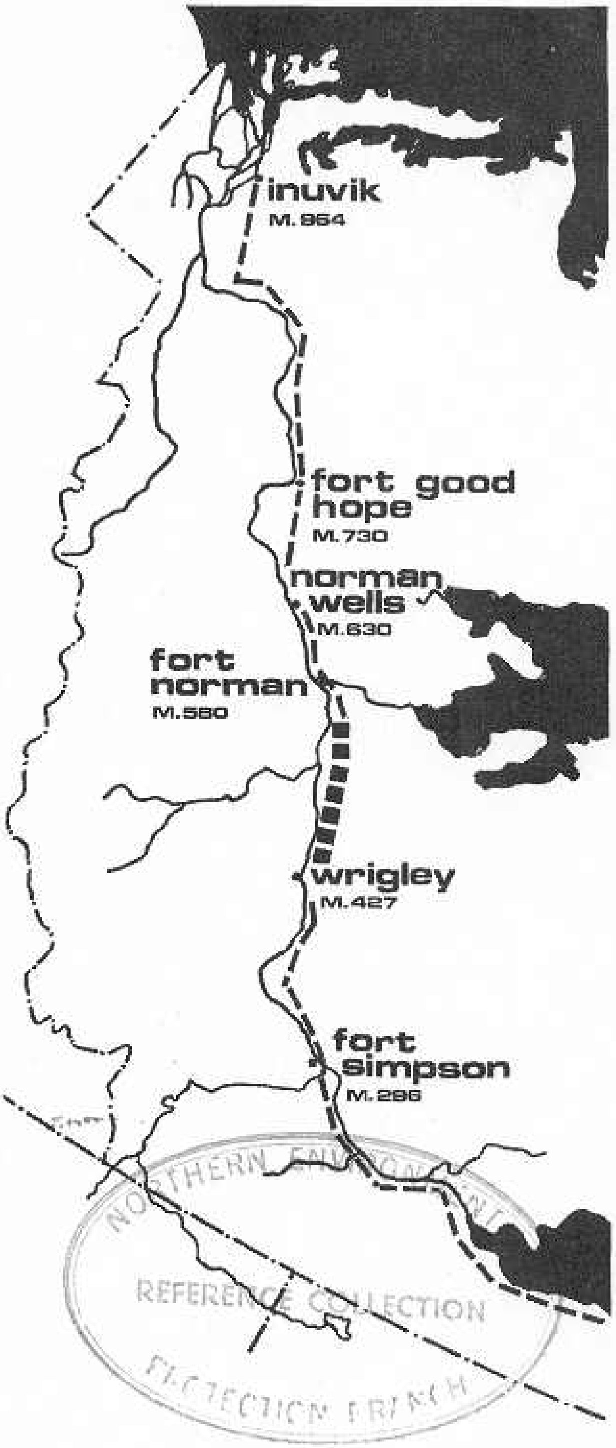


REPORT ON SUBSURFACE SOIL CONDITIONS FOR PROPOSED -

BIG SMITH CREEK BRIDGE MILE 544.0

MACKENZIE HIGHWAY

Underwood McLellan & Associates Limited

ISSUE #39

UMA Underwood McLellan & Associates Limited

11724 KINGSWAY AVENUE, EDMONTON, ALBERTA T5G 0X5 TELEPHONE 454-8505 TELEX 037-2537

OUR FILE NO
April 27, 1973

Department of Public Works
P. O. Box 488
Edmonton, Alberta.

ATTENTION: Mr. F. E. Kimball

Dear Sir:

Re: Subsurface Soil Investigation
Proposed Big Smith Creek Bridge
Mile 545, Mackenzie Highway.

Attached please find our report on the subsoil and foundation conditions for the proposed Big Smith Creek bridge at mile 545 on the Mackenzie Highway, in the Northwest Territories.

If you have any questions concerning the contents of this report, we would be pleased to discuss them with you at your convenience.

Yours very truly,

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

D G Pennell

Per:

D. G. Pennell, Ph.D., P. Eng.

DGP/rr

Encl.

REPORT ON SUBSURFACE
SOIL CONDITIONS FOR PROPOSED
BIG SMITH CREEK BRIDGE MILE 545
MACKENZIE HIGHWAY
NORTHWEST TERRITORIES

Prepared by

UNDERWOOD McLELLAN & ASSOCIATES LIMITED
Consulting Professional Engineers

INDEX

APPENDIX

A. INTRODUCTION

The subsoil investigation undertaken at Big Smith Creek forms part of the overall geotechnical investigation which was conducted from mile 450 to 550 of the Mackenzie Highway for the Department of Public Works, Government of Canada.

It was the intention of the present investigation to determine the vertical subsoil material sequence, permafrost conditions and groundwater conditions existing which would be expected to influence the stability of the valley slope and the design and construction of the proposed bridge foundations.

The included conclusions and recommendations have been based upon exploration and sample acquisition operations conducted at 9 positions adjacent to the proposed bridge centreline in the creek channel and slopes of the bridge approaches.

In the formulation of conclusions and recommendations, the consistency and composition of the subsoil materials between and in the proximity to the individual test boring positions has been assumed, but not verified.

B. FIELD AND LABORATORY INVESTIGATION

A total of nine (9) test holes have been drilled in the Big Smith Creek valley. In addition to the nine (9) structure and centreline test hole logs, borrow hole test logs closest to the bridge site have been included in the Appendix. Test holes along the centreline were drilled to depths varying from 12 to 40 feet below existing site grades. Borrow test holes were generally advanced to the 15 foot level.

Test borings were drilled February 15, 16 and 19, 1973 by Kenting Big Indian Drilling of Calgary utilizing a Mayhew 1000 and Heli drill. Air recovery methods were employed in all test holes.

The locations of the individual test borings were selected and located by Underwood McLellan & Associates Limited. The approximate test boring locations are graphically illustrated on the accompanying Mosaic and Test Hole Location Plan.

All variations of soil, permafrost and groundwater conditions encountered during the test boring operations were noted and representative samples of the existing subsoils were taken. The majority of samples were disturbed, having been obtained by the air recovery method. Standard Penetration blow counts were taken with a two-inch solid penetrometer.

In the laboratory, the samples of materials derived from the drilling operations were subjected to standard laboratory classification procedures including particle size distribution and Atterberg index property determinations. Moisture contents were obtained for all samples returned to the laboratory.

Permafrost samples were classified according to N.R.C. Technical Memorandum No. 79 "Guide to the Field Description of Permafrost". The excess ice content of permafrost samples was obtained by visual inspection and by measured thicknesses of ice lenses. Excess ice content was determined by the division of the ice thickness by the total sample thickness.

All soil samples were classified according to the Unified Soil Classification System.

The results of all laboratory and field tests are summarized in the Appendix on the Test Hole Logs.

Test holes have been designated by mileage, type and number. Example includes 543B632B, 544C448A and 545S441A. The letter symbols and numbers indicate:

543, 544, 545 - mileage.

B, C, S - between mileage and test hole number indicate borrow, centreline and structure test holes, respectively.

632, 448, 441 - test hole numbers.

A, B - after test hole numbers indicate drilling performed by Mayhew 1000 or Heli drill, respectively.

C. SITE AND SUBSOIL CONDITIONS

The Big Smith Creek site is located at mile 545 (chainage 77+00) of the Mackenzie Highway in the North West Territories and flows into the Mackenzie River from the east having a drainage basin which extends to the Franklin Mountains.

The stream elevation at the proposed crossing is 340 (D.P.W. plan-profile datum) with the estimated high water mark at elevation 345. The main stream channel is approximately 8 feet deep with shale bedrock outcropping along the creek banks. The tree growth throughout the relatively shallow valley consists primarily of spruce, aspen and poplar from 15 to 60 feet in height.

Six test holes were drilled in the vicinity of the proposed bridge crossing including 442A, 443A and 444A which were advanced along the C.N.T. right-of-way down to the banks of the main channel and 445A, 446A and 447A which were advanced on the temporary winter road in the main creek channel. It was not possible to advance test holes on the centreline above the river channel as clearing was not allowed and drilling in the river channel on the centreline or C.N.T. line could not be undertaken as a result of free water and thin ice. Five of the six test holes drilled near the proposed crossing had surface elevations above the existing adjacent centreline grades.

There were significant variations in the depth to bedrock as indicated by the test holes which were all drilled west of the proposed centreline. This bedrock variation is indicative of the irregular river downcutting of erodible shales and siltstones. It is estimated that the bedrock elevation in the vicinity of the centreline and piers would be 336 and is covered with 4 to 8 feet of unfrozen gravel overburden.

The most northerly drilled test hole during this investigation is 441A but it was drilled 260 feet west of the proposed centreline. This test hole disclosed 30 feet of dense glacial till overlying the shale bedrock. Two solid penetrometer blow counts were 21 and 109 in the till and the average moisture content was 10% which was about 3% below the plastic limit. The low plastic nature of the till was confirmed by liquid limit of 31% and plasticity index of 16. The water table was encountered at elevation 348 in test hole 441A which was coincident with the north terrace elevation immediately above the creek channel.

Two test holes drilled on the south slopes encountered 3 to 8 feet of silty sand and silty clay over relatively dry gravel.

The 9 test borings advanced in the Big Smith Creek valley indicated non-frozen soil conditions, although it is difficult to establish permafrost conditions in the bedrock.

D. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the present investigation, we wish to offer the following generalized conclusions and recommendations relative to the design and construction of the proposed Big Smith Creek bridge foundations and approaches.

