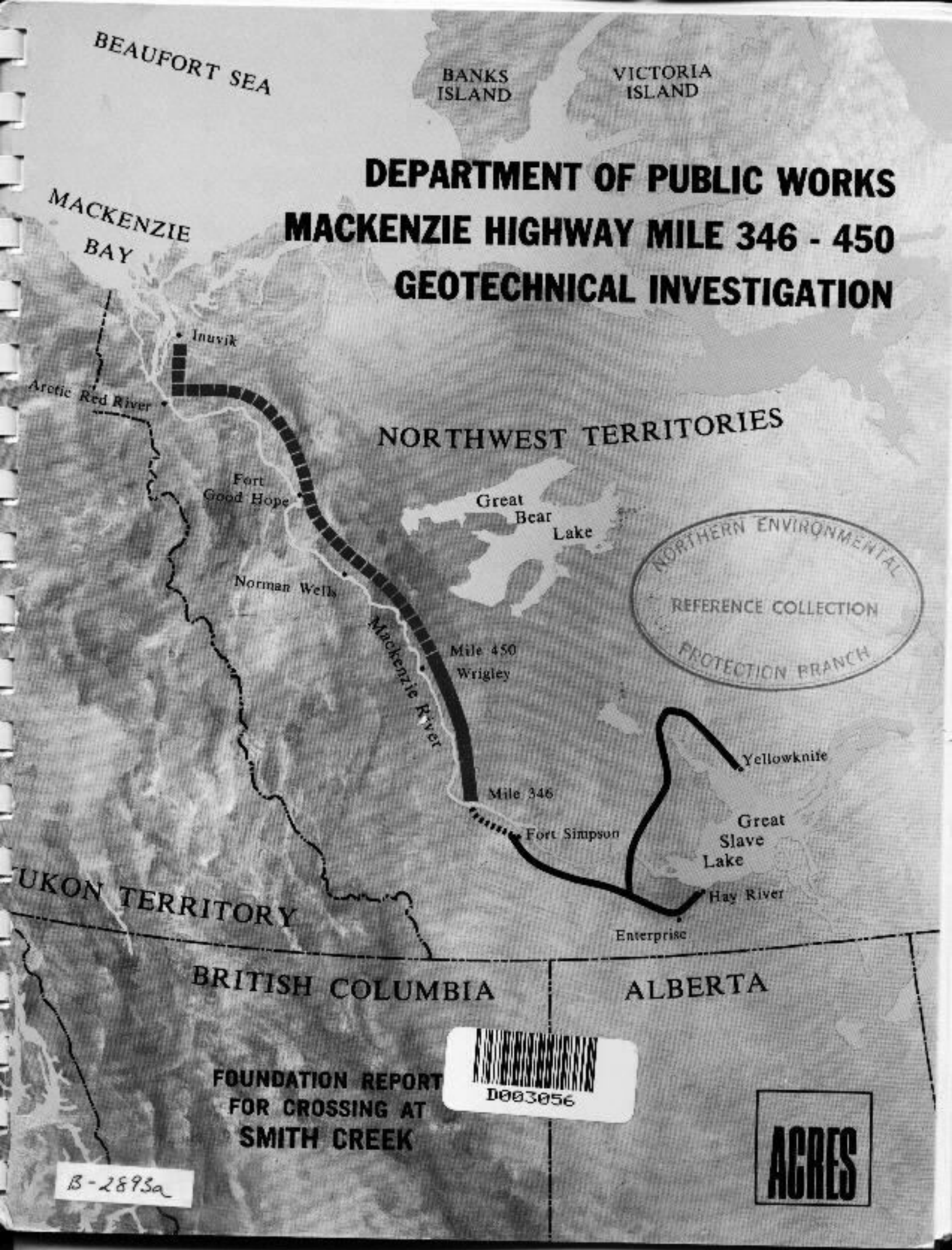


DEPARTMENT OF PUBLIC WORKS
MACKENZIE HIGHWAY MILE 346 - 450
GEOTECHNICAL INVESTIGATION

NORTHERN ENVIRONMENTAL
REFERENCE COLLECTION
PROTECTION BRANCH

FOUNDATION REPORT FOR CROSSING AT SMITH CREEK

D003056

B-2893a

ACRES

Photograph 1: Failing 1000 drill rig mounted on a Flextrac-Nodwell tractor. Note the covered "sloop" which was towed behind the drill rig. This sloop contained a work bench, writing table, extruder, propane heater and a small electric generator. An open deck at the back of the sloop was used for transporting samples and spare fuel.

Photograph 2: The field laboratory. On the right can be seen an electronic Mettler scale. Three electric ovens were kept beneath the benches in order to conserve space. The paper cups and aluminum bread pans contain samples which are ready for drying in the oven.

Photograph 3: Moving camp. The units in this photograph are the generator house (which cannot be clearly seen), the laboratory and utility trailer and the dining trailer at the rear. These units were carried on specially designed wide ski sledges.

Photograph 4: Camp at mile 622. Bunkhouses are at the right. The utility trailer, at the left has been removed from its runners.

Photograph 5: Typical terrain between Norman Wells and the Great Bear River. Notice the sparse growth of spruce at the bottom of the photograph. This is quite typical of many areas in the region.

Photograph 6: Looking south across the Great Bear River from Test Hole 552.

Photograph 7: Looking northerly to Test Hole 459 on the north side of the Great Bear River.

Photograph 8: Looking southerly towards Test Hole 460 at approximately mile 583.

Photograph 11: Approximate location mile 591 (near Test Hole 574). Note the seepage which is causing icing on the trail. Note the stunted spruce and the swamp birch in the background. This vegetation is quite typical of the area.

Photograph 12: Near Test Hole 737 at approximately mile 596. The vegetation here is black spruce which is quite typical of large sections of the alignment between Big Smith Creek and Norman Wells.

Photograph 13: Looking southerly from Test Hole 677 at approximately mile 601. The actual centerline of the road is approximately 50 feet to the right of the CNT pole line. The CNT land line was placed on large tripods in this area because of permafrost.

Photograph 14: View from Jungle Ridge looking easterly at approximately mile 602. Observe the flat terrain which, combined with permafrost, causes poor drainage.

Photograph 15: Creek crossing at Jungle Ridge Creek at approximately mile 604 looking southerly.

Photograph 16: From the center of Nota Creek looking northerly towards Test Hole 723. Mileage is approximately 605.

Photograph 17: From the center of Vermilion Creek looking southerly. Approximate mileage is 607.

Photograph 18: At Test Hole 803 looking northerly. Approximate mileage is 609.

Photograph 19: Cores from Test Hole 503. At the bottom of the photograph can be seen organic clay with high ice content. The center sample (marked D3, D4) is clay till with quite low water content. The top sample (marked D6, D7) is frozen sand.

Photograph 20: Cores taken in Test Hole 507. On the left is a sample of organic clay with high ice content and on the right is a sample of clay till. In this case the clay till has a very high ice content.

Photograph 21: Core samples from Test Hole 569. The material in the top half of the photograph is limestone.

Photograph 22: Clay till cores from Test Hole 612. Observe the ice banding in the lower sample in this photograph.

Photograph 23: A sample of clay till, sandy, from Test Hole 616 at a depth of 11 feet. The water content is about 12 percent. Note that there is no visible ice in this sample.

Photograph 24: A sample of clay till, silty-sandy, water content 9 percent, from Test Hole 834 at a depth of 11 to 14 feet. Note there is no visible ice in this sample.

