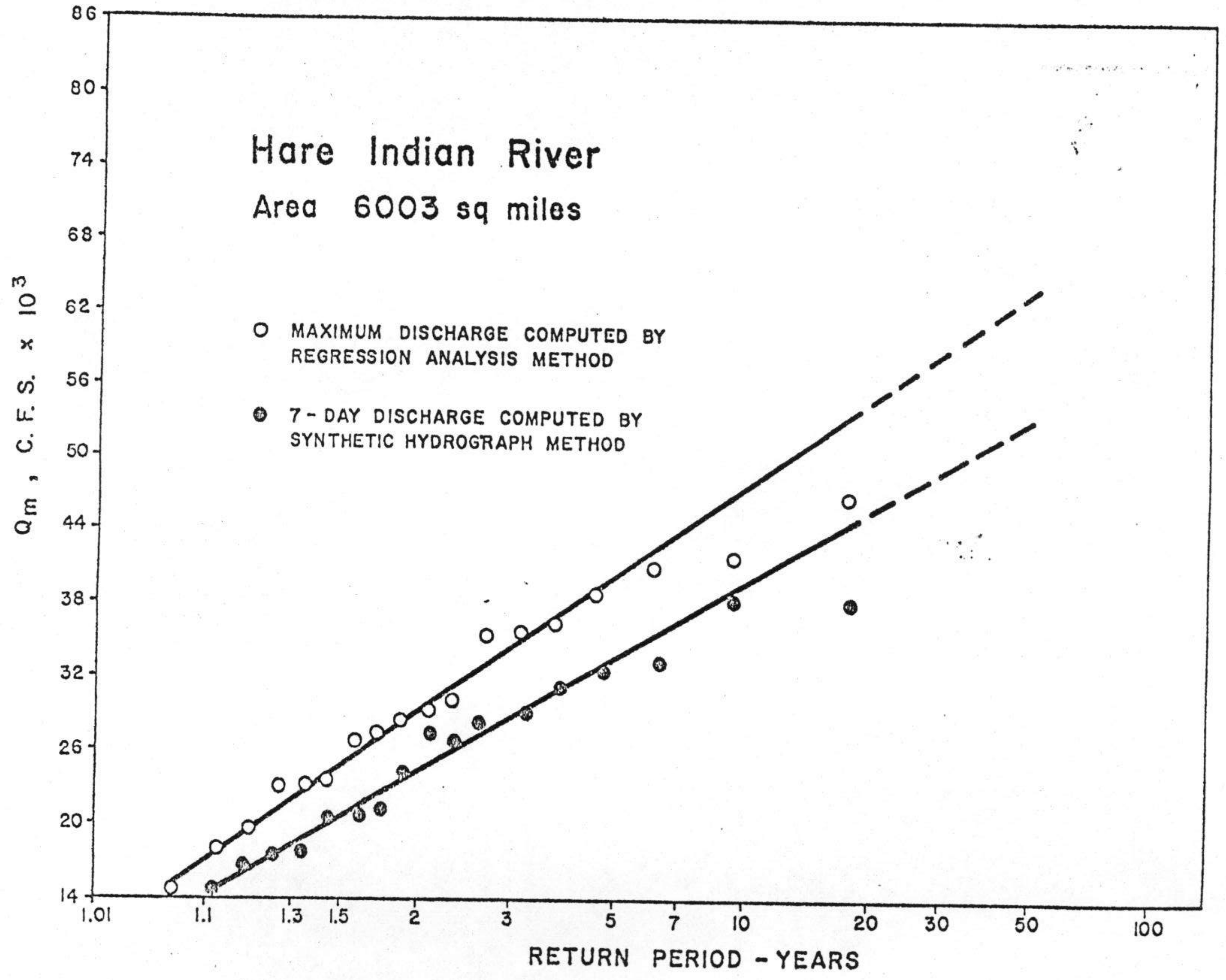


FIGURE 12 Peak and 7—day discharges of the Hare Indian River

HARE INDIAN RIVER BASIN

TOTAL DRAINAGE AREA TO HWY 6003 SQ MI

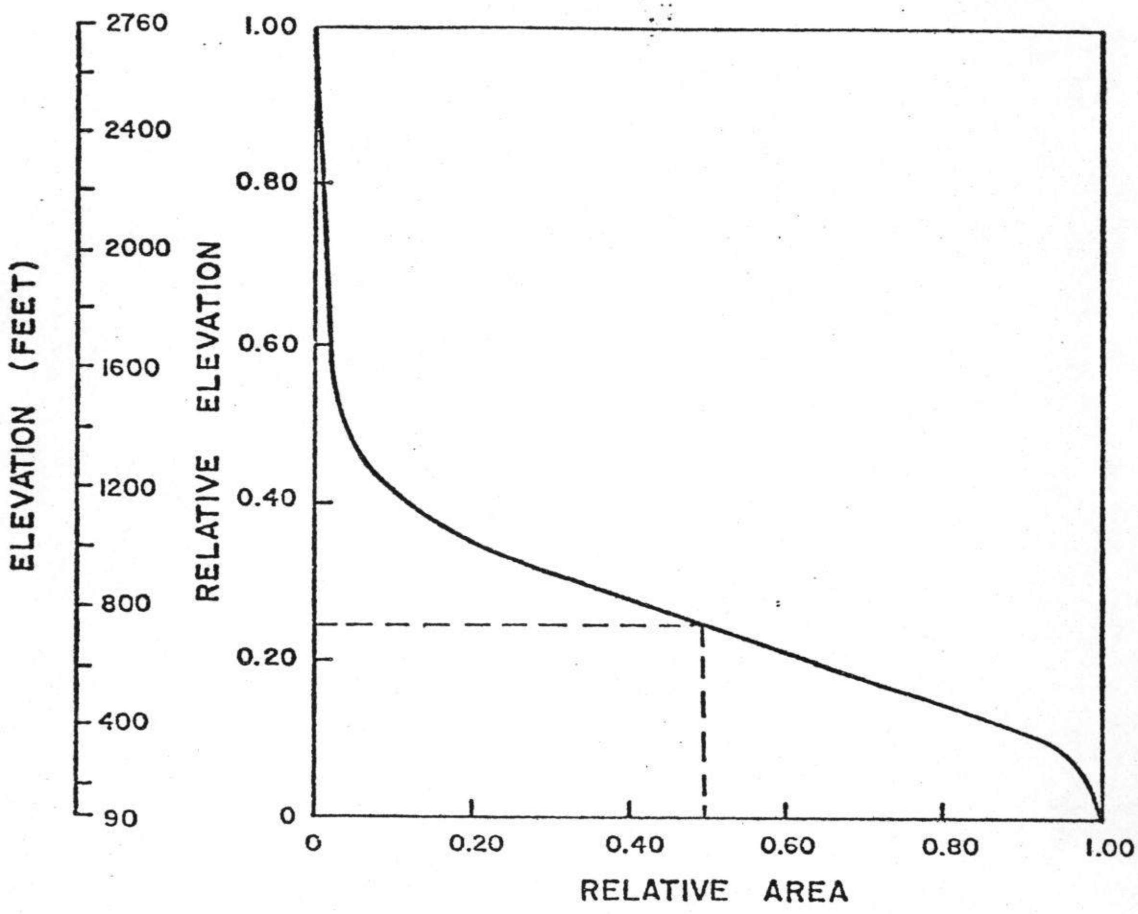


FIGURE 28

FENCO