1. Pier and Abutment Foundation Design

A pier and spread footing type foundation is recommended as a result of the surface outcropping of shale bedrock along the creek shores and drill encounter of bedrock near the surface in test holes advanced adjacent to the centreline. It is recommended that piers be placed at approximately elevation 330 in the shale bedrock. Because drill holes were not advanced along the centreline, it is necessary to confirm competent bedrock during excavation for the bridge piers. An allowable assumptive bearing capacity of 10 tons per square foot may be employed in undisturbed intact bedrock.

Approach bridge embankments of 20 foot depth are proposed at this site. The abutments may be placed on spread footings directly in the approach fill if the embankment is composed of properly compacted granular fill as recommended in Section D3.

As a result of the relatively shallow approaches the abutments may be designed as walls retaining the complete fill for a depth of approximately 20 feet. For this alternative the abutments should bear in bedrock at approximately elevation 336.

If inferior materials or compaction techniques are utilized in the embankment, the abutment may be carried on piles into the bedrock or the second alternative of the abutment bearing directly in the bedrock may be utilized.

Although steel - H or pipe piles may be utilized for the bridge piers, preference is given to the shallow spread footing type foundation as a result of the near surface occurrence of the bedrock.

If piles are employed for either the abutments or piers, they should be driven to "refusal". "Refusal" will depend upon the energy rating of the hammer but is commonly 15,000 ft. lb. As an initial guide, piles should be driven to blow counts of 180 blows/ft. or 15 blows/inch. The pile capacity is largely a function of the amount of energy expended in installing the pile and not just of the recorded resistances. The pile which is driven to a sustained resistance will perform better than one which is terminated the instant a given resistance is attained. Of course, the pile must not be driven until damage occurs and whenever resistance increases greatly, the driving should be terminated.

Steel piles driven to "refusal" can be expected to attain allowable load capacities in the range of 80 tons depending upon the cross-sectional area.

It is not anticipated that any difficulty would be experienced in penetrating the shallow overburden depth above the bedrock.

The lateral resistance of piles can be established by recently developed methods based on the beam on elastic foundation method but the simple and more conventional approach is based on calculation of the Rankine passive earth pressure against the pile. Using Rankine theory the ultimate passive resistance force/ft.^{2} of a pile can be obtained by $P = \frac{1}{2} \gamma_b K_p H^2$. The submerged unit weight of the granular material above the bedrock may be taken as 60 pcf and the passive pressure coefficient K_p as 3.0. In order to establish the allowable lateral load a factor of safety of 2.5 should be applied to the above load. Generally, the lateral load tends to exceed the passive resistance, consequently, the above simplified approach is on the conservative side. Additional lateral resistance can be considered if the bedrock is penetrated.

2. Lateral Abutment Loads

The magnitude of the pressure applied to the abutment will depend upon the characteristics of the backfill chosen for the approach fill and upon the movements that the wall undergoes during and subsequent to fill compaction. It is recommended that granular backfill from the river terraces or borrow pits be utilized for the abutment approach embankments which will be 15 to 20 feet high.

The most common procedures for analysis of the earth pressures against gravity retaining walls include the Rankine and Coulomb methods.

Generally, it is assumed that the wall rotates sufficiently to allow mobilization of the backfill shear strength which reduces the pressure to the active case, the lowest pressure that can be realized. This assumption applies reasonably accurately when the backfill consists of uncompacted granular material but pressures greater than the active occur whenever compaction of the backfill is undertaken. While the total yield at different elevations on the abutment may be adequate for mobilization of the full backfill strength, a gradual build-up of the backfill also results in a gradual yielding of the wall. Therefore, by the time the backfill is complete only a fraction of the total yield of the wall has become effective in decreasing the earth pressure. Recent studies have indicated that the actual earth pressure magnitude will exceed the active case and may approach the earth pressure at-rest. Pressures greater than the at-rest case may occur if heavy compaction equipment is utilized against the concrete abutment.

If the Coulomb approach is utilized, the angle of wall friction between concrete and coarse sand and gravel would be 20 degrees. The angle of internal friction for compacted granular material would be 38 degrees and the dry density may be taken as 115 pcf. For a simple vertical retaining wall abutment with horizontal backfill the Coulomb active coefficient would be .24 and the at-rest coefficient based on $K_o = 1 - \sin \phi$ would be .38. These design parameters are based upon "average" gravel conditions but wherever deep abutments are proposed the actual shear strength parameters of the backfill should be established to accurately evaluate the lateral pressures. In many cases the pressure distribution behind a gravity retaining wall has been shown to be non-triangular, but as a first approximation and for simplicity, the triangular pressure diagram is recommended. It is also recommended that whenever backfill is compacted in lifts by vibratory compaction the at-rest coefficient should be utilized for calculation of the ultimate earth pressure.

Wherever potential fill settlement is anticipated a driven pile foundation has been previously recommended for the abutments which will provide significant lateral resistance but it is further recommended that some batter piles be utilized to ensure adequate lateral support against earth pressures and fill movement. Whenever batter piles are utilized for horizontal resistance, the lateral restraint of vertical piles is neglected.

Positive drainage including horizontal perforated tile and weep holes should be provided to prevent development of hydrostatic pressures against the wall. In addition, drainage will prevent development of frost heaving forces against the abutments.

3. <u>Bridge Approach Grades and Embankments</u>

The centreline grades at the proposed location of the Big Smith Creek will involve fill embankments from 500 feet north of the bridge to the south uplands. These fills will vary from 20 feet at the main creek channel to 10 feet on either side and will overlie unconsolidated river deposited silts, sands and gravels. Some settlement of the surface materials will occur under the superimposed embankment loads but instability of the foundation material will not result. All the surficial deposits investigated throughout the valley were unfrozen except for seasonal frost penetration.

It is recommended that granular fill be compacted at all deep approach fills to 95% of Standard Proctor density utilizing vibratory compaction.

Although construction may be performed during the winter, dry unfrozen granular materials will allow satisfactory compaction. It is emphasized that compaction of these deep approach fills is mandatory to ensure slope stability and prevent settlements at the bridge approaches. All granular fill slopes should be constructed at 2:1. Common excavation will not be available from the bridge site valley slopes as the grade line has been proposed entirely to produce fill sections.

Some difficulty will be experienced in locating suitable stable embankment fill. Consideration should be given to the development of granular borrow pits along the south terrace in sand and gravel deposits as disclosed in test hole 450A. Suitable borrow pits were located on the south uplands but haul distances are 2 to 3 miles. A coarse sand deposit exists at station 21+75, one mile west of the centreline. In addition, shale outcroppings are present at station 17+00, 500 feet east of the centreline.

This subsurface investigation was terminated north of the bridge and the most northerly test hole drilled was 441A, 260 feet west of the centreline. This hole indicated 30 feet of very hard till over bedrock. Consequently, although the soil conditions were not investigated at the proposed cut, station 88+00, it is anticipated that the strata are similar to test hole 441A and potential instability will not result.

APPENDIX

EXPLANATION OF FIELD & LABORATORY TEST DATA

The field and laboratory test results as shown for a particular test boring by the Test Hole Log Data Sheet are briefly described below:-

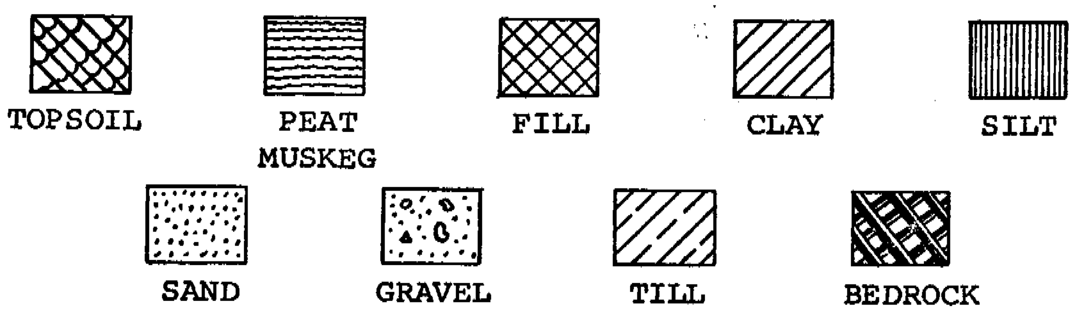
NATURAL MOISTURE CONDITIONS & ATTERBERG LIMITS

The relation between the natural moisture content and depth is significant in determining the subsurface moisture conditions. The Atterberg Limits should be compared to the Natural Moisture Content of the subsurface soil as well as plotted on the Plasticity Chart.

SOIL PROFILE & DESCRIPTION

Each soil strata is classified and described noting any special conditions. The unified classification system is used, and the soil profile refers to the existing ground elevation. When available the ground elevation is shown.

The soil symbols used are briefly shown below but are indicated in more detail in the Soil Classification Chart.



TESTS ON SOIL SAMPLES

Laboratory and field tests are identified by the following symbols:

QU - unconfined compressive strength usually expressed in tons per square foot. This value is used in determining the allowable bearing capacity of the soil.

γ_d - dry unit weight expressed in pounds per cubic foot. This value indicates the density or consistency of the in-situ soil.

C - Consolidation test. These test results are separately enclosed and provide information on the consolidation or settlement properties of the soil strata.

M.A. - grain size analysis. These test results are separately enclosed and indicate the gradation properties of the material tested.