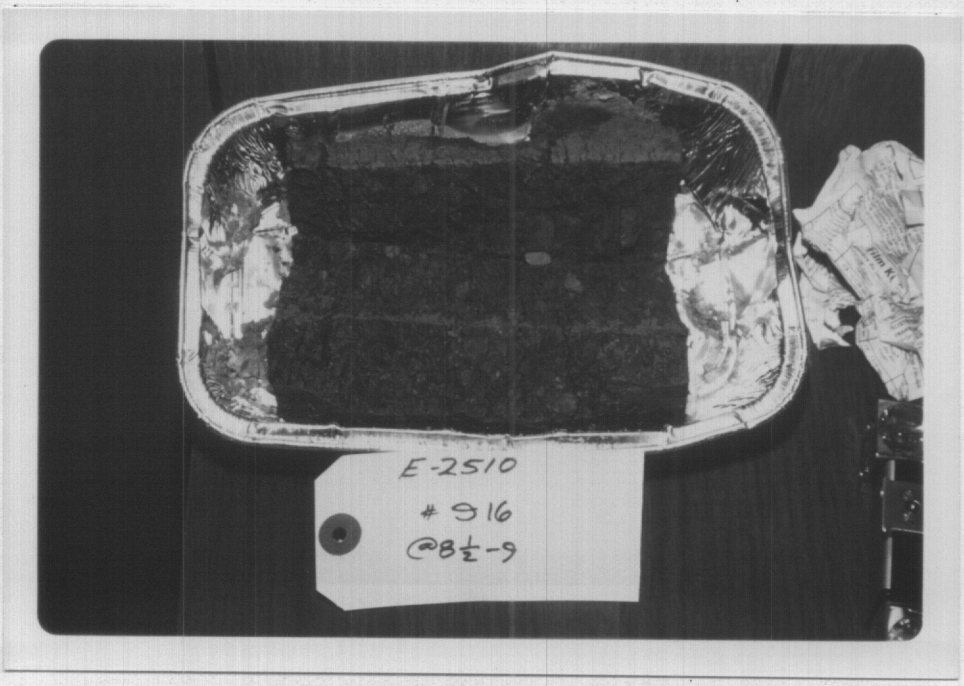
Photograph 25: A sample of clay-shale from Test Hole 843. Depth interval is 6.5 to 7 feet. This material had silt and sandstone partings. Note there is no visible ice.

Photograph 26: A sample of organic silt from Test Hole 885 at a depth interval of 1.5 to 2.0 feet. Note the organic material.

Photograph 27: A sample of clay till from Test Hole 885 at a depth interval of 15 to 15.5 feet. This material contains some pebbles. Water content was 14 percent.

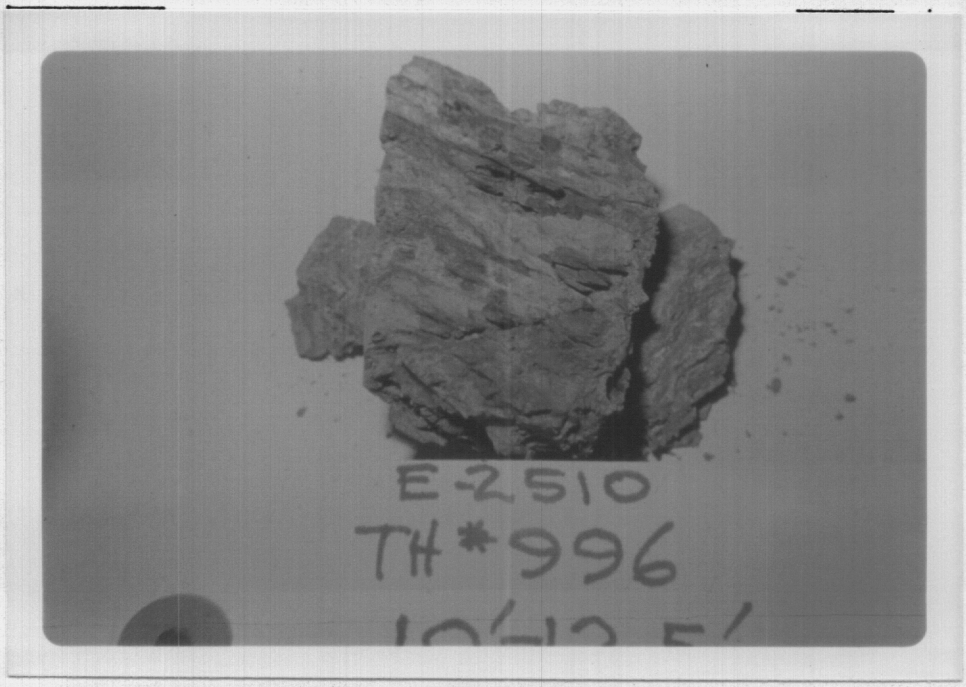
Photograph 28: A sample of varved clay from Test Hole 886. This material was laid down in still water and the light and dark bands are alternating layers of silt and clay. Water content of this material was 28 percent.

Photograph 29: A sample of silty-clay, medium plasticity, from Test Hole 916. Depth interval is 5.2 to 6.0 feet. Water content was 20 percent.



Photograph 30: A sample of silty-clay, medium plasticity, from Test Hole 916. Note the pebbles within this material. Water content was 25 percent.

Photograph 31: A sample of weathered shale from Test Hole 916.



Photograph 32: A sample of clay till, medium plasticity, from Test Hole 996. There was no visible ice in this material and the water content was quite low.

Photograph 33: A sample taken with a Shelby tube from the surface to one foot depth. The surface moss is at the right of the sample and clay is at the left. Between the moss and the clay is peat.

Photograph 34: A close-up of the sample shown in Photograph 33. The peat is category No. 15 using the Radforth system.

Photograph 35: A sample of clay from Test Hole 1022, depth interval 5 to 7 feet. This photograph was taken after the sample had started to thaw in the laboratory. The ice type and content was classified as Vs at 60 percent. The sample is lying on its side and the ice lenses would have been horizontal in the in situ position.

Photograph 36: A close-up of the sample shown in Photograph 35. This photograph is approximately full size. Notice the ice lenses and the pebbles within the material.

APPENDIX B

Data on Borrow Areas and Cuts

POSSIBLE CUT SECTIONS

SUMMARY OF DATA

MILE	STATION	TEST HOLE	DEPTH OF CUT (FT)	SOIL TYPES	ICE CONTENT	WATER CONTENT (%)	REMARKS
579.7	119	33 35		Sand Silt Clay	High	High	Cut not recommended
583.0	40						South side of Great Bear River. No soils information
583.6	76 to 100	522 459 460 521 461	-	Mixed	Varies Low to Very High	High	Cut not recommended
585.9	202	480 481	25	Clay Sand	Varies, Mainly Low	15-25	Cut not recommended
586.2	220	483	20	Clay	Low	15-30	Cut feasible
586.5	235	485 486	20	Silt Clay Shale	Varies	15-30	Cut not recommended
587.5	290	492 493 494 495	30	Clay Sand Silt	Mainly Low - Some High	10-40	Cut feasible, Not recommended

B

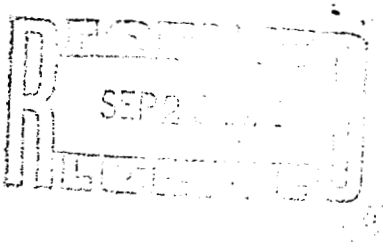
CANADA

Department of Public Works
10th Floor, One Thornton Court,

Ministère des Travaux publics
P. O. Box 488,
Edmonton, Alberta.
T5J 2K1.

September 19, 1972.
your file / votre dossier
our file / notre dossier 9305-52-307.

R. M. Hardy & Associates,
Geotechnical Division,
10214 - 112 Street,
Edmonton, Alberta.



Dear Sirs:

Geotechnical Investigations - Mackenzie Highway.

Attached is a draft of the "Project Brief" for geotechnical consultants, which should be of assistance in preparation of final estimates for your work.

Yours truly,

for R.D. Cook
N. Huculak,
Regional Highways Engineer.

Attach.

7530-21-023-9243

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
13	39	Clay, silt	25 - 45	1,000,000	Water (ice) contents too high for borrow.	573	500
14	38	Clay, silt	25 +	1,000,000	Water (ice) contents too high for borrow.	572	900
15	38	Clay, silt, sand	25 +	1,000,000	Water (ice) contents too high for borrow.	571	1,000
17	38	Sand, fine	20 - 30	1,000,000 +	Some silt. Suitable for borrow.	569	1,700
18	37	Sand, fine	25	400,000	Suitable for borrow.	565	500
19	37	Sand, fine	25	1,000,000	Low-lying area, otherwise suitable for borrow.	564	500
20	37	Sand, fine	25	1,000,000	Suitable for borrow.	563	1,000
22	36A	Sand, fine	10 - 25	1,000,000	Depth to P/frost = 8 - 22 ft. Good source of borrow.	560	4,000
23	35A	Sand, fine	20	1,500,000	Good source of borrow.	557	500
25	35A	Sand, fine	20 - 25	4,000,000	Good source of borrow.	556	800
26	35A	Sand, fine	25	4,000,000	Good source of borrow.	556	500
27	36A	Sand, fine	25	4,000,000	Good source of borrow.	560	2,800
28	35	Sand, fine	5 - 20	600,000	Good source of borrow.	553	500
29	36A	Sand, fine	20 - 25	1,000,000 +	Good source of borrow.	560	1,100
30	37	Sand, fine	20 - 25	600,000	Good source of borrow.	564	500
31	36A	Sand, fine	20 - 25	1,000,000	Good source of borrow.	562	500
32	34	Sand, fine	25	800,000	Good source of borrow.	552	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
33	34	Sand, fine	25	500,000	Good source of borrow.	551	500
34	34	Sand, clay, silt			Poor source of borrow.	550	500
35	34	Sand, fine	25	370,000	Some selection of material would be necessary.	549	500
36	34	Sand, fine	15 - 25	500,000	Good source of borrow.	547	500
37	33	Sand, fine, some silt	15 - 25	400,000	Fair source of borrow.	545	500
38	35	Sand, fine	5 - 15	1,000,000	Good source of borrow.	553	500
39	38	Sand, fine	25 - 30	300,000	Fair source of borrow.	570	4,700
40	38	Sand, fine	25 - 30	600,000	Fair source of borrow.	570	2,100