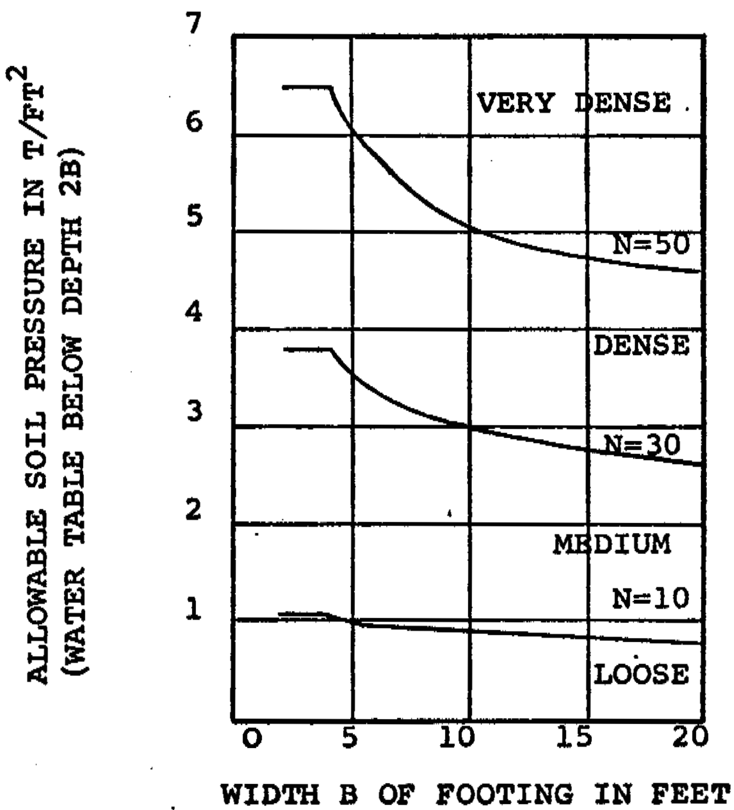
SO_4 - water soluable sulphate content is conducted primarily to determine whether sulphate resistant cement is required for the foundation structure.

N - standard penetration field test. This test is conducted in the field to determine the in-situ consistency of a soil strata. The "N" value recorded is the number of blows from a 140 lb. hammer dropped 30 inches (free fall) which are required to drive a 2" O.D. Raymond type sampler 12 inches into the soil.

The resistance and unconfined compressive strength of a cohesive soil can be related to its consistency as follows:-

N - BLOWS/Ft.	QU - T/Ft.^{2}	CONSISTENCY
2	0.25	very soft
2-4	0.25-0.50	soft
4-8	0.50-1.00	medium or firm
8-15	1.00-2.00	stiff
15-30	2.00-4.00	very stiff
30	4.00	hard

The resistance of a non-cohesive soil (sand) can be related to its consistency as follows:-



SAMPLE CONDITION AND TYPE

The depth and condition of samples are indicated by the following symbols:

UNDISTURBED   DISTURBED   LOST SAMPLE

SAMPLE TYPES

U	-	3" O.D. Shelby tube sample
D.S.	-	drive sample
M	-	moisture content sample
R.C.	-	rock core sample

PERCENTAGE WATER SOLUBLE SULPHATE CONCENTRATION

0   0.1   0.2   0.3   0.4   0.5   0.6   0.7%

Negligible	Positive	Considerable	Severe
RELATIVE DEGREE OF SULPHATE ATTACK			

Negligible - Normal Portland Cement may be used.

Positive - Normal Portland Cement may be used, provided the strength of the concrete is increased up to 500 psi higher than the compressive strength which would normally be used.

Considerable - Type V cement must be used and the concrete compressive strength should be increased to 500 psi higher than the compressive strength which would normally be used.

Severe - Type V cement must be used and the concrete compressive strength should be increased from 500 to 1000 psi higher than the compressive strength which would normally be used.

GROUND WATER TABLE

The water table is indicated by the level of standing water in a test boring after equilibrium has been reached. This is generally taken 24 hours after the drilling operation. The water table is usually an inclined surface that is dynamic in nature with its highest level late in the winter or early spring gradually falling throughout the summer.

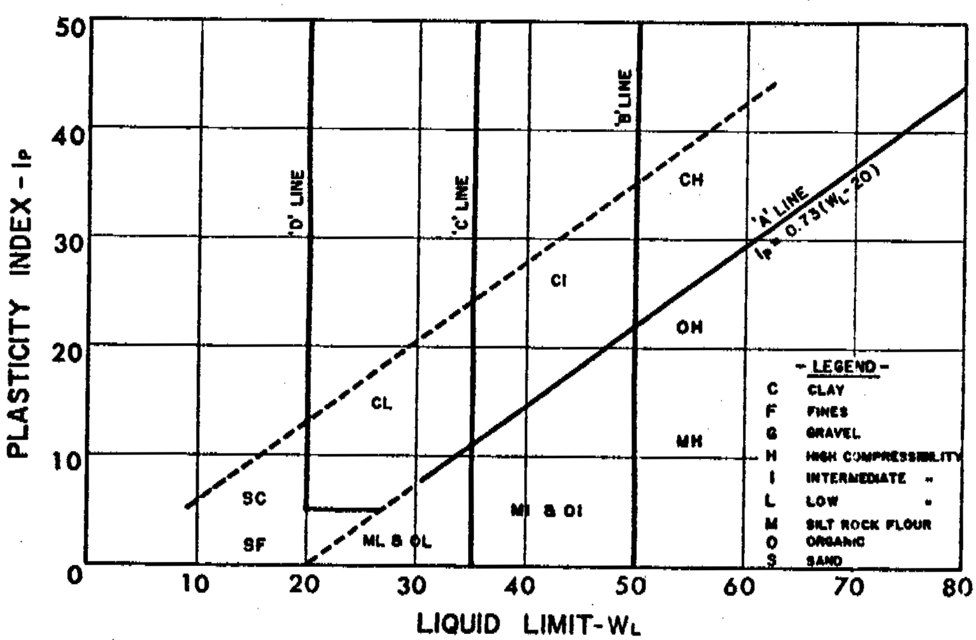
UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION <u>RETAINED</u> ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILTY MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS <u>LARGER</u> THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION <u>PASSING</u> NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT <u>LESS</u> THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS <u>SMALLER</u> THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT <u>GREATER</u> THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

PLASTICITY CHART



FOR LABORATORY CLASSIFICATION OF FINE-GRAINED SOILS

NATIONAL RESEARCH COUNCIL PERMAFROST CLASSIFICATION SYSTEM

Permafrost ground ice occurs in three basic conditions including non-visible, visible (less than one inch in thickness) and clear ice.

A. Non-visible - N

N_f - poorly bonded or friable frozen soil

N_{bn} - well bonded soil, no excess ice

N_{be} - well bonded soil, excess ice

B. Visible - V (less than 1" thick)

V_x - individual ice crystals or inclusions

V_c - ice coatings on particles

V_r - random or irregularly oriented ice formations

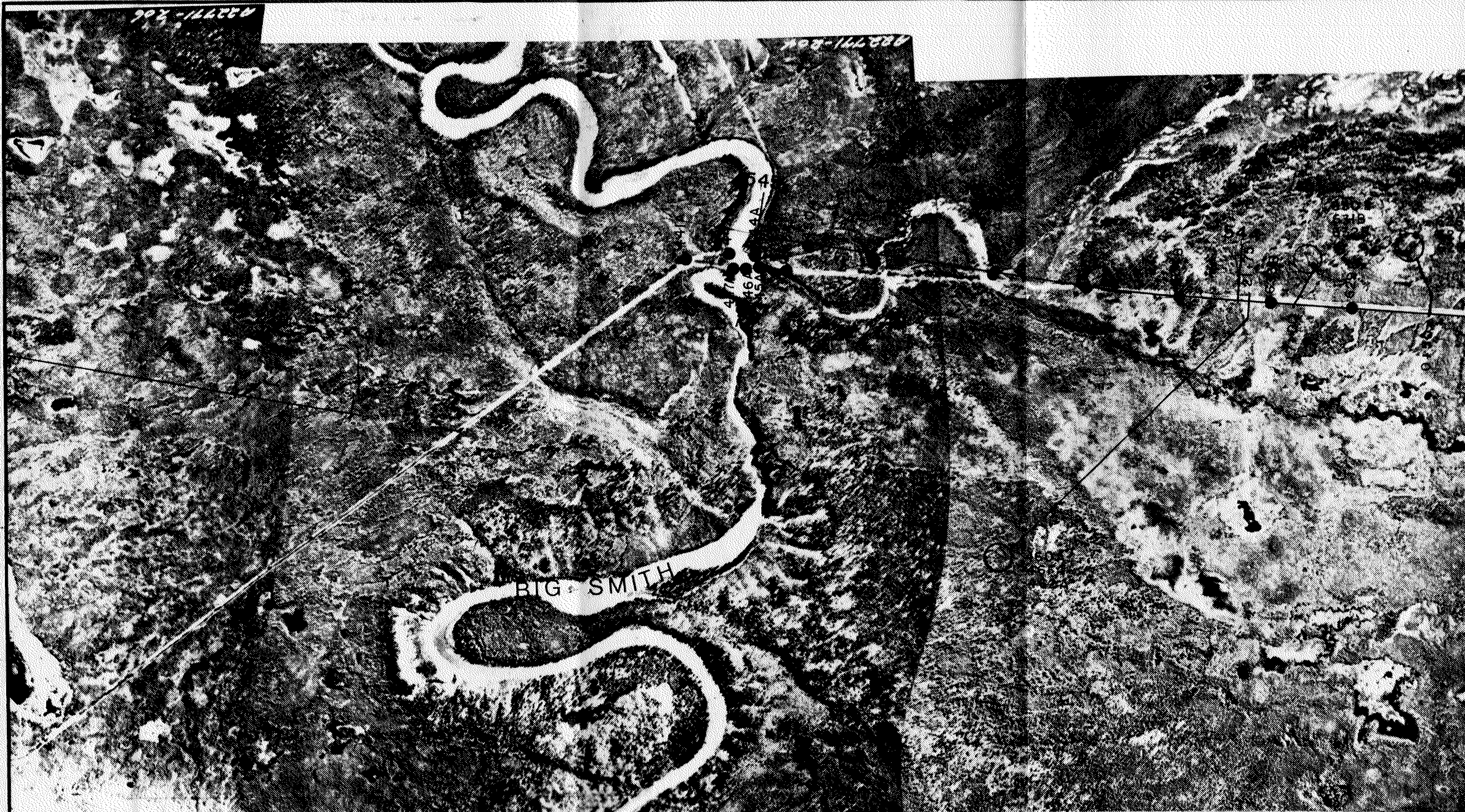
V_s - stratified or oriented ice formations