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
51	41A	Sand, silt, clay	10 - 25	400, 000	Suitable for borrow, some selection and wastage will be necessary.	583	500
52	41A	Clay, clay-shale, till, shale	10 - 20+	400,000	Suitable for borrow, some selection and wastage will be necessary.	584	500
53	41A	Clay	10 - 30	400,000	Poor borrow material.	584	1,000
54	41A	Silt, sand, clay	10 - 20+	400,000	Suitable for borrow, some selection necessary.	585	500
55	41A	Clay, silt, sand	10 - 25+	300,000	Suitable for borrow, some selection necessary.	585	500
56	41A	Silt, gravel, sand clay	10 - 30	350,000	Suitable for borrow, some selection will be necessary.	585	500
57	41A	Sand, clay	10 - 40	300,000	Suitable for borrow, some selection will be necessary.	585	3,200
58	42	Clay, sand	15 - 20+	300,000	Upper material has high water content. Lower material suitable for borrow.	586	500
59	42	Clay, sand	10 - 25	400,000	Suitable for borrow, some selection will be necessary.	586	500
60	42	Clay	10 - 60	250,000	Upper material contains high ice volumes. Generally unsuitable for borrow.	586	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
61	42	Clay	10 - 30	250,000	Upper material unsuitable. Lower material is suitable for borrow.	587	500
62	42	Clay	10 - 30	500,000	Generally suitable for borrow. Some selection may be necessary.	587	500
63	42	Clay, sand	5 - 20	250,000	Generally suitable for borrow. Some selection may be necessary.	587	500
64	42	Clay (some gravel)	10 - 30	400,000	Mainly suitable for borrow. Some selection will be necessary.	587	500
65	43	Clay	10 - 25	400,000	Mainly suitable for borrow. Some selection will be necessary.	588	600
66	43	Clay		500,000	Mainly suitable for borrow. Some selection will be necessary.	588	2,000
67	43	Clay	10 - 40	250,000	Mainly suitable for borrow. Some selection will be necessary.	589	500
68	43	Clay	10 - 20	400,000	Suitable for borrow.	589	500
69	43	Clay, limestone	2 - 30	min.400,000	Good source of bedrock.	590	500
70	43	Clay, limestone	5 - 15	600,000 min.	Good source of bedrock. Overlying till also suitable for borrow.	591	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
71	43	Sand, clay	5 - 25	400,000	Good source of borrow.	591	500
72	43	Clay, gravel, sand	5 - 20	600,000	Good source of borrow.	591	500
73	44	Clay	10 - 20	400,000	Good source of borrow. Some selection will be necessary.	592	500
74	44	Clay	10 - 20	400,000	Good source of borrow.	593	1,600
75	44	Clay		400,000	Good source of borrow. Some selection may be necessary.	593	500
76	44	Clay	10 - 25	500,000	Generally good borrow material. Some selection will be necessary.	594	500
77	44	Clay	5 - 25	400,000	Generally good borrow material. Some selection will be necessary.	594	500
78	44	Clay	10 - 40	400,000	Generally good borrow material. Some selection will be necessary.	594	500
79	44	Clay	10 - 30	500,000	Generally good borrow material. Some selection will be necessary.	595	500
80	44	Clay	5 - 30	500,000	Generally good borrow material. Some selection will be necessary.	595	500
81	44	Clay (some sand)	5 - 35	500,000	Generally good borrow material. Some selection will be necessary.	596	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
82	44	Clay	10 - 40	400,000	Generally suitable for borrow. Some selection and waste will be necessary.	596	500
83	44	Clay, limestone (some shale)	5 - 40	1,000,000	Good source of rock. Some over-burden could also be used as borrow.	596	900
84	45	Clay, shale	3 - 45	1,000,000	Good source of borrow. Some wastage of surface material will be necessary.	597	500
85	45	Clay	5 - 40	350,000	Good source of borrow. Some wastage of surface material will be necessary.	597	500
86		Clay	7 - 45	400,000	Good source of borrow. Some wastage of surface material will be necessary.	599	500
87	45	Clay	10 - 60	400,000	Good source of borrow. Some wastage of surface material will be necessary.	600	500
88	45	Clay	10 - 40	350,000	Good source of borrow. Some wastage of surface material will be necessary.	600	500
147	45	Clay, shale	5 - 60	400,000	Good source of borrow. Some wastage of surface material will be necessary.	600	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
89	46	Clay, shale	10 - 40	500,000	Not suitable for borrow. Water contents too high.	602	500
90	46	Clay	15 - 60	500,000	Poor material for borrow. Selection would be too difficult.	601	500
91	47	Clay, shale	5 - 40	300,000	Suitable for borrow but considerable quantities would be wasted and selection would be difficult.	603	500
92	47	Clay, shale	5 - 40	250,000	Suitable for borrow but considerable quantities would be wasted and selection would be difficult.	604	500
93	47	Clay, shale	5 - 20	500,000	Good source of borrow. Very little waste will be required.	604	1,200
94	47	Clay, shale	5 - 80	250,000	Unsuitable for borrow. Too much waste would be required.	604	500
95	47	Clay	5 - 50	400,000	Unsuitable for borrow. Too much waste.	605	500
96	47	Clay, shale	5 - 25	600,000	Generally good source of borrow. Some selection and waste will be necessary.	606	500
97	48	Clay, shale	2 - 50	350,000	Generally good borrow material. Some wastage of surface material would be necessary.	607	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
98	48	Clay, shale	10 - 40	300,000	Generally good borrow material. Some wastage of surface material would be necessary.	608	500
99	48	Clay, shale	5 - 40	600,000	Generally good borrow material. Some wastage of surface material would be necessary.	609	900
100	48	Clay, shale	10 - 30	500,000	Generally good borrow material. Some wastage of surface material would be necessary.	610	1,100
101	48	Clay, shale	5 - 40	500,000	Generally good borrow material. Some wastage of surface material would be necessary.	611	800
102	49	Clay, sand, gravel	5 - 35	300,000	Generally good borrow material. Some wastage of surface material would be necessary.	612	500
103	49	Clay, shale	10 - 25	400,000	Generally good borrow material. Some wastage of surface material would be necessary.	612	500
104	49	Clay, shale	10 - 30	300,000	Generally good borrow material. Some wastage of surface material would be necessary.	614	1,000
105	49	Clay, shale	10 - 30	350,000	Generally good borrow material. Some wastage of surface material would be necessary.	614	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
106	49	Clay	5 - 20	250,000	Generally good borrow material. Some wastage of surface material would be necessary.	615	500
107	49	Silt, clay	10 - 50		Not suitable for borrow. Water contents too high.	615	500
108	49	Sand, clay	10 - 30+		Not suitable for borrow. Water contents too high.	615	500
109	49	Clay, sand	5 - 15	250,000	Good source of borrow.	616	500
110	49	Silt, clay, sand	5 - 30+	300,000	Upper material would be wasted due to high water content. Lower material good source of borrow.	617	500
111	49	Sand, silt, gravel, clay	5 - 45	350,000	Upper material would be wasted. Lower material good source of borrow.	617	500
112	50	Sand, gravel, silt	10 - 40		Not suitable for borrow. Water contents too high.	617	800
113	50	Clay, mixed	8 - 55		Some material would be suitable but selection of good material would not be practical.	618	500
114	50	Clay, silt, shale sand	10 - 60		Waste material would form too high a ratio to suitable borrow. This pit not suitable.	618	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
115	50	Clay, silt, gravel	10 - 40+		Waste material would form too high a ratio to suitable borrow. This pit not suitable.	619	500
116	50	Clay, silt, sand	10 - 40		Waste material would form too high a ratio to suitable borrow. This pit not suitable.	619	500
117	50	Clay, sand	5 - 40		Waste material would form too high a ratio to suitable borrow. This pit not suitable.	620	500
118	51	Clay, silt, gravel	5 - 40		Waste material would form too high a proportion of this pit. Not suitable.	620	500
119	51	Gravel, silt, clay sand	5 - 25	250,000	Good source of borrow.	621	500
120	51	Clay, silt, gravel	8 - 35	100,000	Good source of borrow. Some waste will be necessary.	621	500
121	51	Sand	5 - 25	150,000	Good source of borrow. Some waste will be necessary.	621	700
122	51	Clay	10 - 25	150,000	Good source of borrow. Some waste will be necessary.	621	500
123	51	Clay	5 - 25	100,000	Good source of borrow.	622	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
124	51	Sand	5 - 8	20,000	Good source of borrow.	622	500
125	51	Sand, gravel	5 - 15	200,000	Excellent source of borrow.	622	500
126	51A	Clay, shale, sand	8 - 40	150,000	Good source of borrow. Some waste will be necessary.	623	500
127	51A	Clay, shale	10 - 60		Water content too high. This pit unsuitable.	624	500
128	51A	Clay, shale	5 - 30	160,000	Lower material is good borrow. Upper material would be wasted.	624	500
129	51A	Gravel, sandstone, shale, clay	5 - 30	300,000+	Good source of borrow and rock. Some till overburden would be wasted.	625	500
130	51A	Clay	5 - 45	200,000	Some wastage would be necessary otherwise a good borrow source.	625	500
131	51A	Clay	5 - 25	300,000	Some wastage would be necessary otherwise a good borrow source.	626	500
132	52	Mixed	5 - 20	200,000	Good source of borrow.	627	500
133	52	Silt, clay	5 - 30	200,000	Fairly good source of borrow but selection may be difficult due to high water contents.	627	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
134	52	Sand, shale	5 - 15	200,000	Good source of borrow.	627	1,500
135	52	Sand, clay	10 - 20	300,000	Good source of borrow. Some waste will be necessary.	628	500
136	52	Clay, sand	5 - 18	300,000	Good source of borrow. Some wastage of surface soil will be necessary.	626	500
137	52	Clay	5 - 20	200,000	Good source of borrow. Some wastage of surface soil will be necessary.	626	500
138	52	Silt, clay	8 - 45		Too much waste in proportion to useable borrow. This pit unsuitable.	627	500
139	52	Sand, gravel	5 - 15	100,000	Good source of borrow.	627	500
140	52	Gravel, sand, clay silt	5 - 40	400,000 min.	Good source of borrow. Some selection will be necessary.	627	500
141	52	Clay, gravel, silt sand	5 - 40		Too much waste in proportion to useable borrow. This pit unsuitable.	628	500
142	52	Clay, gravel, sand	5 - 15+	400,000	Good source of borrow. Some wastage will be necessary.	628	500

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
143	52	Clay, silt	10 - 30		Too much waste in relation to useable borrow. This pit unsuitable.	629	500
144	52	Sand, clay	5 - 15	200,000	Good source of borrow.	629	500
145	53	Silt, clay	10 - 20+	400,000	Fairly good source of borrow but selection will be necessary.	630	900
146	53	Clay, sand, silt-stone	5 - 30+		Proportion of waste to useable borrow is too high. This pit unsuitable.	631	500

POSSIBLE CUT SECTIONS

SUMMARY OF DATA

MILE	STATION	TEST HOLE	DEPTH OF CUT (FT)	SOIL TYPES	ICE CONTENT	WATER CONTENT (%)	REMARKS
544.1	2000	383	10	Mixed	High	30 +	Cut not recommended
548.3	1778	385	6	Clay	High	40	Cut not recommended
459.9	1696	371	7	Silt Sand	Low	10	Cut feasible
551.1	1633	359	8	Mixed	Low to High	25-70	Cut not recommended
553.0	1534	346 347	5	Sand	Low	25	Cut feasible
553.2	1520	346	15	Sand	Low	25	Cut feasible
553.5	1508	345 344	35	Sand	Low	25	Cut feasible
554.0	1480	340 341	50	Sand	Low	20	Cut feasible
554.9	1430	334 298	10 10	Clay Silt	High High	40 + 30 +	Cut not recommended

POSSIBLE CUT SECTIONS

SUMMARY OF DATA

MILE	STATION	TEST HOLE	DEPTH OF CUT (FT)	SOIL TYPES	ICE CONTENT	WATER CONTENT (%)	REMARKS
555.4	1407	296	10	Sand	Low	25	Cut feasible
555.8	1380	293 294	20	Sand	Low	20	Cut feasible
556.7	1337	289 290	15	Sand	Low	5 - 25	Cut feasible
557.0	1322	289	15	Sand	Low	5	Cut feasible
557.8	1276	284	10	Sand	Low	20	Cut feasible
562.5	1028	261	20	Sand	Low	5	Cut feasible
563.1	998	258	15	Sand	Low	20	Cut feasible
568.2	730	219 220 221 222	30 to 40	Mixed	High	- 40	Cut not recommended
574.0	425	156	-	Mixed	High	Very High	Cut not recommended

POSSIBLE CUT SECTIONS

SUMMARY OF DATA

MILE	STATION	TEST HOLE	DEPTH OF CUT (FT)	SOIL TYPES	ICE CONTENT	WATER CONTENT (%)	REMARKS
590.0	425	566	25	Clay	Low	5-10	Cut feasible
590.4	439	568	25	Clay Limestone	Low	5	Cut feasible
591.0	473 to 496	572 573 574 575	-	Clay Limestone	Low	5-15	Cut feasible
593.4	590	598	22	Clay	Low	15	Cut feasible but not recommended
604.3	1178	722 884 723	5	Clay	High	20-40	Cut not recommended
605.5	1240	751 854 760 882 789 790	-	Clay Shale	Varies	High at Surface Otherwise Low	Bridge site. Cuts not recommended but may be unavoidable.