C. Visible Ice - (greater than 1" thick)

Ice - ice with soil inclusions

Ice + Soil - ice without soil inclusions.

A more complete description of this system is included in NRC publication TM 79.



Issue	Date	Remarks	No.	Revision	Date	By	Approved

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

CONSULTING ENGINEERS – TOWN PLANNERS

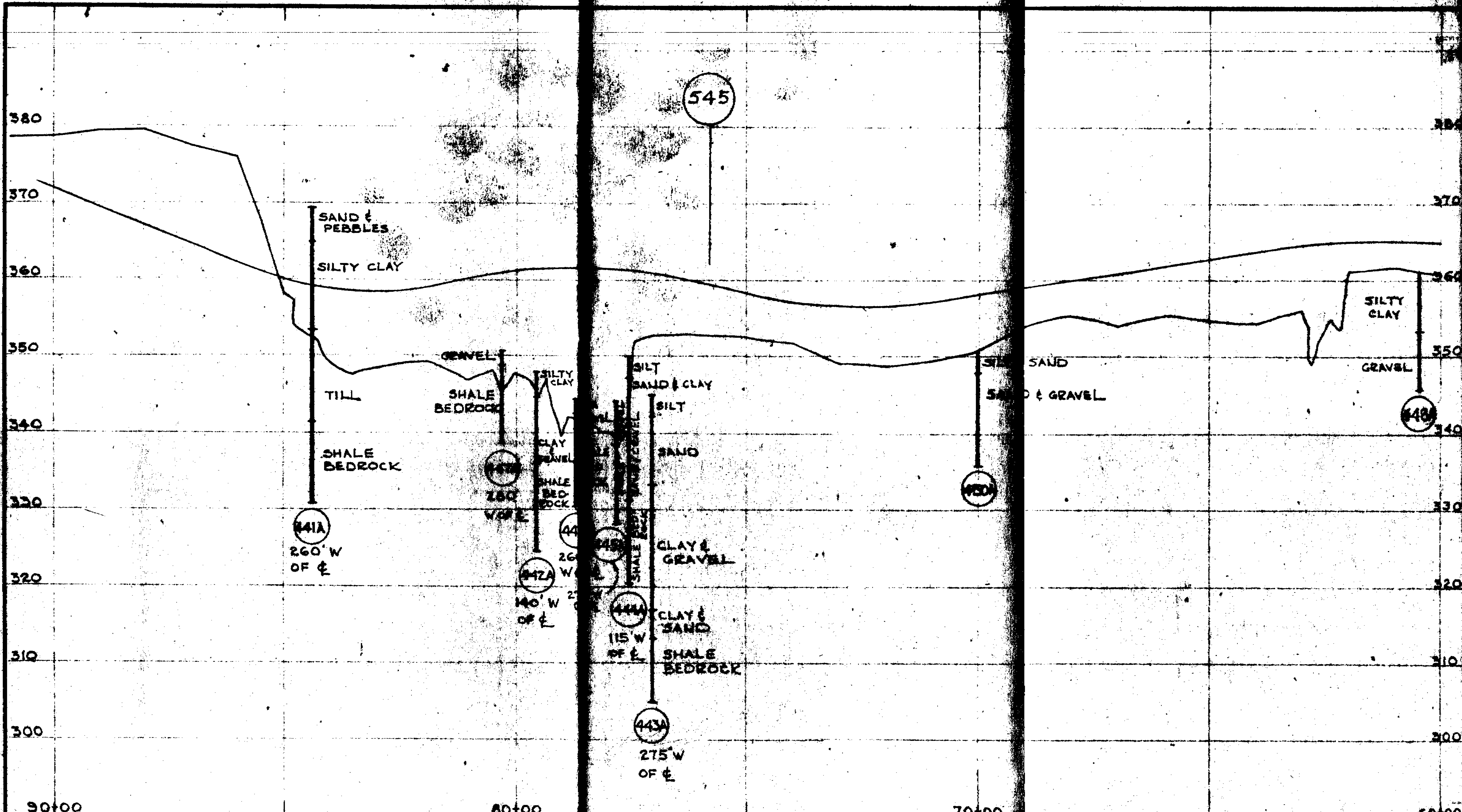
BRITISH COLUMBIA • ALBERTA • SASKATCHEWAN • MANITOBA • ONTARIO

Drawn: H.M.S.
Checked: D.G.P.
Design:
Traced:
Scale: 1" = 1000'

MACKENZIE HIGHWAY

BIG SMITH MOSAIC AND TEST HOLE LOCATION PLAN

Date: APRIL/73
Job:
Sheet:
Drawing: PLATE-1
Issue:



Issue	Date	Remarks	No.	Revision	Date	By	Approved

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CONSULTING ENGINEERS – TOWN PLANNERS

BRITISH COLUMBIA • ALBERTA • SASKATCHEWAN • MANITOBA • ONTARIO

Drawn:	M.S.
Checked:	D.G.P.
Design:	
Traced:	
Scale:	AS SHOWN

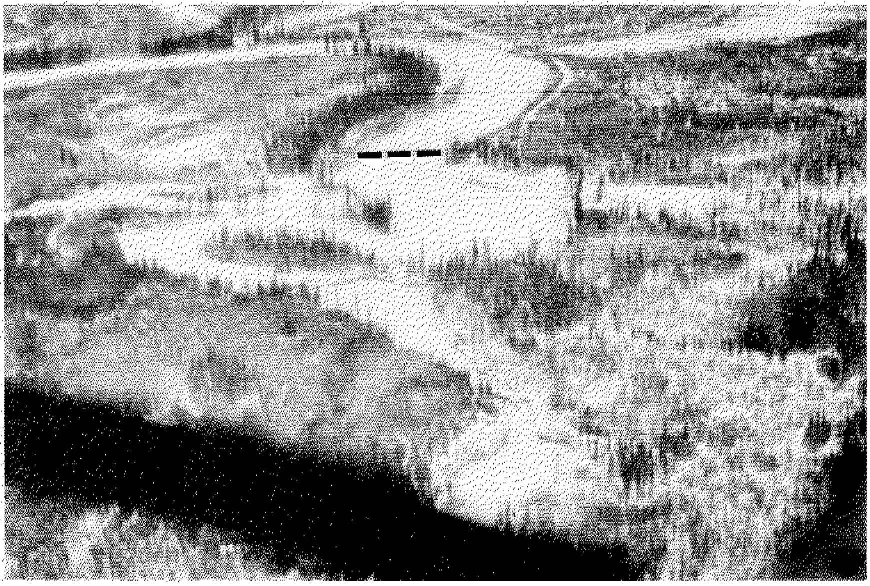
MACKENZIE HIGHWAY

BIG SMITH BRIDGE SITE

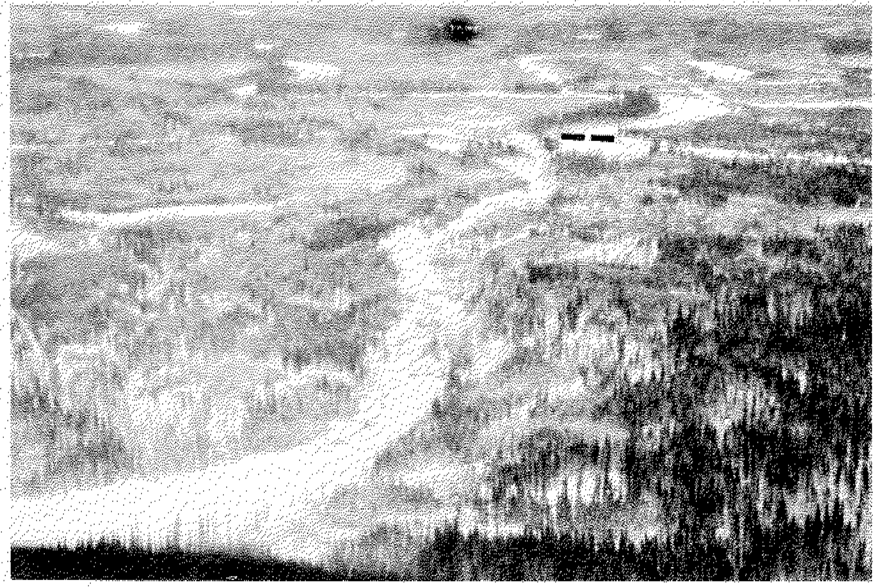
PROFILE & SOIL CROSS SECTION

Date:	MAR/73
Job:	
Sheet:	
Drawing:	PLATE-2
Issue:	

BIG SMITH CREEK
CROSSING MILE 545.