POSSIBLE CUT SECTIONS

SUMMARY OF DATA

MILE	STATION	TEST HOLE	DEPTH OF CUT (FT)	SOIL TYPES	ICE CONTENT	WATER CONTENT (%)	REMARKS
612.5	1603	772 773 774 853 775 851 852 776 777 778	60 feet assumed	Clay Sand Shale	High in Overburden	5-40	Cut feasible as most of it would be in rock. Problems may arise due to failure of surface soils.
620.5	2030	938 939	20	Clay	High	30	Cut not recommended
626.4	2345	969 1019 970	10	Mixed	High	10-30	Massive ice at 13 ft. depth. In test hole 1019 cut feasible but will require over-excavation and backfilling

POSSIBLE CUT SECTIONS

SUMMARY OF DATA

MILE	STATION	TEST HOLE	DEPTH OF CUT (FT)	SOIL TYPES	ICE CONTENT	WATER CONTENT (%)	REMARKS
							CHAINAGE EQUATION: MILE 629.12 BACK EQUALS MILE 626.47 AHEAD
630.8	4950	973	10	Clay	Low	10-20	Cut not recommended
631.5	4915	1102 1103	20	Clay Sand	High	10-60	Cut not recommended

APPENDIX C

Terms of Reference

BORROW SUMMARY

PIT NUMBER	MOSAIC SHEET NUMBER	SOIL MATERIAL	WATER CONTENT RANGE (%)	ESTIMATED AVAILABLE QUANTITY (cu. yd.)	REMARKS	MILE-POST	DISTANCE TO CENTER-LINE (feet)
1	41	Sand, silt, clay	25 +	3,000,000	Water (ice) contents generally too high.	582	900
2	41	Sand, silt, clay	25 +	1,000,000	Water (ice) contents generally too high.	581	500
3	41	Sand, silt, clay	25 +	500,000	Water (ice) contents generally too high.	581	1,800
4	41	Sand, silt, clay	25 +	1,000,000	Water (ice) contents generally too high.	580	500
5	40	Mainly sand	25 +	2,000,000	Sand could be used but careful selection would be necessary.	579	500
6	40	Silt, clay	25 - 40	1,000,000 +	Water (ice) contents too high for borrow.	579	500
7	40	Clay, silt, sand	25 - 40	1,000,000 +	Water (ice) contents too high for borrow.	578	500
8	40	Silt, clay	25 - 40	400,000	Water (ice) contents too high for borrow.	577	500
9	40	Silt, clay	25 - 40	300,000	Water (ice) contents too high for borrow.	577	500
10	40	Silt, clay	25 - 40	1,000,000	Some clay could be used but selection in field would be extremely difficult.	576	500
11	39	Silt, clay	25 - 30	1,000,000 +	Water (ice) contents too high for borrow.	575	1,300
12	39	Clay, silt	25 - 45	1,000,000 +	Water (ice) contents too high for borrow.	574	500

Mackenzie Highway - Geotechnical Investigations - Mile 346 to Mile 725

1. General

Soil and permafrost conditions vary considerably over the 375 mile reach of the Mackenzie Valley which will be the subject of this investigation. These variations, in combination with other factors such as mobilization, existence of major water course, etc. will result in quite different field programmes for each geotechnical consultant appointed along the route.

The four geotechnical consultants appointed to date and sections of the route designated to each are as follows:

Acres Consulting Services Ltd.	Mile 346 to 450
Underwood-McLellan & Associates Ltd.	Mile 450 to 550
R. M. Hardy & Associates	Mile 550 to 650
E. W. Brooker & Associates Ltd.	Mile 650 to 725

As with any geotechnical project of the magnitude of the proposed Mackenzie Highway investigations, it is not difficult to generalize what the items of concern may be, but it is much more difficult to translate these into an estimate of the numbers and locations of borings, the depths to which these should be drilled, and the sampling and testing requirements. Some guidance in this respect is provided herein.

2. Soil and Permafrost Conditions

To date copies of the Preliminary Engineering Alignment Report outlining the route location from Mile 297 to Mile 544 have been provided to the consultants appointed through this section. A preliminary alignment report for the remainder of the route is currently being prepared and will be available to consultants by September 21.

The route will cross the Mackenzie River at Camsell Bend, run generally northward to the Willow Lake River, and then northward to Norman Wells approximately following the existing C.N. Telegraph line. In the following paragraphs the soil and permafrost conditions expected along the proposed route are summarized.

a) Mackenzie River Crossing to Willow Lake River - Mile 346 to 395.

From the Mackenzie River crossing to the Willow Lake River, the road passes through the broad Interior Plain Region. The surficial deposits in this section are predominantly clay till to within about ten miles of the Willow Lake River, after which interbedded silt, fine sand and sandy clays are anticipated. The thickness of peat will probably average less than 1½ feet but local occurrences up to 15 feet thick are anticipated.

Permafrost will likely be encountered in about one-third of the borings drilled near the Mackenzie crossing, and an increasing frequency to about one-half of the holes drilled near the Willow Lake River. It is unlikely that the frozen soil will contain much excess ice.

Between the Mackenzie and Willow Lake Rivers there are no major watercourses intersecting the proposed route.

b) Willow Lake River to Wrigley - Mile 395 to 435.

From the Willow Lake River to Wrigley the road passes through the Cordilleran Region. To about Mile 425, sands interbedded with silts and silty clays and till-like soil are likely to predominate. Beyond Mile 425, silty clays covered with up to two feet of peat are the predominant soils. Peat up to ten feet thick has been found in bogs along this section. Bedrock may be found close to the surface in places. Obvious material sources will include numerous sand dunes, some eskers and occasionally limestone outcrops.

Permafrost along this section of the route is anticipated in about 50 percent of the borings but the frozen soils will most likely contain little excess ice in the form of pore ice and ice lenses.

Major water courses in this reach of highway are the Willow Lake River (Mile 395) and the River Between Two Mountains (Mile 411), and one stream near Mile 430 which will require a large culvert. Terrain along this section is more undulating than the previous 50 miles.

c) Wrigley to Blackwater River - Mile 435 to 492.

The surficial deposits in this section consist principally of silty clays with some organic clay and till-like soils except at river beds and in fan formations where silty sands and sandy gravels are prevalent. These Pleistocene deposits are underlain by limestones and shales of the Franklin Mountains. The peat thickness to be encountered will likely range up to four feet. Obvious material sources will include large gravel deposits and limestone outcrops in the vicinity of Wrigley.

Permafrost in this section is widespread and frozen soil can be expected in two-thirds of the borings. The frozen soil is likely to contain excessi ice in silts and organic clays but little excess ice in other materials.