Viewing Crossing in a Easterly
Direction.



Viewing Crossing in a North Easterly
Direction

Plate 3.

UNDERWOOD McLELLAN & ASSOCIATES LIMITED | DRILL HOLE REPORT | DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN A E W	FIELD ENG R S	DATE DRILLED 15/2/73	AIRPHOTO NO:	CHAINAGE:
OFFSET: ℄				
CKD DGP	TECH:	RIG AIR	SURFACE DRAINAGE:	VEGETATION: SPRUCE & POPLAR TO 30'
ELEV. 69.38				

TEST HOLE

MILE	B,C,S	NUMBER
545	S	441A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (PCF)	DRY DENSITY (PCF)	REMARKS
0–4					SP	SAND	F		7		85	8			
4															SO_4-0.11 %
4–15				21 BLS	GC	TILL SILTY CLAY WITH SMALL PEBBLES	UF								
15–16						SAND SEAM									
16–30				109 BLS	GC										
30–40						BEDROCK SHALE									
40						END OF HOLE									

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

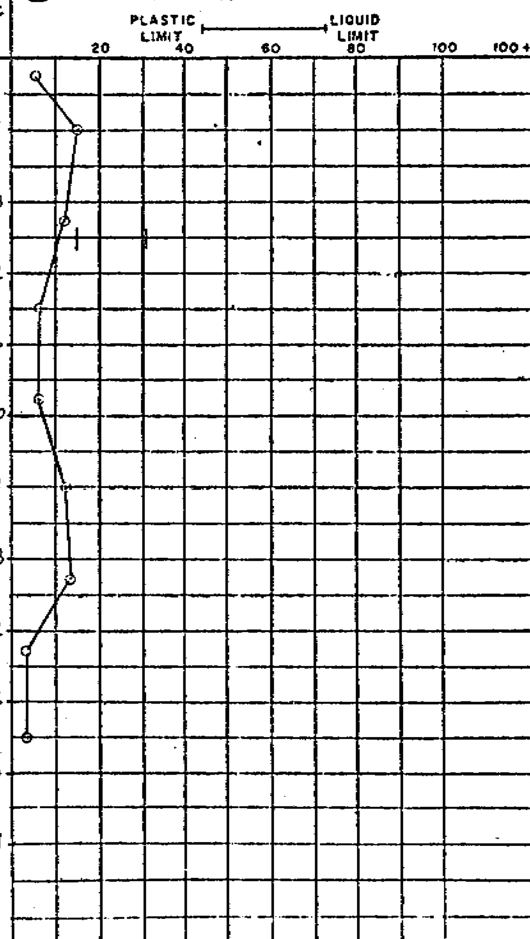


PLATE 4

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

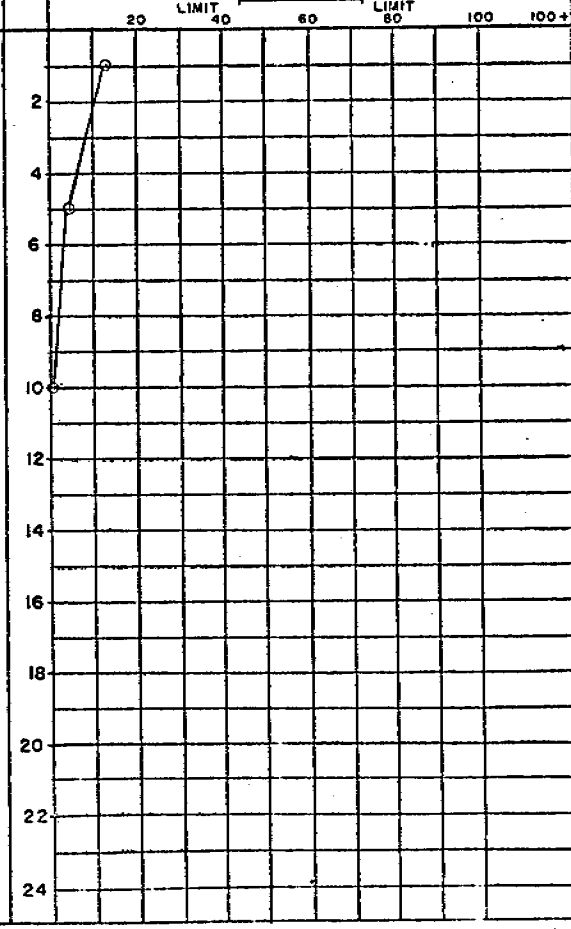
DRN AEW	FIELD ENG R.S.	DATE DRILLED 15/2/73	AIRPHOTO NO:	CHAINAGE: 80+39	OFFSET: 280' W of ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE:	VEGETATION:	ELEV. 350.51

TEST HOLE

MILE	B,C,S	NUMBER
545	S	447A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–12						GRAVEL & BED ROCK	UF	
12						END OF HOLE		

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



GRAIN-SIZE ANALYSIS: CLAY % | SILT % | SAND % | GRAVEL % — WET DENSITY (PCF) — DRY DENSITY (PCF)

REMARKS

SO_4 = 0.09%

PLATE 5

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

CAN: A E W	FIELD ENG: R. S	DATE DRILLED: 15/2/73	AIRPHOTO NO:	CHAINAGE: 79+53	OFFSET: 140' W OF ℄	TEST HOLE
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE	ELEV: 348.14	

MILE	B,C,S	NUMBER
545	S	442A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (PCF)	DRY DENSITY (PCF)	REMARKS
0–1.5						SAND	F								
1.5–3					SM	SILTY CLAY	UF								
3–12					GM	GRAVEL CLAY				8	26	66			
12–23						BEDROCK									
23						END OF HOLE									

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

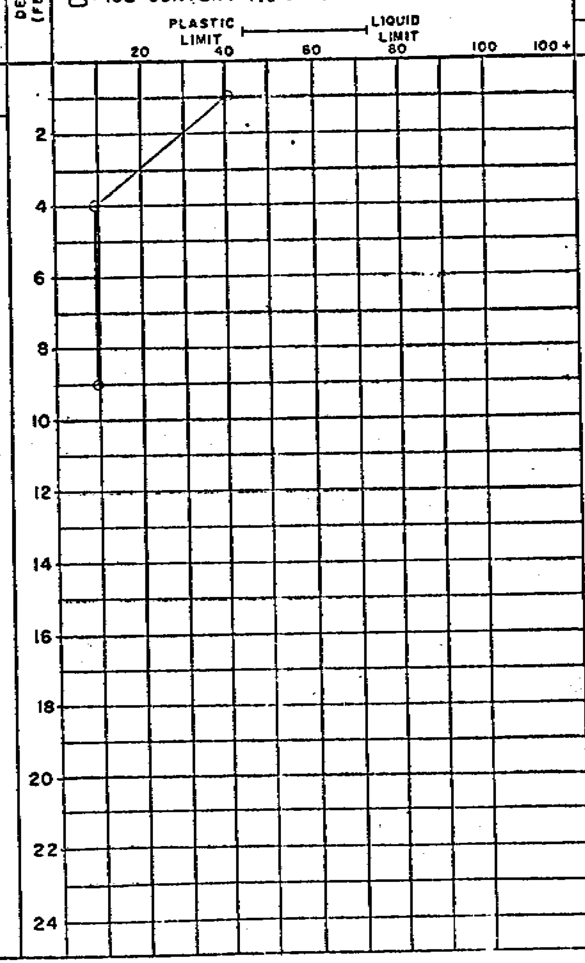


PLATE 6

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DRN A.E.W	FIELD ENG R.S.	DATE DRILLED 15/2/73	AIRPHOTO NO:	CHAINAGE:	OFFSET: ℄	TEST HOLE
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE:	VEGETATION:	ELEV. 44.45	

MILE	B,C,S	NUMBER
545	S	446A

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

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	WATER / ICE CONTENT (PLASTIC LIMIT, LIQUID LIMIT; 20 40 60 80 100 100+)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (PCF)	DRY DENSITY (PCF)	REMARKS
0–2						ICE	F										
2–4						GRAVEL	UF		2								
4–15						BEDROCK			4								
15						END OF HOLE											

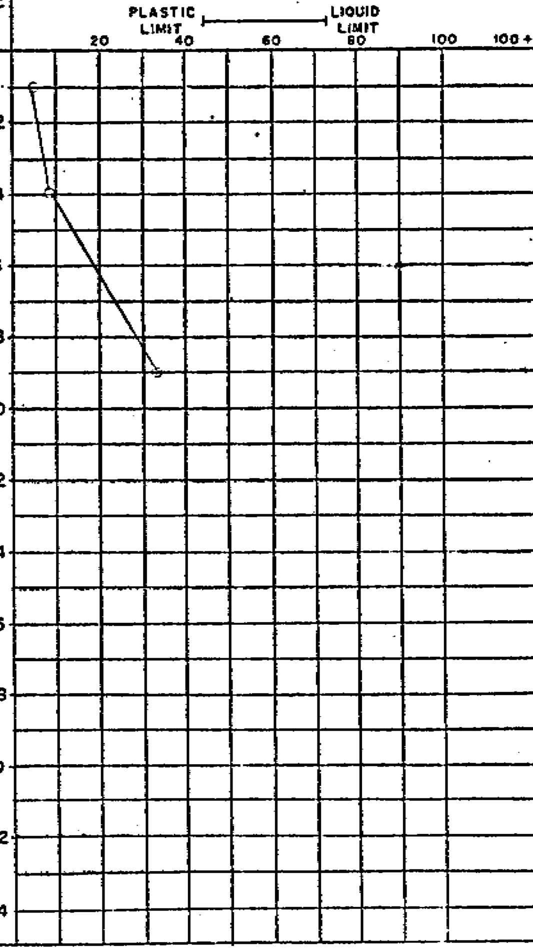
UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

[illegible] AEW	FIELD ENG R.S.	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE:	OFFSET: ℄	TEST HOLE
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE:	VEGETATION:	ELEV. 44.18	

MILE	B,C,S	NUMBER
545	S	445A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–5		◪ (1.5–2.5, 4.5–5.5)			GW	GRAVEL	F	
					GC	TILL		
6–15		◪ (9.5–10.5, 14.5–15.5)				BEDROCK	UF	
15						END OF HOLE		

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



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

PLATE 8

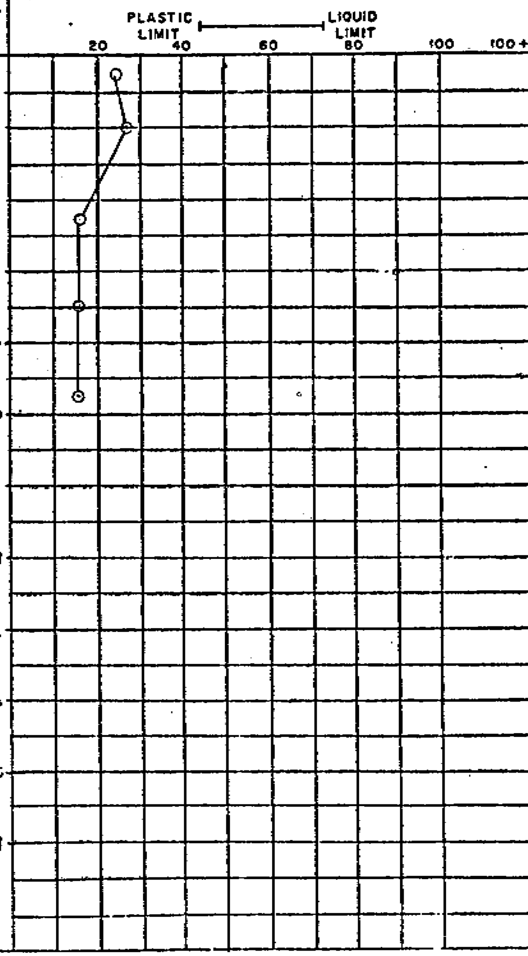
UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DR. A E W	FIELD ENG B M	DATE DRILLED 15/2/73	AIRPHOTO NO:	CHAINAGE: 77+60	OFFSET: 115' W OF ℄	TEST HOLE
CKD D G D	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE & WILLOW	ELEV. 349.70	

MILE	B,C,S	NUMBER
544	S	444A

DEPTH (FEET)	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2	SM	SILT 2" ORGANIC	F	
2–19	CL	CLAY WET SAND & GRAVEL WATER	UF	
19–30		BEDROCK		
30		END OF HOLE		

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



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

REMARKS: ROCK CHIPS IN SAMPLES

PLATE 9

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN: A.E.I.	FIELD ENG: R.S.	DATE DRILLED: 15/2/73	AIRPHOTO NO:	CHAINAGE: 77+10	OFFSET: ℄
CKD: D.G.P.	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE TO 70'	ELEV: 4520

TEST HOLE

MILE	B,C,S	NUMBER
545	S	443A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–3					SM	SILT, LIGHT BROWN	F								
3–12					SP	SAND, PEBBLES	F (to 8); UF				90	10			
12–32					GC	GRAVEL, CLAY, SAND	UF								
32–40					GC	BEDROCK, SHALE	UF								
40						END OF HOLE									

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

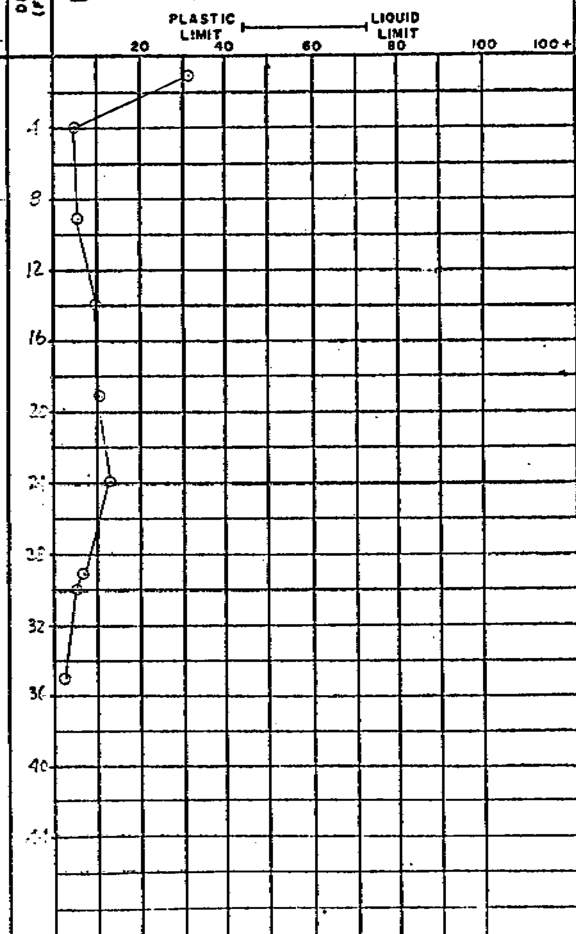


PLATE 10

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN A.E.W	FIELD ENG B.M	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE: 70+00	OFFSET: ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: POOR	VEGETATION: SPRUCE TO 15'	ELEV.

TEST HOLE

MILE	B,C,S	NUMBER
544	C	450A

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT ——— LIQUID LIMIT
20 40 60 80 100 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–3					SP	SAND 2" ORGANIC	F								
3–15					GW	GRAVEL SAND	UF								
~9.5										3	24	73			
14					GW										
15						END OF HOLE									

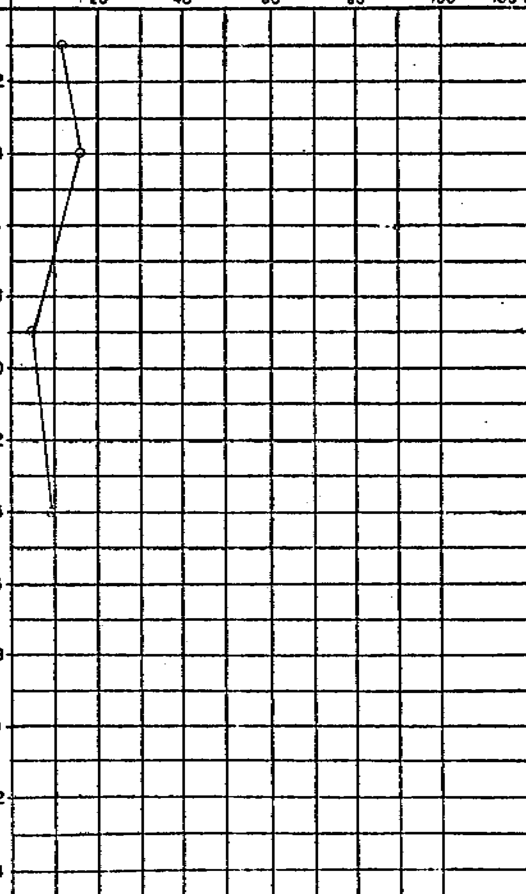


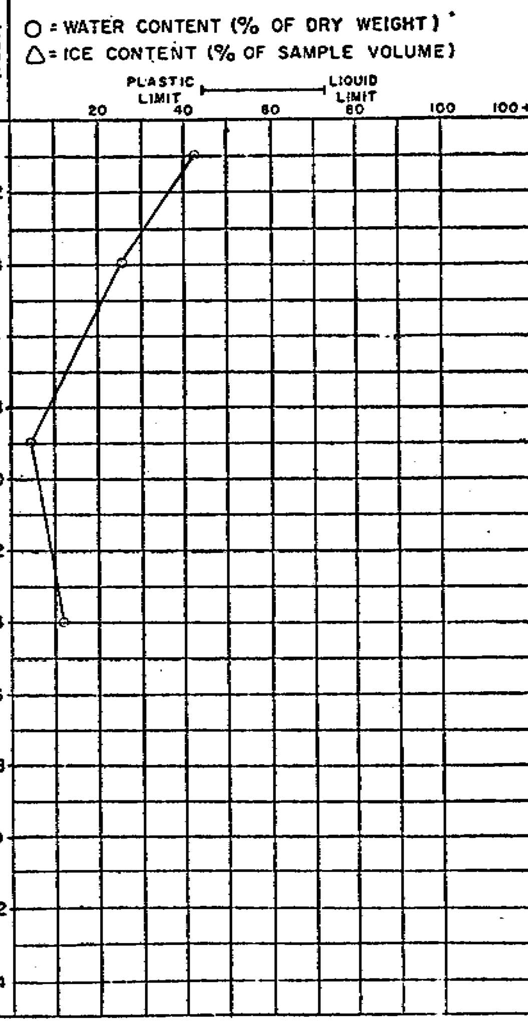
PLATE 11

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN A E W	FIELD ENG R.S.	DATE DRILLED 15/2/73	AIRPHOTO NO:	CHAINAGE: 60+00	OFFSET: ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: FAIR	VEGETATION: SPRUCE TO 60'	ELEV.