This section of the highway will cross Hodgson Creek (Mile 436), the Ochre River (Mile 455) and significant streams at approximately Mile 460 ar Mile 471 all of which will require bridges. As well, the route crosses a number of minor watercourses and valleys and large culverts are anticipated at roughly Mile 462, Mile 469 and Mile 479.

d) Blackwater River to Little Smith Creek - Mile 492 to Mile 533.

From the Blackwater River to the Saline River, the surficial soils is predominantly silty clay with silty sand and sandy gravel being common at rivers and in fan formations. Peat up to four feet in thickness has been found to overlie the mineral soils. From the Saline River to Little Smith Creek, silts and silty clays underlain by gravel-sand-clay mixtures are predominant. Occasional rock outcrops will present some obvious material sources through this section.

Permafrost in this section is widespread and is likely to be present in about two-thirds of the borings. Excess ice in quantity is likely to be found in silts and clays from the Saline River to Little Smith Creek.

The terrain in this section is very irregular. Bridge crossings will be necessary at the Blackwater River, for a stream at approximately Mile 511 and for the Saline River (Mile 521). Large culverts will be required for streams near Mile 498, 514, 519 and 528.

e) Little Smith Creek to Ft. Norman - Mile 533 to 584.

From Little Smith Creek to Big Smith Creek, the terrain traversed by the highway is relatively free from lakes. From Big Smith Creek northward to Fort Norman, however, the highway will pass through a region of thermokarst lakes and muskeg. Surficial deposits are largely silty sand. Peat cover up to 15 feet thick has been found in bogs along this section.

Permafrost in this region is widespread and will likely be encountered in 75 percent of the borings. The soils contain considerable ice, ranging from pore ice not visible to the naked eye to ice lenses of a few inches in thickness.

Little Smith Creek and Big Smith Creek are the major streams to be crossed by the highway in this section.

f) Ft. Norman to Norman Wells - Mile 584 to 630.

From Ft. Norman to Norman Wells the route traverses along the base of the Norman Range and crosses numerous drainage channels with headwaters in the adjacent mountains. Surficial soils are predominantly silts and silty clays with some sandy gravels. Bedrock consisting primarily of shales, sandstones and some limestone can be expected at shallow depths in many locations. Organic cover will generally be 1 to 4 feet but thicknesses of peat up to 15 feet have been encountered at some locations through this area.

Permafrost in this section is widespread and will likely be encountered in 75 - 80% of borings. Ice will be excessive in silts and some clays, but not excessive in gravels.

Bridge crossings will be required at the Great Bear River (Mile 585), Jungle River Creek (Mile 601), Vermillion Creek (Mile 605), Prohibition Creek (Mile 612), Christina Creek (Mile 615), Helava Creek (Mile 616), Francis Creek (Mile 618) and Canyon Creek (Mile 620).

Obvious material sources through this stretch will include shale and sandstone outcrops parallel to the highway, large talus slopes, and limestone ridges parallel to the route.

g) Norman Wells to Ft. Good Hope - Mile 630 to 725.

North of Norman Wells the route will continue along the base of the Norman Range to Gibson Ridge, swing east of Gibson Ridge and proceed north near Chick Lake to Ft. Good Hope. Surficial soils are predominantly silts and clays with some silty sands and sandy gravels. Permafrost can be expected in 90 - 100 percent of test holes and excessive ice will be encountered in all fine grained soils. Obvious materials sources will include rock outcrops and ridges, primarily shale, and large talus slopes.

Bridges or large culverts will be required at Bosworth Creek (Mile 632), Oscar Creek (Mile 650), Elliot Creek (Mile 660), Hanna Creek (Mile 670),

Donnelly River (Mile 685), Snafu Creek (Mile 695), Tsintu River (Mile 710), Jackfish Creek (Mile 722) and Hare Indian River (Mile 725).

3. Objective of Investigation

a) General

In general terms, the geotechnical consultant in each designated section will be responsible for providing sufficient subsoil data on the route centreline and on selected borrow areas to permit the Department to proceed with final highway design and tender call for construction. In addition, the consultant shall conduct foundation investigations at major stream crossing in collaboration with the bridge consultants appointed by the Department. The following paragraphs will outline specific concern and responsibilities of the consultant.

b) Differential Settlements

In addition to the identification and classification of general soil conditions along the centreline of the proposed highway, it is expected the consultant will provide a terrain classification along the route and will indicate areas of excessive ice, extensive peat zones, etc. which could result in subsidence of the road embankment and a maintenance problem. It is not expected the consultant should conduct thermal analyses and indicate fill height requirements to maintain permafrost in the underlying soil, but that potential areas of extensive embankment subsidence due to thaw be delineated and an estimate of the total subsidence be provided. Centreline boreholes should therefore not be located on a regimented basis but should be located from airphoto analysis of terrain and from field judgement and assessment of preceding boreholes data. A borehole depth of no more than 15' on centreline is considered adequate and the number of holes will depend upon the variation in terrain.

c) Roadway Stability

Overall stability of the roadway may be aproblem in some high fills and cuts on side hills, especially if the latter is of a part cut, part fill nature. The number, location and depth of holes necessary to adequately define a particular situation, however, will depend largely on the grade and alignment of the road. Since grade lines are unlikely to have been established at the time of the geotechnical investigation, the consultants engineering staff must use their experience to judge cut and fill requirements, identify potential problem areas and outline solutions in general terms.

Liquefaction and soil pumping may cause problems with some soils in certain grade situations. An assessment of the potential occurrence of these phenomena should be included.

d) Selection of Borrow

The utilization of borrow areas along a highway route must depend not only upon the location of suitable materials but upon the economics of construction. Consequently it is expected the consultant will take into consideration various items on the construction of embankment sections in

his selection of the borrow pits to be tested. These factors will include deadhaul, overburden, clearing, access roads, and the comparison of excavation and haul costs for common material or rock borrow. A pre-established search corridor centered along the right-of-way need not be the range-limit in the search for suitable borrow, but rather on economic limit based upon the factors outlined above should be used. In assessing borrow locations, the suitability of material in obvious cut sections should be considered, but it can be generally assumed the majority of the highway will be embankment (especially so north of Willow Lake River) with minimal cut sections, and embankment requirements will be approximately 60,000 cubic yards per mile.

All potential borrow areas should initially be located from airphoto analysis and route reconnaissance. The areas subsequently investigated in the field should depend upon continued field judgement as acceptable borrow areas are proven. It is estimated an average of four borrow areas per mile will require evaluation to strategically locate suitable borrow sources. The number, depth and location of boreholes in any area should be a field judgement based upon drilling results, the characteristics of the feature being tested, and the estimated borrow requirements.

e) Backslope Stability and Slope Erosion.

Backslope stability in cuts, and slope erosion along cuts and sidehills, ditches and toes of embankment has been a fairly common source of trouble in permafrost affected areas. With the current emphasis on environmental protection and restoration, these aspects are currently more significant than ever. The proposed highway design in cut sections will include only V-ditches hence erosion problems could be significant. It is expected the consultant will identify potential erosion or back-slope stability problem areas and suggest solutions in general terms.

f) Drainage

The Department will conduct drainage surveys, and surface drainage will be outside the scope of these geotechnical investigations. However, subsurface drainage is prevalent in the active layer in many parts of the Mackenzie Valley, and interceptions of such seepage paths with a highway may result in the formation of icings during the winter. The consultants field staff should be on the lookout for seepage areas and any suspect regions should be noted, described and sampled, wherever possible.

g) Bridge Locations

Permafrost conditions at river crossings are usually quite complex. Many of the banks and beds of the watercourses draining into the Mackenzie River from the east along this reach of the Mackenzie Valley are free from permafrost to a considerable depth. Exposure of the banks, however, is a significant variable and the permafrost conditions will have to be confirmed at the specific locations chosen for bridge crossings.