TEST HOLE		
MILE	B,C,S	NUMBER
544	C	448A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–1					Pt	CLAY	F	
2		╲			ML			
4		╲				SILTY, SANDY		
8					SM		UF	
9–10		╲				GRAVEL		
12					GW	CLAY		
14		╲						
15						END OF HOLE		



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

PLATE 12

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN AEW	FIELD ENG B.M	DATE DRILLED 19/2/73	AIRPHOTO NO:	CHAINAGE: 21+75
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: POOR	VEGETATION: SPRUCE & POPLAR TO 50'

OFFSET: 1 MILE W OF ℄

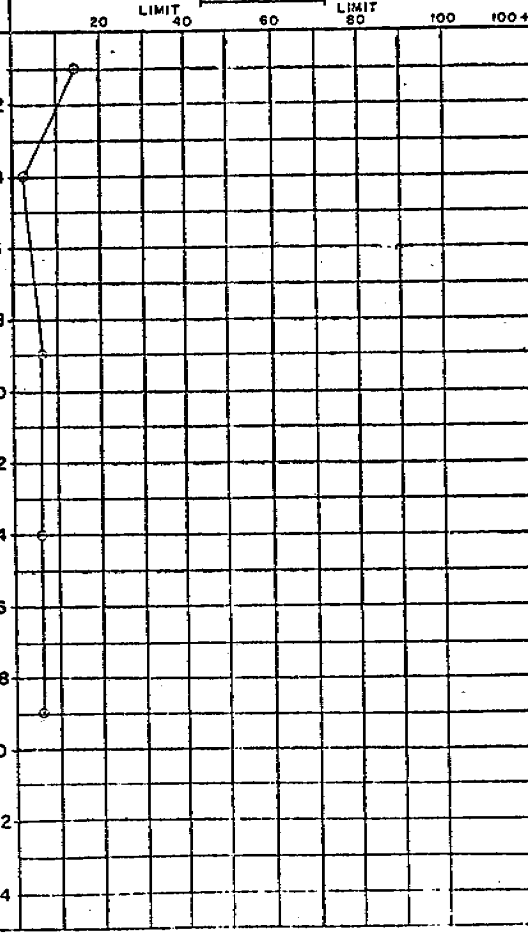
ELEV.

TEST HOLE

MILE	B,C,S	NUMBER
544	B	460A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–3					SP	SILT 4" ORGANIC	F								
3–20					SP, SP	SAND	UF		2		82	16			
20						END OF HOLE									

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



UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

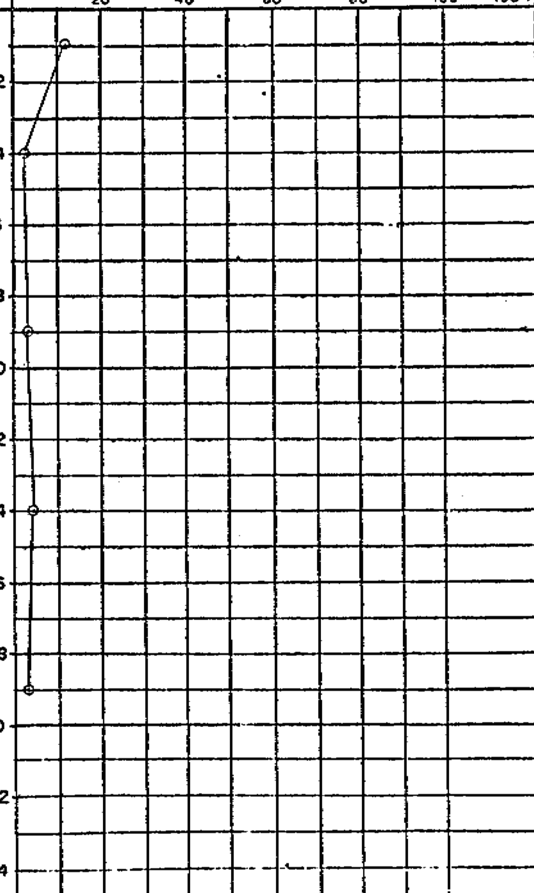
DRN A E W	FIELD ENG B M	DATE DRILLED 19/2/73	AIRPHOTO NO:	CHAINAGE: 21+75	OFFSET: 1 MILE W OF ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: POOR	VEGETATION: SPRUCE & POPLAR TO 60'	ELEV.

TEST HOLE

MILE	B,C,S	NUMBER
544	B	461A

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–3					SM	SILT 3" ORGANIC SOME PEBBLES	F	
3–20					SP	SAND	UF	
20					SP	END OF HOLE		

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



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

PLATE 14

UNDERWOOD McLELLAN & ASSOCIATES LIMITED — DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

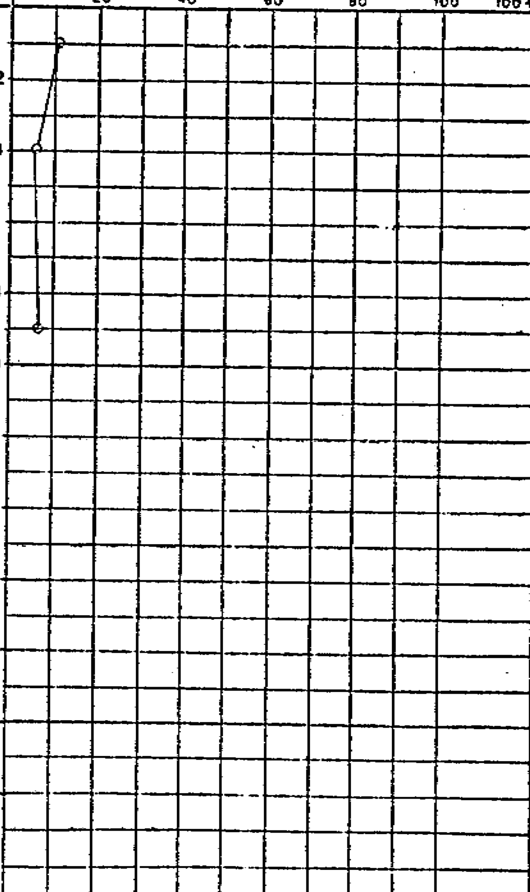
[illegible] A.E.W.	FIELD ENG B.M	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE: 17+00	OFFSET: 500' E OF ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: FAIR	VEGETATION: SPRUCE & ASPEN TO 25'	ELEV

TEST HOLE

MILE	B,C,S	NUMBER
543	B	630B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	REMARKS
0–3					SW	SAND 3" ORGANIC GRAVEL	F		
3–14						SHALE ALTERNATE LAYERS OF LIGHT & DARK GREY SHALE			WATER SEEPING IN AT 9'
14						END OF HOLE			

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



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

PLATE 16

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN A.E.W.	FIELD ENG B.M.	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE: 17+00	OFFSET: 500' E OF ℄	TEST HOLE
CKD D.G.P.	TECH:	RIG: AIR	SURFACE DRAINAGE: FAIR	VEGETATION: SPRUCE & ASPEN	ELEV.	

MILE	B,C,S	NUMBER
543	B	631 B

○ = WATER CONTENT (% OF DRY WEIGHT)
△ = ICE CONTENT (% OF SAMPLE VOLUME)
PLASTIC LIMIT —— LIQUID LIMIT; 20, 40, 60, 80, 100, 100+

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION	DEPTH (FEET)	GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (P.C.F.)	DRY DENSITY (P.C.F.)	REMARKS
0–1						SILT 3" ORGANIC, SANDY, BROWN										
1–13						SHALE SOFT, LIGHT TO DARK GREY LIGHT TO DARK GREY VERY SOFT										
13						END OF HOLE										

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

PLATE 17

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

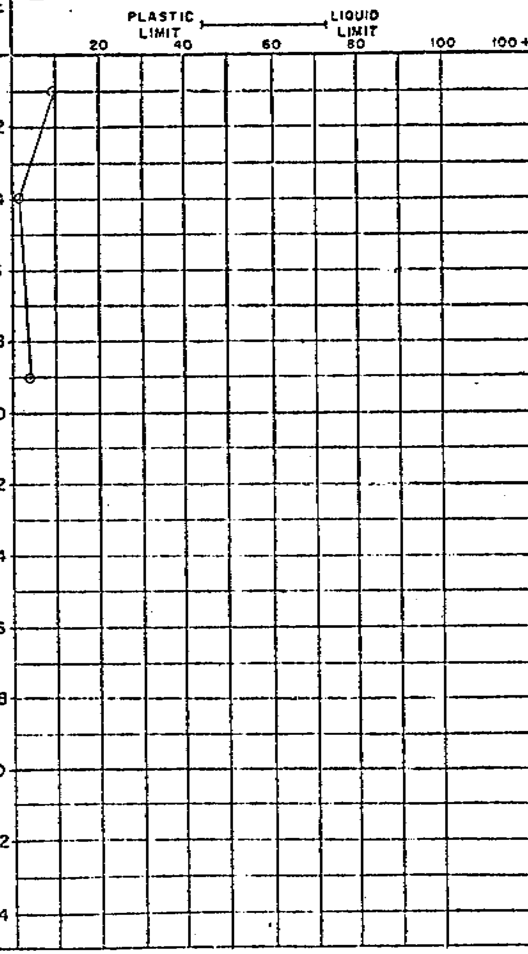
BY: AEW	FIELD ENG: B M	DATE DRILLED: 16/2/73	AIRPHOTO NO:	CHAINAGE: 17+00	OFFSET: 500' E OF ℄
CKD: DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: FAIR	VEGETATION: SPRUCE & ASPEN TO 25'	ELEV:

TEST HOLE

MILE	B,C,F	NUMBER
543	B	632B

DEPTH (FEET)	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–2	SILT 3" ORGANIC SANDY, BROWN	F	
2–13	SHALE LIGHT GREY. VERY SOFT DARK GREY LIGHT GREY, SOFT DARK GREY		
13	END OF HOLE		

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



GRAIN SIZE ANALYSIS: CLAY % | SILT % | SAND % | GRAVEL % — WET DENSITY (PCF) — DRY DENSITY (PCF) — REMARKS

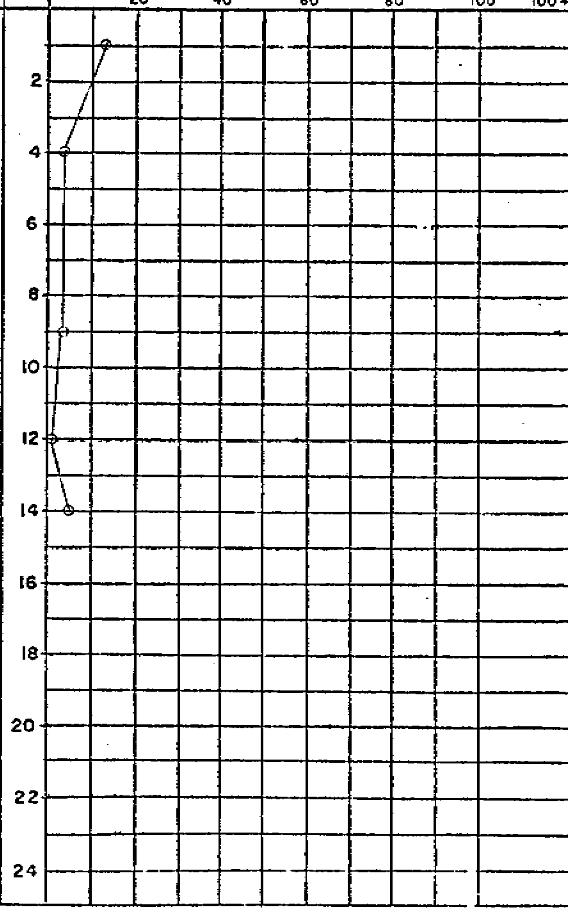
PLATE 18

UNDERWOOD McLELLAN & ASSOCIATES LIMITED	DRILL HOLE REPORT	DEPARTMENT OF PUBLIC WORKS, CANADA MACKENZIE HIGHWAY

DWN AEW	FIELD ENG B M	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE: 0+50		OFFSET: 600' E OF ℄	TEST HOLE
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: ASPEN & SPRUCE		ELEV.	

MILE	B,C,S	NUMBER
543	B	626B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0–1					Pt	ORGANIC PEBBLES	F	
1–5					GM	GRAVEL SOME SAND & CLAY		
5–15						SHALE GREY, QUITE HARD SOFTER GREY ROCK, QUITE SOFT		
15						END OF HOLE		



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

GRAIN-SIZE ANALYSIS CLAY %	SILT %	SAND %	GRAVEL %	WET DENSITY (PCF)	DRY DENSITY (PCF)	REMARKS

PLATE 19

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

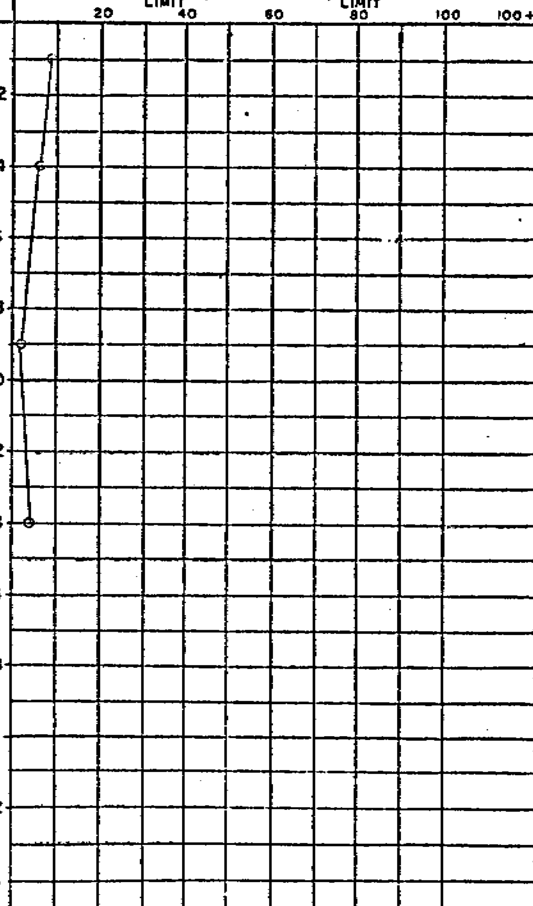
DWN A.E.W.	FIELD ENG. BM	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE: 0+50	OFFSET: 600' E OF ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: ASPEN & SPRUCE TO 25'	ELEV:

TEST HOLE

MILE	B,C,S	NUMBER
543	B	627 B

DEPTH (FEET)	SAMPLE NUMBER	SAMPLE TYPE	% RECOVERY	PENETRATION RESISTANCE	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND	ICE DESCRIPTION
0					Pt	ORGANIC	F	
1–2		⧅			S/A	SAND GRAVEL		
3–9		⧅ (4–5)				SHALE SOFT GREY ROCK SEDIMENTARY SOFT LIGHT BROWN ROCK		
9–15		⧅ (9–10), ⧅ (14–15)				SHALE HARD GREY ROCK BECOMES SOFTER WITH DEPTH SOFT, LIGHT BROWN ROCK		
15						END OF HOLE		

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



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

REMARKS

PLATE 20

UNDERWOOD McLELLAN & ASSOCIATES LIMITED

DRILL HOLE REPORT

DEPARTMENT OF PUBLIC WORKS, CANADA
MACKENZIE HIGHWAY

DWN A E W	FIELD ENG B.M.	DATE DRILLED 16/2/73	AIRPHOTO NO:	CHAINAGE: 0+50	OFFSET: 600' E OF ℄
CKD DGP	TECH:	RIG: AIR	SURFACE DRAINAGE: GOOD	VEGETATION: SPRUCE & ASPEN	ELEV.

TEST HOLE

MILE	B,C,S	NUMBER
543	B	628 B

DEPTH (FEET)	UNIFIED SOIL SYMBOL	SOIL DESCRIPTION	LIMITS OF FROZEN GROUND
0–1.5	Pt	SILT 2" ORGANIC SANDY BROWN	F
1.5–15		SHALE	UF
		SOFT GREY ROCK SEDIMENTARY	
		HARDER, DARK GREY	
		LIGHT, SOFT, GREY ROCK	
		DARK GREY, ROCK	
		HARDER ALTERNATING LAYERS OF LIGHT & DARK	
		END OF HOLE	

Other column headings (no entries): SAMPLE NUMBER, SAMPLE TYPE, % RECOVERY, PENETRATION RESISTANCE, ICE DESCRIPTION, GRAIN-SIZE ANALYSIS (CLAY %, SILT %, SAND %, GRAVEL %), WET DENSITY (PCF), DRY DENSITY (PCF), REMARKS.

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

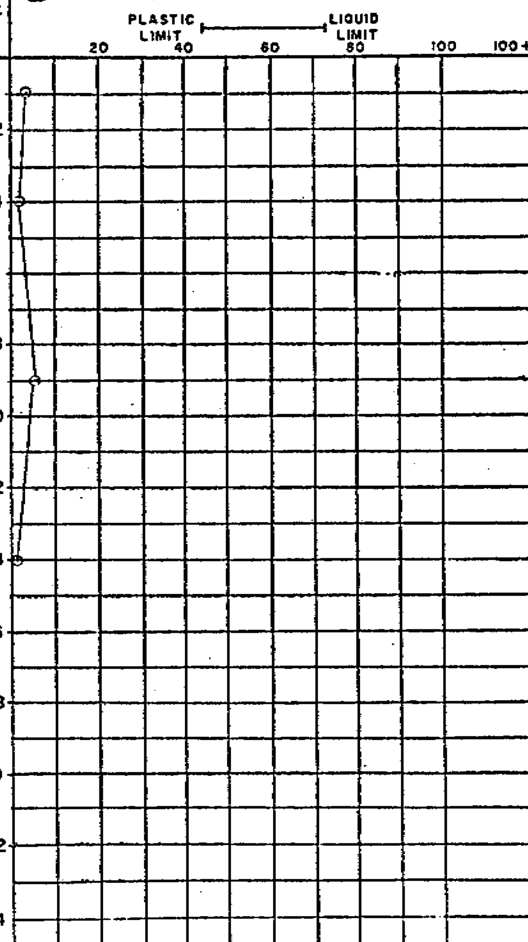


PLATE 21