From a soils point of view, the bridge designer will be interested in the nature and stability of the soils forming the banks, the permafrost profil the strength and density profiles of the soils, the depth of the present and future, (i.e. anticipated post-construction), active layer, the

foundation design criteria, and whether approach fills or cuts will endanger the structure. Many of the watercourses intersected by the highway route flow in deeply incised valleys having steep slopes, and there is evidence of valley wall erosion and channel shift in some. They represent areas which will require fairly extensive investigation to establish foundation design criteria, even if they are found to be free from permafrost.

At all stream crossings the geotechnical consultant shall respond to the requirements of the bridge consultants and/or the hydrology consultants appointed by the Department. The firms commissioned to date are summarized below. Bridge consultants beyond Mile 550, and hydrology consultants beyond Mile 500, will be appointed in the near future and the geotechical consultant(s) involved in these sections will be notified accordingly. Bridge site drilling requirements will be provided by the various bridge consultants by at least December 1, 1972.

Bridge Consultants

T. Lamb, McManus & Associates - Willow Lake River

Canada North Engineering Ltd. - Blackwater River

Reid Crowther & Partners Ltd. - Mile 300 - 460

Stanley Associates Engineering Ltd. - Mile 461 - 550.

Hydrology Studies

Bolter, Parish & Trimble - Mile 300 - 500

h) Field Observations, Sampling and Laboratory Testing.

Due to the cost and time limitations imposed on the field operations, movement of drill crews along the route must be relatively rapid - in the order of 1 to 2 miles per day. Hence it will be difficult, if not impossible, to confirm field drill logs at any location with laboratory test results, until drill crews have advanced several miles along the route. The success of the field operations must, therefore, depend largely upon the information and data obtained, and the judgements made, by drill inspectors and field engineers. Pertinent information recorded in the field should include:

(i) Visual identification and classification of the mineral and organic soils in accordance with the Modified Unified Classification System. Where permafrost is found, ice description should be in accordance with the methods set forth in N.R.C. Technical Memorandum No. 79, Guide to the Field Description of Permafrost.

(ii) Depth of the active layer (where apparent).

(iii) Description of the type of vegetation cover, terrain relief, drainage and snow cover. Photographic records should be taken in regions of major interest or at anticipated problem areas.

Soil sampling in centreline borings should be sufficient to reveal the general soil conditions along the route, to provide data on ice (moisture)

contents and volumes of ice, and to provide samples from which thaw settlements can be estimated. These samples can be largely disturbed for classification testing, however some semi-continuous cores will be required in ice rich zones for ice volume and thaw settlement evaluations.

Sampling in borrow areas should be sufficient to confirm the drill inspectors logs, and to provide moisture contents and soil classification data which will be included in the tender documents for construction. Since compaction control will not be exercised during construction, moisture density relationships on borrow materials will not be required.

Sampling and testing in anticipated problem areas such as deep cuts, high fills, seepage zones, etc. should be sufficient to accurately define the problem. It is anticipated sampling would be semi-continuous with coring or penetration sampling devices.

Sampling and testing at bridge sites should be consistent with normal engineering practice for foundation investigations. Sampling should be on a semi-continuous basis using coring, Shelby tubes or penetration sampling devices.

4. Field Operations

a) Consultant Responsibility

The consultant will be responsible for all aspects of the field operations including mobilization of equipment and camps, staffing and operational support. Anticipated equipment requirements will include two track mounted drilling rigs, at least one of which must be capable of drilling rock, dozer support for clearing access to borrow pits, ground transport vehicles for crews, camp trailers and fuel sloops. Camps must be mobile and either track mounted or sled mounted for travel on the cleared highway centreline. Field laboratories may be utilized however the benefits of on-site testing and the inherent costs of a field lab and maintaining technicians in the field should be balanced against the cost and disadvantages envisaged in shipping samples 'south' for testing. Support for field crews should be supplied in the most economical means available.

The consultant should endeavour to employ residents of the N.W.T. whenever possible, subject to the availability of the skills required. All employment of local staff must be through the Canada Manpower Centres at Ft. Simpson or Inuvik.

b) Departmental Activities.

The Department will commence centreline clearing of the route by means of dozers and mobile camps on November 1, 1972 and access with tracked vehicles will be possible thereafter. Centreline clearing will begin at 3 locations - the starting mileages, direction of work and clearing contractors are outlined below. The progress rate for clearing is estimated at approximately 2 miles per day and geotechnical consultants can plan field operations accordingly. No dozer assistance will be provided by the Department for the borrow pit clearing.

Contractor	Equipment	Work Schedule
Robert Reason Contracting	2 - D-7 Dozers	Start at Mackenzie River Crossing-Mile 346-and work north to Mile 470.
Dallas Contracting	2 - D-8 Dozers	Start at Ft. Norman-Mile 584-and work south to Mile 470.
Carl Mueller Contracting	1 - D-7 Dozer 1 - D-8 Dozer	Start at Ft. Good Hope-Mile 725-and work south to Ft. Norman-Mile 604.

The Department will establish and maintain camps at Ft. Simpson (Mile 297), Willow Lake River (Mile 395), Blackwater River (Mile 492), Norman Wells (Mile 630), and Ft. Good Hope (Mile 720). With the exception of Ft. Simpson, the camps will be staffed with only a skeleton crew during the winter months, however consultants may utilize the camps as staging areas and may make use of the accommodation facilities available at anytime during their field operations. Food supplies at the camps will be minimal and consultants will be expected to provide their own resources in this regard.

c) Land Use Regulations

All consultant field operations must comply with Territorial Land Use Regulations. The department will obtain a General Land Use Permit for operations on the route right-of-way, however all movement off the right-of-way must be approved by an additional permit or by an extension to the general permit. In order for the Department to obtain a permit for exploration off the right-of-way it will be necessary to indicate the extent of movement into virgin terrain. Therefore the consultant shall pre-select potential borrow sources from air photo study and route reconnaissance and submit a mosaic outlining these tentative exploration areas to the Department prior to the start of field operations. Since any request for a land use permit requires approximately 1 month for approval, these mosaics should be available as quickly as possible to avoid any delay in field operations. Any specific queries regarding Land Use Regulations during field operations should be directed to:

Mr. D. J. Gee, Regional Manager, Water, Forests & Land
Department of Indian Affairs and Northern Development,
Yellowknife, N.W.T.

5. Available Route Information

The Department has assembled existing terrain mapping and borehole data along the general route corridor to roughly Mile 660, and this data is available to consultants. In addition, two sets of airphotos (1000 and 3000 feet to the inch - flown in summer 1972) are available for study in the Regional Office in Edmonton. Copies of the airphotos will be made available to the consultants as soon as possible.

6. Schedules

Narrative reports outlining the progress of the investigations should be submitted to the Department on a bi-weekly basis, and very preliminary technical reports consisting primarily of borehole logs should be provided at the same time. Final reports on the centreline, borrow pit and problem area investigations, including laboratory testing and recommendations, shall be submitted by April 30, 1973. Foundation reporting on bridge sites should be co-ordinated through the bridge consultants, however, it is anticipated a final report on any bridge site should be available within 5 weeks after completion of the field work at the bridge site.

APPENDIX D

Explanation Sheets

EXPLANATION OF TERMS AND SYMBOLS

USED ON TEST HOLE LOG SHEETS

Depth

This column refers to the depth below the ground surface in feet.

Sample Number

Tube and core samples were numbered consecutively from the surface. Grab samples were not numbered.

Sample Type

This column indicates the depth interval and condition of each sample attempted. Undisturbed samples in this program were obtained with Shelby tubes of 18 inches length and 3 inches diameter, manufactured from 11 gauge steel, or by core drilling. Cores were of 2.85 inch diameter and up to 36 inches long.

Disturbed samples were obtained from the returned cuttings.

T indicates tube sample

C indicates core sample

 indicates large grab sample

Note: Grab samples taken for water content and visual examination are not indicated in this column.

Percent Recovery

This column shows the length of sample recovered as a percentage of the length attempted. 100% recovery is not indicated and may be assumed where no value is shown.

Penetration Resistance

No standard penetration tests were performed during this program.

Soil Symbol

The soil symbols used are explained in full on page 5 of this appendix.

Soil Description

Soils of different engineering classification are grouped generically for ease of reference. The system used is the Modified Unified Classification System for Soils.

Frozen Ground

The depth intervals over which frozen and unfrozen ground were encountered are indicated by F and UF respectively. No attempt was made to differentiate between seasonal frost and permafrost.

Ice Description

The ice content of permafrost soils has been classified according to the National Research Council System for describing permafrost. A brief review of the NRC System is contained on page 9 of this appendix. Where no entry is made, the type was not recorded in the field.

The amount of ice contained in a soil sample was estimated in the field laboratory by inspection. The value arrived at by the laboratory technician has been left unchanged.

Water Content

The natural water content of the soil at the time of drilling is plotted against depth on the chart at the right hand side of the log. The water content, which is indicated by a circle, is expressed as a percentage of the dry weight of the soil. It will be observed that water contents in excess of 100% are indicated in the column at the right of the chart by figures.

Volume of Ice

The total volume of ice in undisturbed samples is indicated on the same chart as water contents. The value is indicated by a triangle. This volume is the total volume of ice in an undisturbed sample and includes intersticial ice, as well as excess ice, and is expressed as a percentage of the total volume of the sample.

Grain Size Analysis

The proportions of clay, silt, sand and gravel in a sample are summarized. Grain size curves for each sample so analyzed are on separate sheets.

Wet Density

The wet in situ density of undisturbed samples is the total weight of the sample in pounds (including ice and water) divided by the volume of the sample in cubic feet.

Dry Density

The dry in situ density of undisturbed samples is the weight of dry soil divided by the volume of the sample in cubic feet.

Atterberg Limits

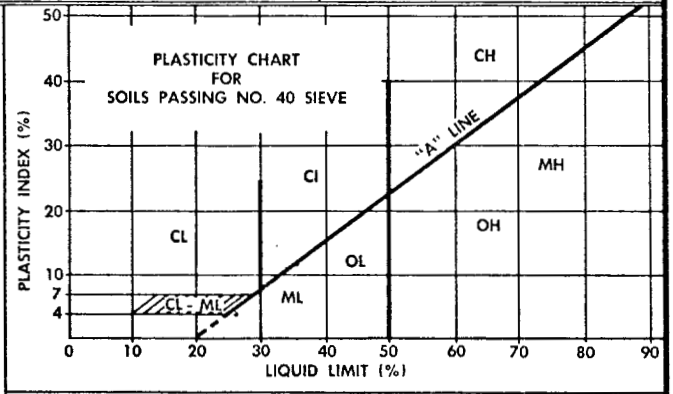
The plastic and liquid limits are shown on the water content chart by a horizontal bar. The Atterberg system is discussed in the following section.

NOTES ON ATTERBERG LIMITS

Soils which possess a significant fraction of clay can exist in liquid, plastic or solid states according to the water content. Where the water content is very high, so that the soil is in the form of a slurry, the soil behaves as a liquid. If the water content is reduced, for example through evaporation, the clay will enter into a plastic state. If the water content is reduced yet further, the clay will become a solid. The transition from one state to another occurs gradually over a range of water content. Atterberg, a Swedish agronomist, developed a method for delineating the boundaries between the three states. If his method is used, the water content which marks the dividing line between the plastic and liquid state is known as the Liquid Limit. These water contents are all expressed as percentages of the dry weight of soil. The range of water content between the plastic

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP		RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP		RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	



1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11.
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%.

and liquid limit is known as the plastic range and the numerical difference between the liquid and plastic limits is called the Plasticity Index.

It will be appreciated that where the natural water content is in excess of the liquid limit, the soil mass will be most unstable and will readily flow into excavations or trenches. Such considerations will not apply where the soil mass is kept frozen. However, in cases where the frozen soil is allowed to thaw, the relationship between the natural water content and liquid limit becomes critical.

On page 5 there is a chart showing the relationship between the Plasticity Index, the Liquid Limit and the group symbols of the Unified Classification System. The Atterberg Limit system is extremely useful for identifying and classifying soils.

NOTES ON THE RADFORTH SYSTEM FOR CLASSIFYING PEAT

The Radforth classification system for describing muskeg (organic terrain) is a method for classifying the three elements of vegetation, topography and organic surface cover using letter and figure symbols. Height and type of vegetation is described by using capital letters (A through I). Topography is described by using lower case letters (a through p) Organic cover type if described by using figures (1 through 16).

Table I outlines these figure symbols and the peat structure and type represented by them. A complete description of the Radforth system is contained in "Guide to a Field Description of Muskeg" published by National Research Council, Ottawa, from which has been copied Table I.

TABLE I

SUBSURFACE CONSTITUTION

Predominant Characteristic	Category	Name
	1.	Amorphous-granular peat
	2.	Non-woody, fine-fibrous peat
	3.	Amorphous-granular peat containing woody fine fibres
	4.	Amorphous-granular peat containing woody fine fibres
	5.	Peat, predominantly amorphous-granular, containing non-woody fine fibres, held in a woody, fine fibrous framework.
	6.	Peat, predominantly amorphous-granular containing woody fine fibres, held in a woody, coarse-fibrous framework.
	7.	Alternate layering of non-woody, fine fibrous peat and amorphous-granular peat containing non-woody fine fibres.
	8.	Non-woody, fine-fibrous peat containing a mound of coarse fibres.
	9.	Wood, fine fibrous peat held in a woody, coarse-fibrous framework.
	10.	Woody particles held in a non-woody, fine-fibrous peat.
	11.	Woody and non-woody particles held in fine-fibrous peat.
	12.	Woody, coarse-fibrous peat.
	13.	Coarse fibres criss-crossing fine-fibrous peat.
	14.	Non-woody and woody fine-fibrous peat held in a coarse-fibrous framework.
	15.	Woody mesh of fibres and particles enclosing amorphous-granular peat containing fine fibres.
	16.	Woody, coarse-fibrous peat containing scattered woody chunks.

NOTES ON THE NATIONAL RESEARCH COUNCIL SYSTEM FOR DESCRIBING PERMAFROST

Ground ice occurs in three conditions. Non-visible, visible (but less than one inch in thickness) and clear ice. Non-visible ice is designated N with an added suffix of one or two lower case letters. Visible ice is designated V with an added suffix of one lower case letter. Clear ice is designated ICE with notes on ice type.

TABLE IV

Symbol	Description
Nf	Non-visible ice, frozen soil in friable condition.
Nbn	Non-visible ice, frozen soil well bonded, no excess ice.
Nbe	Non-visible ice, frozen soil well bonded, excess ice revealed on melting sample.
Vx	Visible ice crystals.
Vc	Ice coatings on soil particles.
Vr	Ice formations irregularly orientated.
Vs	Stratified ice lenses.
ICE	Clear ice over one inch in thickness.
ICE + soil	Ice over one inch thick with soil inclusions.

A complete description of this system is contained in "Guide to a Field Description of Permafrost" published by National Research Council, Ottawa.